

CLINICAL STUDIES REFERENCE GUIDE

APRIL 2024

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NEW STUDIES

Category	Title
Lung disease and Internal medicine	<ul style="list-style-type: none"> • Greater exercise tolerance in COPD during acute intermittent compared to continuous shuttle walking protocols: A proof-of-concept study • Repeated cardiopulmonary performance measurements in young competitive handball players with and without SARS-CoV-2 infection • Haemodynamic compensations for exercise tissue oxygenation in early stages of COPD: an integrated cardiorespiratory assessment study • Cardiac output and arteriovenous oxygen difference contribute to lower peak oxygen uptake in patients with fibromyalgia • Cardiorespiratory fitness in women after severe pre-eclampsia
Cardiology	<ul style="list-style-type: none"> • Rightward imbalanced pulmonary perfusion predicts better exercise stroke volume in children after Fallot repair • Interventional Heartworm Extraction in Two Dogs: The Clinical Application of Impedance Cardiography • Intrapulmonary distribution of blood flow during exercise in pulmonary hypertension assessed by a new combination technique • Exercise training affects hemodynamics and exercise capacity in cases of heart failure with preserved ejection fraction: a non-randomized controlled trial in individuals aged 65-80 years • Non-Invasive Assessment of Cardiodynamics by Impedance Cardiography during the Six-Minute Walk Test in Patients with Heart Failure • Hemodynamic Response to Exercise Training in Heart Failure With Reduced Ejection Fraction Patients • Cardiac hemodynamics phenotypes and individual Cardiac hemodynamics phenotypes and individual responses to training in coronary heart disease patients • Determinants of $\dot{V}+O_2$ peak Changes After Aerobic Training in Coronary Heart Disease Patients
Physiology	<ul style="list-style-type: none"> • Central and peripheral response to incremental cycling exercise in older untrained active men: a comparison of those in-between • A randomized crossover study on the effects of a custom-made mouthguard on cardiopulmonary parameters and cortisol differences in a validated handball specific course • Facemask Use During High Intensity Interval Exercise in Temperate and Hot Environments • Intensity-dependent cardiopulmonary response during and after strength training • The Impact of the Cold Pressor Test on Inter-arm Differences in Blood Pressure • Effect of home-based online training and activity feedback on oxygen uptake in patients after surgical cancer therapy: a randomized controlled trial • Cardiopulmonary response to exercise in adults born very preterm • Exercise induced plasma volume expansion lowers cardiovascular strain during 15-km cycling time-trial in acute normobaric hypoxia

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INTRODUCTION

This document is a list of abstracts of the studies that have been published involving the PhysioFlow technology. Some of them are abstracts of full papers published in peer reviewed journals and some are abstracts of presentations at conventions. They are categorized following the intent of the study (validation, application, or pure research) and also following applications (critical care, cardiology, physiology, etc.). They represent the start of the art about PhysioFlow, to the best of our knowledge.

Some of these studies are quite old and reflect the performance of the technology at an early stage and some are recent and involve our latest innovations (HD-Z motion cancellation filter for instance). Most of the papers are about our PF05-Lab1 design but some recent ones are about the PF07-Enduro, which is newer but offers the same degree of performance.

Also, it is important to note that some teams follow our recommendations strictly and obtain impressive results and some other ones intentionally or unintentionally drift away from our instructions (choice of electrodes, software version, protocol, etc.) and thus generally underperform.

Enjoy your reading and please feel free to contact us should you have questions.

1 VALIDATIONS

1.1 FICK PRINCIPLE/EXERCISE

A New Impedance Cardiograph Device for the Non-invasive Evaluation of Cardiac Output at Rest and During Exercise: Comparison with the "Direct" Fick Method

Abstract, European Journal of Applied Physiology, Volume 82 Issue 4 (2000) pp 313-320

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Abstract:

The objectives of this study were to evaluate the reliability and accuracy of a new impedance cardiograph device, the PhysioFlow, at rest and during a steady-state dynamic leg exercise (work intensity ranging from 10 to 50 W) performed in the supine position. We compared cardiac output determined simultaneously by two methods, the PhysioFlow ($Q\dot{c}_{PF}$) and the direct Fick ($Q\dot{c}_{Fick}$) methods. Forty patients referred for right cardiac catheterisation, 14 with sleep apnoea syndrome and 26 with chronic obstructive pulmonary disease, took part in this study. The subjects' oxygen consumption values ranged from 0.14 to 1.19 l · min⁻¹. The mean difference between the two methods ($Q\dot{c}_{Fick} - Q\dot{c}_{PF}$) was 0.04 l · min⁻¹ at rest and 0.29 l · min⁻¹ during exercise. The limits of agreement, defined as mean difference ± 2SD, were -1.34, +1.41 l · min⁻¹ at rest and -2.34, +2.92 l · min⁻¹ during exercise. The difference between the two methods exceeded 20% in only 2.5% of the cases at rest, and 9.3% of the cases during exercise. Thoracic hyperinflation did not alter $Q\dot{c}_{PF}$. We conclude that the Physio Flow provides a clinically acceptable and non-invasive evaluation of cardiac output under these conditions. This new impedance cardiograph device deserves further study using other populations and situations.

Keywords:

- Impedance,
- Cardiography,
- Cardiac output,
- Fick principle,
- Exercise

Non-invasive Cardiac Output Evaluation during a Maximal Progressive Exercise Test, Using a New Impedance Cardiograph Device

European Journal of Applied Physiology, Volume 85 Issue 3/4 (July 2001) pp 202-207
DOI 10.1007/s004210100458

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Accepted: 10 April 2001 / Published Online: 4 July 2001

Abstract:

One of the greatest challenges in exercise physiology is to develop a valid, reliable, non-invasive and affordable measurement of cardiac output (CO). The purpose of this study was to evaluate the reproducibility and accuracy of a new impedance cardiograph device, the Physio Flow, during a 1-min step incremental exercise test from rest to maximal peak effort. A group of 12 subjects was evaluated to determine the reproducibility of the method as follows: (1) each subject performed two comparable tests while their CO was measured by impedance cardiography using the new device (COImp1, COImp2), and (2) in a subgroup of 7 subjects CO was also determined by the direct Fick method (COFick) during the second test. The mean difference between the values obtained by impedance (i.e. COImp1-COImp2) was $-0.009 \text{ l}\cdot\text{min}^{-1}$ (95% confidence interval: $-4.2 \text{ l}\cdot\text{min}^{-1}$, $4.2 \text{ l}\cdot\text{min}^{-1}$), and CO ranged from $3.55 \text{ l}\cdot\text{min}^{-1}$ to $26.75 \text{ l}\cdot\text{min}^{-1}$ ($n=146$). When expressed as a percentage, the difference (COImp1-COImp2) did not vary with increasing CO. The correlation coefficient between the values of COImp and COFick obtained during the second exercise test was $r=0.94$ ($P<0.01$, $n=50$). The mean difference expressed as percentage was -2.78% (95% confidence interval: -27.44% , 21.78%). We conclude that COImp provides a clinically acceptable evaluation of CO in healthy subjects during an incremental exercise.

Keywords:

- *Impedance,*
- *Cardiography,*
- *Cardiac output,*
- *Maximal exercise test*

Measurements of Cardiac Output during Constant Exercises: Comparison of Two Non-Invasive Techniques

Int J Sports Med 2004; 25: 145-149 DOI: 10.1055/s-2004-819949

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Abstract:

We compared cardiac output (CO) determined simultaneously by electrical impedance cardiography method (COICG) and by the CO₂ rebreathing technique (CO₂REB) during three different steady-state exercises (target heart rate of 120, 140, and 160 min⁻¹) in 8 healthy fit young men. The mean difference correlation coefficient obtained between the values of COICG and CO₂REB was 0.85 and the mean difference (COICG-CO₂REB) was 0.06 l/min (0.12 %). At 120 min⁻¹, COICG was lower than CO₂REB but the tendency was reversed at 140 and 160 min⁻¹ where COICG was higher than CO₂REB. This evolution may be explained by the difficulty of using CO₂ rebreathing technique at the highest steady-state exercises and by the progressive acidemia due to exercise. The present results suggest that electrical impedance cardiography method provides acceptable evaluation of CO and may favourably replace the CO₂ rebreathing technique during mild (or moderate) to high steady-state exercises.

Keywords:

- *Impedance,*
- *Cardiography*
- *Co₂ rebreathing technique,*
- *Indirect Fick principle,*
- *Steady state exercise*

Does Thoracic Bioimpedance Accurately Determine Cardiac Output in COPD patients during Maximal or Intermittent Exercise?

Chest. 2005 Apr;127(4):1122-31.

Authors:

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Study objectives:

The monitoring of cardiac output (CO) during exercise rehabilitation in patients with COPD, often including strenuous exercise, is advisable. Invasive methods (thermodilution, Fick method) are accurate, but for clinical routine use noninvasive CO estimation is required. We have shown that impedance cardiography (Physio Flow; Manatec Biomedical; Macheren, France) is reliable in COPD patients at rest and during a recumbent, light-intensity exercise. The aim of our study was to evaluate the validity of this noninvasive device in COPD patients during a maximal incremental exercise test (IET) and also during a strenuous intermittent work exercise test (IWET).

Design:

Prospective comparative study of the impedance cardiograph vs the direct Fick method applied to oxygen

Measurements and main results:

Forty-nine simultaneous measurements of CO by means of the direct Fick method (CO_{fick}) and CO measured by the impedance cardiograph (CO_{pf}) were obtained during the IET, and 108 measurements were made during the IWET. The correlation coefficients between the two measurements were $r = 0.85$ and $r = 0.71$ for the IET and the IWET, respectively. CO_{pf} was higher than CO_{fick}. The difference between the two methods was 3.2 ± 2.9 L/min during the IET and 2.5 ± 2.1 L/min during the IWET. Expressed as a percentage of the mean of the two measurements, this corresponded to $31 \pm 21\%$ and $25 \pm 20\%$, respectively.

Patients:

Eight patients with moderate-to-severe COPD (59 \pm 6 years old; FEV₁, 38 \pm 15% predicted; residual volume, 194 \pm 64% predicted) [mean \pm SD].

Conclusion:

The relatively high number of values differing by $> 20\%$ precludes the use of impedance cardiography in clinical routine in such a difficult setting (hyperinflated patients and intense exercise).

IMPORTANT NOTE FROM THE MANUFACTURER:

In an effort to present all publications involving PhysioFlow we have decided to include this particular one in our list. Its results may not look as favourable as all the other abstracts. However, it is to be noted that the protocol was performed in a way that is not compliant with the manufacturer's instructions: The investigators have used a particular prototype version of the PhysioFlow software in spite of our insistence that they should not do so. They have used electrodes that were not those recommended for optimal results. Moreover, data of this study have disappeared from the hard disk of the computer, making it impossible to reanalyse them with the appropriate version of the software. In addition, it is questionable that the Fick would perform well under incremental or strenuous intermittent work exercise test.

Reliability of Peak VO₂ and Maximal Cardiac Output Assessed using Thoracic Bioimpedance in Children

Eur J Appl Physio., 2005 Jun; 94(3):228-34. Epub 2005 May 26.

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Abstract:

The purpose of this study was to evaluate the reliability of a thoracic electrical bioimpedance based device (PhysioFlow) for the determination of cardiac output and stroke volume during exercise at peak oxygen uptake (peak VO₂) in children. The reliability of peak VO₂ is also reported. Eleven boys and nine girls aged 10-11 years completed a cycle ergometer test to voluntary exhaustion on three occasions each 1 week apart. Peak VO₂ was determined and cardiac output and stroke volume at peak VO₂ were measured using a thoracic bioelectrical impedance device (PhysioFlow). The reliability of peak VO₂ cardiac output and stroke volume were determined initially from pairwise comparisons and subsequently across all three trials analysed together through calculation of typical error and intraclass correlation. The pairwise comparisons revealed no consistent bias across tests for all three measures and there was no evidence of non-uniform errors (heteroscedasticity). When three trials were analysed together typical error expressed as a coefficient of variation was 4.1% for peak VO₂ 9.3% for cardiac output and 9.3% for stroke volume. Results analysed by sex revealed no consistent differences. The PhysioFlow method allows non-invasive, beat-to-beat determination of cardiac output and stroke volume which is feasible for measurements during maximal exercise in children. The reliability of the PhysioFlow falls between that demonstrated for Doppler echocardiography (5%) and CO₂ rebreathing (12%) at maximal exercise but combines the significant advantages of portability, lower expense and requires less technical expertise to obtain reliable results.

Does Advanced Cardiac Impedance Technology Accurately Measure Cardiac Output During Submaximal Steady State Exercise?

Control/Tracking Number: 09-SA-3991-ACSM

Activity: Scientific Abstract

Current Date/Time: 11/3/2008 8:13:33 PM

Authors:

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Abstract:

This study determined if advanced cardiac impedance technology (ACI) could accurately measure cardiac output during steady-state cycling exercise compared to values calculated using the direct Fick equation developed by Stringer et al (1997). METHOD: VO₂ max was determined on both a treadmill (Mean = 3.96 ± 1.2 liters/min) and cycle ergometer (Mean = 3.42 ± 1.2 liters/min) in 15 subjects (Age; 34.3. ± 9.4 yrs). Steady-state exercise wattage was set at 25%, 50%, and 75% of peak watts achieved. Subjects exercised 8 mins at each stage. The last 4 mins were used to determine the ACI values for cardiac output (Q), heart rate, stroke volume, EDV, SBP, DBP, and systemic vascular resistance. Both the submaximal and maximal exercise trials were performed in duplicate to assure accurate data collection. No significant differences were observed in test-retest trials. Thus, the mean of duplicate trials was used for all data analyses.

Keywords:

- Cardiac impedance,
- Steady state exercise
- Cycle ergometry

Category:

204 acute exercise

Author Disclosure Information:

C.E. Broeder,
PhysioFlow
Corporation, Contracted
Research.

Results:

There was no significant difference between the cardiac output determined by the Stringer equation and the ACI measured Q value. The percent differences across exercise intensity's for Q were 4.2%, -1.5%, and -6.7% for the 25%, 50%, and 75% of max watts, respectively. Linear regression analyses indicated rsquared = 0.99, SEE = 0.20 liters, p = .001. For all trials combined, the mean percent difference between the stringer cardiac output and the ACI cardiac output was 0.5%.

STAGE INTENSITY	VO2	% OF VO2 MAX	A-V DO2	STRINGER Q	ACI Q	% DIFFERENCE
25% MAX WATTS	1.37	40.1	0.097258	14.1	13.5	4.2%
50% MAX WATTS	2.17	63.5	0.120650	18.0	18.3	-1.5%
75% MAX WATTS	3.02	88.3	0.145504	20.8	22.2	-6.7%
MEAN OF ALL TRIALS	2.19	63.9	0.121138	18.1	17.97	0.5%

Conclusion:

In conclusion, these data indicate that the ACI system used in this study was highly accurate in determining a person's Q during steady state exercise ranging between 40.1% and 88.3% of VO₂ max. Future studies need to determine if similar accuracy can be achieved using other forms of exercise, i.e., treadmill.

The Ergogenic Effect of Recombinant Human Erythropoietin on VO₂max Depends on the Severity of Arterial Hypoxemia

Citation:

• Robach P, • Calbet JAL, • Thomsen JJ, • Boushel R, • Mollard P, • et al. (2008) The Ergogenic Effect of Recombinant Human Erythropoietin on V̇O₂max Depends on the Severity of Arterial Hypoxemia. PLoS ONE 3(8): e2996. doi:10.1371/journal.pone.0002996

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Competing Interests:

The authors have declared that no competing interests exist.

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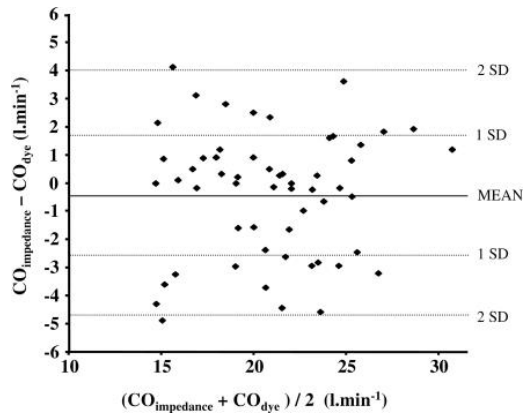
Abstract:

Treatment with recombinant human erythropoietin (rhEpo) induces a rise in blood oxygen-carrying capacity (CaO₂) that unequivocally enhances maximal oxygen uptake (V̇O₂max) during exercise in normoxia, but not when exercise is carried out in severe acute hypoxia. This implies that there should be a threshold altitude at which V̇O₂max is less dependent on CaO₂.

To ascertain which are the mechanisms explaining the interactions between hypoxia, CaO₂ and V̇O₂max we measured systemic and leg O₂ transport and utilization during incremental exercise to exhaustion in normoxia and with different degrees of acute hypoxia in eight rhEpo-treated subjects. Following prolonged rhEpo treatment, the gain in systemic VO₂max observed in normoxia (6–7%) persisted during mild hypoxia (8% at inspired O₂ fraction (FIO₂) of 0.173) and was even larger during moderate hypoxia (14–17% at FIO₂ = 0.153–0.134). When hypoxia was further augmented to FIO₂ = 0.115, there was no rhEpo-induced enhancement of systemic V̇O₂max or peak leg V̇O₂. The mechanism highlighted by our data is that besides its strong influence on CaO₂, rhEpo was found to enhance leg V̇O₂max in normoxia through a preferential redistribution of cardiac output toward the exercising legs, whereas this advantageous effect disappeared during severe hypoxia, leaving augmented CaO₂ alone insufficient for improving peak leg O₂ delivery and V̇O₂. Finally, that V̇O₂max was largely dependent on CaO₂ during moderate hypoxia but became abruptly CaO₂-independent by slightly increasing the severity of hypoxia could be an indirect evidence of the appearance of central fatigue.

measurement:

Agreement between impedance and dye dilution for cardiac output



This graph shows the agreement (Bland-Altman plot) between the cardiac impedance technique and the indocyanine green dye dilution method for measuring cardiac output during exercise obtained from 55 measurements in seven subjects. For each measurement, the difference between the two methods is plotted against the average of both techniques. The solid line indicates the mean bias, while the dotted lines indicate the 95% confidence intervals (2×standard deviation).

Poor accuracy of noninvasive cardiac output monitoring using bioimpedance cardiography [PhysioFlow(R)] compared to magnetic resonance imaging in pediatric patients

Anesth Analg. 2012 Apr;114(4):771-5. doi: 10.1213/ANE.0b013e318246c32c. Epub 2012 Feb 7.

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Abstract:

Identification of low cardiac output (CO) states in anesthesia is important because preoperative hemodynamic optimization may improve outcome in surgery. Accurate real-time CO measurement would be useful in optimizing "goal-directed" therapy. We sought to evaluate the reliability and accuracy of CO measurement using bioimpedance cardiography (PhysioFlow®, NeuMedx, Bristol, PA) in pediatric patients with and without cardiac disease undergoing anesthesia for magnetic resonance imaging (MRI).

Methods:

All consenting patients undergoing anesthesia for cardiac MRI were enrolled. After equilibration of anesthesia for ≥ 10 minutes, 6 PhysioFlow electrodes were applied to the patient's chest for continuous real-time monitoring for 10 minutes. Data were stored in 15-second epochs and later averaged offline to obtain CO. Phase contrast MRI measurements of flow volumes in the superior vena cava and ascending and descending aorta were made from a single imaging plane through all 3 vessels at the level of the right pulmonary artery. Both CO measurements were indexed to body surface area. The anesthetic technique was the same for both measurements. Agreement was assessed using Bland-Altman analysis.

Results:

Thirty-one patients were enrolled and 23 were analysed. The median age at study was 2.8 years (range, 0.02-8.02 years) and median body surface area was 0.54 m² (range, 0.21-1.00 m²). Eleven of the 23 patients (48%) were males. Patients were grouped into those with univentricular physiology, 6 of 23 (26%); biventricular physiology with shunt, 3 of 23 (13%); biventricular without shunt, 10 of 23 (43%); and no structural heart disease, 4 of 23 (17%). The mean bias was -0.34 ± 1.50 L/min/m² (P = 0.29). The 95% limits of agreement were -3.21 to $+2.69$ L/min/m². Only 8 of 23 measurements (35%) were within 20% and 14 of 23 measurements (61%) were within 30% of each other.

Conclusion:

PhysioFlow performance was not sufficiently accurate in this population. Modifications of the algorithm and further testing are required before this device can be recommended for routine clinical use in pediatric patient.

IMPORTANT NOTE FROM THE MANUFACTURER:

We do respect the Toronto Sick Children hospital team for their friendliness and professionalism. However there was a technical mistake in their data manipulation and all PhysioFlow recordings were lost by the research team before we could take a look at it and see what happened.

Please bear in mind that it was the very first time our system was applied to such a patient population and it was never calibrated for it before. It would have been extremely helpful to access the PhysioFlow recordings to

- 1) Assess their quality and potential operator's mistakes
- 2) Reprocess them with newer algorithms we developed later (these ones date back to 2004)
- 3) Calibrate the system to adapt it to this patient population.

This was the initial plan but it could never be implemented because of the loss of data.

Evaluation of Impedance Cardiography for Measurement of Stroke Volume in Congenital Heart Disease.

Pediatr Cardiol. 2016 Dec;37(8):1453-1457. Epub 2016 Aug 25.
PMID: 27562130 DOI: 10.1007/s00246-016-1456-x

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Abstract:

Noninvasive measurement of cardiac output (CO) and particularly stroke volume (SV) remain difficult but potentially valuable. These variables can be particularly challenging to measure in children with congenital heart disease (CHD). Impedance cardiography (IC) is a technique shown to be accurate in measuring SV in adults and in children with structurally normal hearts. The ease of use and rapidity of SV measurement using IC makes it potentially attractive for young patients with CHD. Advances in IC technology have led to more sophisticated signal-morphology IC (SMIC) devices that may further improve accuracy. We tested the accuracy of SMIC to measure SV in 21 subjects with CHD by comparing measurements with those from cardiac magnetic resonance (CMR) imaging. There was good agreement between SMIC and CMR in measurement of SV: mean difference = 1.7 ml ($p = 0.47$); $r = 0.89$. The agreement and correlation persisted when controlling for the differences in blood pressure and heart rate during the two testing methods. We conclude that SMIC is accurate at measuring SV and thus CO when compared to CMR in a variety of forms of CHD.

Keywords:

- Cardiac output;
- Congenital heart disease;
- Impedance cardiography;
- Stroke volume

IMPORTANT NOTE FROM THE MANUFACTURER:

This positive article confirms that the previous one contained severe methodological errors.

Evaluation of two methods for continuous cardiac output assessment during exercise in chronic heart failure patients

Submitted 20 March 2008. Accepted 16 October 2008.

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Abstract:

The purpose of this study was to evaluate the accuracy of two techniques for the continuous assessment of cardiac output in patients with chronic heart failure (CHF): a radial artery pulse contour analysis method that uses an indicator dilution method for calibration (LiDCO) and an impedance cardiography technique (Physioflow), using the Fick method as a reference. Ten male CHF patients (New York Heart Association class II–III) were included. At rest, cardiac output values obtained by LiDCO and Physioflow were compared with those of the direct Fick method. During exercise, the continuous Fick method was used as a reference. Exercise, performed on a cycle ergometer in upright position, consisted of two constant-load tests at 30% and 80% of the ventilatory threshold and a symptom-limited maximal test. Both at rest and during exercise LiDCO showed good agreement with reference values [bias ± limits of agreement (LOA), $-1\% \pm 28\%$ and $2\% \pm 28\%$, respectively]. In contrast, Physioflow overestimated reference values both at rest and during exercise (bias ± LOA, $48\% \pm 60\%$ and $48\% \pm 52\%$, respectively). Exercise-related within-patient changes of cardiac output, expressed as a percent change, showed for both techniques clinically acceptable agreement with reference values (bias ± LOA: $2\% \pm 26\%$ for LiDCO, and $-2\% \pm 36\%$ for Physioflow, respectively). In conclusion, although the limits of agreement with the Fick method are pretty broad, LiDCO provides accurate measurements of cardiac output during rest and exercise in CHF patients. Although Physioflow overestimates cardiac output, this method may still be useful to estimate relative changes during exercise.

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Cardiac output during exercise: A comparison of four methods

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Abstract:

Several techniques assessing cardiac output (Q) during exercise are available. The extent to which the measurements obtained from each respective technique compares to one another, however, is unclear. We quantified Q simultaneously using four methods: the Fick method with blood obtained from the right atrium (QFick-M), Innocor (inert gas rebreathing; QInn), Physioflow (impedance cardiography; QPhys), and Nexfin (pulse contour analysis; QPulse) in 12 male subjects during incremental cycling exercise to exhaustion in normoxia and hypoxia (FiO₂ = 12%). While all four methods reported a progressive increase in Q with exercise intensity, the slopes of the Q/oxygen uptake (VO₂) relationship differed by up to 50% between methods in both normoxia [4.9 ± 0.3, 3.9 ± 0.2, 6.0 ± 0.4, 4.8 ± 0.2 L/min per L/min (mean ± SE) for QFick-M, QInn, QPhys and QPulse, respectively; P = 0.001] and hypoxia (7.2 ± 0.7, 4.9 ± 0.5, 6.4 ± 0.8 and 5.1 ± 0.4 L/min per L/min; P = 0.04). In hypoxia, the increase in the Q/VO₂ slope was not detected by Nexfin. In normoxia, Q increases by 5–6 L/min per L/min increase in VO₂, which is within the 95% confidence interval of the Q/VO₂ slopes determined by the modified Fick method, Physioflow, and Nexfin apparatus while Innocor provided a lower value, potentially reflecting recirculation of the test gas into the pulmonary circulation. Thus, determination of Q during exercise depends significantly on the applied method.

Keywords:

- *Inert gas rebreathing*
- *Impedance*
- *Cardiography*
- *Pulse contour*
- *Analysis*
- *Hypoxia*
- *Maximal oxygen uptake*

IMPORTANT NOTE FROM THE MANUFACTURER:

The research team, contacted for the first time after publication, did not wish to share details about the software version that was used (which is important regarding the filtering of signals), nor the skin preparation methodology/electrode type. However they found that PhysioFlow generates fewer impossible /implausible readings than other methods.

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Scandinavian Journal of Medicine & Science in Sports

Comparison of Thoracic Bioimpedance with Acetylene Uptake for Measuring Cardiac Output.

Int J Sports Med. 2014 Jun 2. [Epub ahead of print]

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Abstract:

Cardiac output is shown to be a key determinant for oxygen transport, performance and health. Reliable and accurate non-invasive measurements of cardiac output, especially during exercise, are therefore of importance. The present study compared a new thoracic bioimpedance method with the established single-breath acetylene uptake method. We assessed cardiac output in 20 (24±4 years.) moderately trained males, at rest and during cycling. Both methods showed good test-retest reliabilities with ±2 SD limits of agreement of 3.67 and -4.50 L · min⁻¹ (thoracic bioimpedance) and 4.46 and -5.69 L · min⁻¹ (single breath), respectively. When thoracic bioimpedance was compared with single breath, the ±2 SD limits of agreement were poor (-6.05 and 9.57 L · min⁻¹). Thoracic bioimpedance displayed significantly lower (p<0.05) absolute cardiac output values than single breath, and the cardiac output-oxygen consumption slopes (y=5.7x+5.5 (single breath) and y=5.0x+5.0 (thoracic bioimpedance) tended (p=0.08) to show less increase for thoracic bioimpedance. Conclusions: Results from the single-breath method are in line with previous findings, showing a good reliability. Although thoracic bioimpedance showed a similar reliability as the single-breath method, and is easier to use, the agreement with single breath was poor, and thoracic bioimpedance seems not to be able to replace it.

IMPORTANT NOTE FROM THE MANUFACTURER:

The Enduro unit on loan in Trondheim was an early stage device and had a defective ECG detection in the firmware, which has been corrected in the meantime. It resulted in a poor calculation of HR and also a bad trigger for the signal stabilization filter. We were offered the opportunity to reprocess the data. Unfortunately the team did not maintain the patients at real rest after calibration and therefore re-calculating the calibration and the test was not productive. This study should not have been published without mention of these issues as they affect its entire validity.

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PMID: 24886928 [PubMed - as supplied by publisher]

Reliability of exercise cardiac output measurement in COPD using impedancemetry: comparison with CO₂ and inert gas rebreathing.

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Rationale:

Interest in the measurement of exercise cardiac output (Qc) in patients with Chronic Obstructive Pulmonary Disease (COPD) has resurged due to the recent proposition that dynamic hyperinflation may result in blood trapping within the pulmonary circulation, thereby limiting oxygen delivery and exercise capacity. To date, the ability to measure Qc non-invasively in these patients is constrained by techniques dependent upon appropriate ventilation: perfusion for adequate pulmonary blood-gas diffusion. The technique of thoracic bioimpedance presents an interesting alternative as it does not depend on gas lung transfer factors, provides continuous measurement from rest to peak exercise and is free of patient interaction, unlike rebreathing methods. This study reports on the reliability of thoracic bioimpedance (Physioflow®) compared to standard CO₂- rebreathing and inert-gas rebreathing (Innocor®) techniques for use in test-retest submaximal steady state exercise.

Methods:

Stable COPD patients (N=8; 66±4 yrs; FEV₁= 56±6% pred.) were assessed on 2 occasions separated by at least 2 days. Qc was measured using the 3 techniques at the end of 5-minute steady-state cycling at 20, 35, 50 and 65%peak power bouts. The reported Qc was the average of 2 consecutive measures at each workload.

Results:

All techniques provided measurements in a physiologically acceptable range for the power output and showed good reproducibility with no difference in test-retest mean values. CO₂ rebreathing resulted in systematically higher values both at rest and during exercise as compared to Physioflow® (mean Δ L/min: 0.5 rest; 0.7, 0.3, 0.8 at 20, 35, 50% peak power). In contrast, Innocor® resulted in systematically lower rest and exercise values as compared to Physioflow® (mean Δ L/min: 1.6 rest; 1.6, 1.2, 1.8 at 20, 35, 50% peak power). Results also showed the coefficient of reproducibility calculated on test-retest to be highest in Physioflow® (R² = 0.80) compared with Innocor® and CO₂ rebreathing (R² = 0.72 and 0.53)

Conclusion:

These preliminary results suggest that thoracic bioimpedance presents a valuable tool to monitor Qc in COPD under resting and moderate exercise conditions resulting in significant hyperventilation and moderate dynamic hyperinflation.

Funded by: Respiratory and Epidemiology Clinical Research Unit of the McGill University Health Center

American Journal of Respiratory and Critical Care Medicine 2010;181:A5942

Cardiac output measurement during exercise in COPD: A comparison of dye dilution and impedance cardiography

2019 Apr;13(4):222-231 crj.13002. Epub 2019 Feb 28.

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Abstract :

Introduction:

Impedance cardiography (IC) derived from morphological analysis of the thoracic impedance signal is now commonly used for noninvasive assessment of cardiac output (CO) at rest and during exercise. However, in Chronic Obstructive Pulmonary Disease (COPD), conflicting findings put its accuracy into question.

Objectives:

We therefore compared concurrent CO measurements captured by IC (PhysioFlow: COIC) and by the indocyanine green dye dilution method (Codd) in patients with COPD.

Methods:

Fifty paired CO measurements were concurrently obtained using the two methods from 10 patients (FEV1 : $50.5 \pm 17.5\%$ predicted) at rest and during cycling at 25%, 50%, 75% and 100% peak work rate.

Results:

From rest to peak exercise COIC and Codd were strongly correlated ($r = 0.986$, $P < 0.001$). The mean absolute and percentage differences between COIC and Codd were 1.08 L/min (limits of agreement (LoA): 0.05-2.11 L/min) and $18 \pm 2\%$, respectively, with IC yielding systematically higher values. Bland-Altman analysis indicated that during exercise only 7 of the 50 paired measurements differed by more than 20%. When data were expressed as changes from rest, correlations and agreement between the two methods remained strong over the entire exercise range ($r = 0.974$, $P < 0.001$, with no significant difference: 0.19 L/min; LoA: -0.76 to 1.15 L/min). Oxygen uptake (VO_2) and Codd were linearly related: $r = 0.893$ ($P < 0.001$), $Codd = 5.94 \times VO_2 + 2.27$ L/min. Similar results were obtained for VO_2 and COIC ($r = 0.885$, $P < 0.001$, $COIC = 6.00 \times VO_2 + 3.30$ L/min).

Conclusion:

These findings suggest that IC provides an acceptable CO measurement from rest to peak cycling exercise in patients with COPD.

Cardiac output with modified cardio-impedance against inert gas rebreathing during sub-maximal and maximal cycling exercise in healthy and fit subjects

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Abstract :

Purpose:

We measured cardiac output ([Formula: see text]) during sub-maximal and supra-maximal exercise with inert gas rebreathing ([Formula: see text]) and modified cardio-impedance ([Formula: see text]) and we evaluated the repeatability of the two methods.

Methods:

[Formula: see text] O_2 and [Formula: see text] were measured twice in parallel with the two methods at sub-maximal (50-250 W) and supra-maximal exercise in 7 young subjects (25 ± 1 years; 74.4 ± 5.2 kg; 1.84 ± 0.07 m).

Results:

[Formula: see text] and [Formula: see text] increased by 3.4 L·min⁻¹ and by 5.1 L·min⁻¹ per 1 L·min⁻¹ of increase in [Formula: see text], respectively. Mean [Formula: see text] (23.3 ± 2.5 L·min⁻¹) was 9% lower than [Formula: see text] (25.8 ± 2.2 L·min⁻¹) during supra-maximal exercise. Bland-Altman analysis showed that: (i) bias ([Formula: see text]-[Formula: see text]) was significantly different from zero (-0.65 ± 2.61 L·min⁻¹) and; (ii) the ratios [Formula: see text] ÷ [Formula: see text] were linearly related with [Formula: see text], indicating that [Formula: see text] tended to overestimate [Formula: see text] in comparison with [Formula: see text] for values ranging from 10.0 to 15.0 L·min⁻¹ and to underestimate it for larger values. The coefficient of variation was similar for sub-maximal values (8.6% vs. 7.7%; 95% CL: ×/÷1.31), but lower for [Formula: see text] (7.6%; 95% CL: ×/÷ 2.05) than for [Formula: see text] (27.7%; 95% CL: ×/÷2.54) at supra-maximal intensity.

Conclusion:

[Formula: see text] seems to represent a valuable alternative to invasive methods for assessing [Formula: see text] during sub-maximal exercise. The [Formula: see text] underestimation with respect to [Formula: see text] during supra-maximal exercise suggests that [Formula: see text] might be less optimal for supra-maximal intensities.

Determination of Cardiac Output in Pulmonary Hypertension Using Impedance Cardiography

2018;96(6):500-506 000486423. Epub 2018 Feb 9.

Authors:

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|---|---|

Abstract :

Background:

Cardiac output (CO) is a prognostic factor in pulmonary hypertension (PH). Right heart catheterisation using the direct Fick method or thermodilution (TD) is the reference technique for CO measurement. Impedance cardiography (IPc) is a known non-invasive method of measuring CO.

Objectives:

In our study, we assume that the measurement of CO by IPc using the PHYSIOFLOW® system is as accurate as TD or using the direct Fick method in patients with PH in group 1 or group 4.

Methods:

A total of 75 patients were enrolled in a prospective study carried out at the hypertension reference centre of Toulouse University Hospital. Right heart catheterisation was performed for the diagnosis or follow-up of the disease. CO was measured using the Fick method, TD, and IPc simultaneously. A Bland-Altman analysis was plotted.

Results:

CO was 5.7 ± 1.9 L/min as measured by the Fick method, 5.4 ± 1.5 L/min by TD, and 5.5 ± 1.7 L/min by IPc. The bias between CO measurements by IPc and the direct Fick method was 0.149 L/min (95% CI, -0.298 to 0.596). The bias between CO measurements by IPc and the TD method was -0.153 L/min (95% CI, -0.450 to 0.153). The correlation decreased with the more extreme CO values (< 3 L/min or > 7 L/min). A few factors changed the agreement between measurements (BMI or membership in group 4).

Conclusion:

To conclude, this study shows that the measurement of CO by IPc in PH patients is reliable compared to the direct Fick method and TD obtained by right heart catheterisation. This accuracy decreases for extreme CO values.

1.2 THERMODILUTION/ECHO-DOPPLER/REST

Cardiac Output Measurements: Comparison between a New Transthoracic Electrical Bioimpedance Method (Physioflow™) and the Swan-Ganz Method (Continuous Cardiac Output or Bolus Technique)

Published at the French Anaesthesiology Society, Sept 2001

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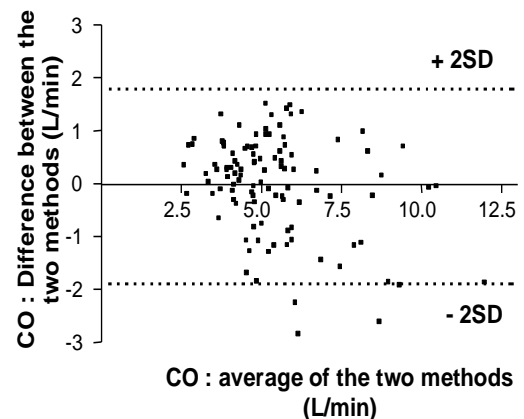
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Abstract:

Cardiac Output (CO) measurement using Transthoracic Electrical Bioimpedance (TEB) has been recently improved. We have tested a system using exclusively relative values of the impedance signal, and not absolute values (Z0). Indeed, the Z0 value has been described as being at origin of the practical limitations of TEB. We have chosen the Swan-Ganz method to provide reference values, using boluses (B), or continuous cardiac output (CCO) (BAXTER™ Vigilance®).

Results:

107 ICU patients underwent simultaneous CO measurements using the two methods (CO Swan Ganz : 20 B and 87 CCO). One measurement was performed on every patient (84 Male/23 Female, age 69±11 years, weight 75±15 Kg, height 167±8 cm). Pathologies : aortic and bypass surgery 65 %, septic shock 18%, heart failure 7%, pulmonary patients 7%, misc. 3%. Linear regression factor was 0.88 (p<0.001). CO PhysioFlow = 0.75 CO Swan + 1.33. Bland and Altman diagram is represented below (bias = -0.014 L/min).



Conclusion:

This study has been done under the most difficult conditions for TEB : one single measurement per patient, and patients presenting a very large variety of pathologies. This new TEB method deserves further investigations, using the Fick method, on the same range of unselected ICU patients. Indeed, literature displays that Fick as a reference method features a reduced dispersion of results compared to thermodilution¹.

References:

- ¹ : Charloux et al., Eur. J. Appl. Physiol. (2000) 82: 313-320

Conclusion of the report on PhysioFlow Studies performed at MUSC Charleston, SC and UPMC Pittsburgh, PA, 2007

This multicenter study has been performed on a population of representative American patients referred to major medical institutions for severe cardiovascular diseases. In that frame PhysioFlow has proven that it is substantially equivalent to the predicate device (Philips) and FDA should grant clearance because:

It performs much better than the predicate device in terms of accuracy and ability to provide clinically relevant numbers, even in difficult patients. Its comparative measurements to a clinically accepted reference method are as good as expected with reference to the best scientific literature. It performs as well as the best established invasive reference technique (Fick) with comparison to thermodilution

In conclusion, this study achieved its objective of demonstrating

- 1) The agreement in CO between the PhysioFlow ICG PF-05 and thermodilution is similar to or better than the agreement between the Philips ICG and thermodilution; and
- 2) Absolute agreement between the PhysioFlow ICG PF-5 itself and thermodilution is adequate when accounting for the known variability in the thermodilution reference method.

Value of Impedance Cardiography in Pulmonary Hypertension

Pulmonary Hypertension Posters
Tuesday, November 2, 2010

Authors:

•Adriano R., •MD; Robin Carrie,
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•Hassan Alnuaimat, •Kamal Mubarak, MD

*University of Florida, Gainesville, FL

Purpose:

To assess impedance cardiography as a method for obtaining a non-invasive hemodynamic evaluation in patients with pulmonary hypertension (PH).

Methods:

A total of 39 patients (age 57 ± 14 years, 87% women) with presumed (23%) or confirmed PH (77%) of different etiologies who underwent right heart catheterization (RHC) at University of Florida from August 2009 to March 2010 agreed to be studied by impedance cardiography (PhysioFlow(r) PF-05, Manatec Biomedical, Macheren, France) immediately after RHC. PhysioFlow(r) measures cardiac output (CO) and end-diastolic volume (EDV), among other parameters.

Results:

The median pulmonary artery pressure was 36 (IQR 26-56)mm Hg. The CO (mean \pm SD in l/m) by thermodilution (CO-T), Fick methodology (CO-F) and impedance cardiography (CO-IC) was 5.9 ± 2.2 , 5.5 ± 1.6 and 5.6 ± 1.5 , respectively. Bland-Altman analysis of CO-T versus CO-F showed mean of 0.4 L/min (95% limit of agreement (LoA) 3.4 and -2.6), CO-T versus CO-IC a mean of 0.3 L/min (95% LoA 2.8 and -2.2) and CO-F versus CO-IC a mean of -0.1 L/min (95% LoA 2.5 and -2.7). Correlation between CO-T and CO-IC was $R^2 = 0.7$, $p < 0.001$. In patients with PH the correlation of CO-T and CO-IC had a mean of 0.4 L/min(95% LoA 2.9 and -2.2), $R^2 = 0.75$, $p < 0.001$. Pulmonary artery occlusion pressure (PAOP) correlated with EDV ($R^2 = 0.2$, $p = 0.005$). By ROC analysis EDV of 200 ml had a sensitivity of 53% and a specificity of 86% for PAOP > 15 mm Hg (AUC: 0.78).

Clinical Implications:

Impedance cardiography reliably measures cardiac output in patients with pulmonary hypertension. This methodology may serve as a valid tool for the hemodynamic evaluation of this group of patients.

Conclusion:

Impedance cardiography allows a reliable and non-invasive measurement of cardiac output in patients with PH. End-diastolic volume correlated with pulmonary artery occlusion pressure.

Disclosure:

Adriano Tonelli, No Financial Disclosure Information; No Product/Research Disclosure Information

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(Chest. 2010; 138:359A)
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Value of Impedance Cardiography in Patients Studied for Pulmonary Hypertension

Pulmonary Hypertension Posters
24 May, 2011

Authors:

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Abstract:

The aim of this study was to evaluate the accuracy and precision of impedance cardiography as a method for noninvasive hemodynamic evaluation of patients with pulmonary hypertension (PH). We performed a prospective and blinded study of patients who underwent right heart catheterization (RHC) for evaluation of known or presumed PH at the University of Florida from August 2009 to March 2010. The cohort consisted of a total of 39 patients (age = 57 ± 14 years, 87% women) with presumed (23%) or confirmed PH (77%) of different etiologies. Patients underwent RHC and impedance cardiography using the PhysioFlow PF-05.

The PhysioFlow PF-05 measures cardiac output (CO) and LV end-diastolic volume (LVEDV), among other parameters. The median pulmonary artery pressure was 36 (IQR 26-56) mmHg. The CO (mean \pm SD) by thermodilution (CO-T) and by impedance cardiography (CO-IC) was 5.9 ± 2.2 and 5.6 ± 1.5 L/min, respectively. Bland-Altman analysis of CO-T versus CO-IC revealed a mean of 0.3 L/min (95% LoA: -2.2 to 2.8). In patients with PH, the correlation of CO-T and CO-IC had a mean of 0.4 L/min (95% LoA: 2.9 and -2.2). Pulmonary artery occlusion pressure (PAOP) correlated with LVEDV ($R^2 = 0.2$, $p = 0.005$). By ROC analysis, EDV C 200 ml had a sensitivity of 53% and a specificity of 86% for PAOP[15 mmHg (AUC = 0.78). In patients with PH, impedance cardiography had good accuracy and fair precision for CO determination when compared with thermodilution. Impedance cardiography may provide information about the preload status and has the potential to become a cost-effective and noninvasive method for the follow-up of patients with PH.

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Lung, October 2011, Volume 189, Issue 5, pp 369–375

The PhysioFlow Thoracic Impedancemeter Is Not Valid for the Measurements of Cardiac Hemodynamic Parameters in Chronic Anemic Patients

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Published: October 22, 2013

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Abstract:

The aim of the present study was to test the validity of the transthoracic electrical bioimpedance method PhysioFlow® to measure stroke volume in patients with chronic anemia. Stroke volume index (SVI), as well as cardiac index (CI) obtained by transthoracic electrical bioimpedance method and doppler echocardiography were compared in healthy subjects (n = 25) and patients with chronic anemia (i.e. mainly with sickle cell anemia; n = 32), at rest. While doppler echocardiography was able to detect difference in SVI between the two populations, the Physioflow® failed to detect any difference. Bland & Altman analyses have demonstrated no interchangeability between the two methods to assess CI and SVI in anemic patients and healthy subjects. While doppler echocardiography displayed a good concordance for SVI results with those obtained in the literature for anemic patients, the Physioflow® did not. Finally, in contrast to doppler echocardiography:

- 1) the CI obtained with the Physioflow® was not correlated with the hemoglobin level and
- 2) the stroke volume determined by the Physioflow® was highly influenced by body surface area. In conclusion, our findings indicate that the Physioflow® device is inaccurate for the measurement of SVI and CI in patients with chronic anemia and has a poor accuracy for the measurement of these parameters in African healthy subjects.

IMPORTANT NOTE FROM THE MANUFACTURER:

This is an absurd outcome generated by a very early development software that should never have been used by any customer and was unfortunately released by mistake to one center in France and passed on to this center in Abidjean. In truth, PhysioFlow SVi is NOT correlated to body height or weight.

The research team, contacted for the first time after publication, did not wish to share details about the software version that was used nor accepted our offer to reprocess recordings with the appropriate version of the software, which is highly regrettable. There is absolutely no evidence precluding the use of PhysioFlow in the African population.

Stroke Volume Variation Measured by Impedance Cardiography During Passive Leg Raising to Assess Fluid Responsiveness After Cardiac Surgery

Copyright © 2013 American Society of Anesthesiologists

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Abstract:

After cardiac surgery, fluid management is critical and has a major impact on morbidity and mortality. A reliable parameter to predict fluid responsiveness is essential. The aim of this study was to investigate whether the measure of stroke volume variations (ΔSV) by impedance cardiography during passive leg raising (PLR) can reliably predict preload dependency after cardiac surgery, in comparison to a reference parameter: velocity time integral variation (ΔVTI) measured by transthoracic echocardiography (TTE).

Material and methods:

A prospective, observational study was conducted after obtaining ethics committee approval and informed consent, on patients requiring cardiac surgery with extracorporeal circulation.

The PLR maneuver was performed within the two first hours after surgery on sedated patients under mechanical ventilation and with sinus rhythm. All hemodynamic variables (heart rate, systolic and diastolic arterial pressure, central venous pressure (CVP), left auricular pressure (LAP), SV, VTI, cardiac output and index, left ventricular filling pressures (LVFP), ejection fraction) were measured before and after PLR.

We classified patients as responders (R) or non responders (NR): R were defined as patients presenting a $\Delta VTI \geq 12\%$ during the 90 seconds following PLR, and NR as patients presenting a $\Delta VTI < 12\%$.

The ΔSV measured by impedance cardiography was compared to the ΔVTI . The area under the ROC curve was determined to assess the ability of ΔSV to classify the R and NR patients.

Secondary aims of the study were to search for other predictive parameters for preload dependence: CVP, LAP and LVFP variations after PLR and respiratory variations of inferior vena cava.

Patients were otherwise treated according to the regular protocol of the ICU. The physicians of the ICU were blinded to impedance cardiography measures.

Results:

Among the 50 included patients, 24 were R (48%) and 26 NR (52%).

The area under the ROC curve was 0.818 ($p = 0.0008$). A $\Delta SV \geq 20.7\%$ allowed discrimination between R and NR with a sensitivity of 86.2% and a specificity of 90.5%.

We didn't find any other significantly predictive parameter for preload dependency.

Conclusion:

Based on the comparison to ΔVTI measured by TTE, ΔSV measured by impedance cardiography during a PLR maneuver seems to be a reliable predictor for preload dependency after cardiac surgery.

Validation of impedance cardiography in pulmonary arterial hypertension

Clinical Physiology and Functional Imaging 2017 February 6
doi: 10.1111/cpf.12408.

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- Alistair C Church,
- Andrew J Peacock,
- Martin K Johnson

Background:

Non-invasive methods of measuring cardiac output are highly desirable in pulmonary arterial hypertension (PAH). We therefore sought to validate impedance cardiography (ICG) against thermodilution (TD) and cardiac magnetic resonance (CMR) in the measurement of cardiac output in patients under investigation for PAH.

Methods:

A prospective, cross-sectional study was performed to compare single-point measurements of cardiac output obtained by impedance cardiography (COICG) technology (PhysioFlow®) with (i) contemporaneous TD measurements (COTD) at rest and steady-state exercise during right heart catheterization and (ii) CMR measurements (COCMR) at rest obtained within 72 h.

Results:

Paired COICG and COTD measurements were obtained in 25 subjects at rest and 16 subjects at exercise. COCMR measurements were obtained in 16 subjects at rest. There was unsatisfactory correlation and agreement between COICG and COTD at rest ($r = 0.42$, $P = 0.035$; bias: 1.21 l min^{-1}), 95% CI: -2.33 to 4.75 l min^{-1}) and exercise ($r = .65$, $P = .007$; bias: 1.41 l min^{-1}); 95% CI: -3.99 to 6.81 l min^{-1}) and in the change in COICG and COTD from rest to exercise ($r = 0.53$, $P = 0.033$; bias: 0.76 l min^{-1}), 95% CI: -3.74 to 5.26 l min^{-1}). There was also a lack of correlation and unsatisfactory agreement between resting COICG and COCMR ($r = 0.38$, $P = 0.1$; bias: 1.40 l min^{-1}), 95% CI: -2.48 to 5.28 l min^{-1}). In contrast, there was close correlation and agreement between resting COTD and COCMR ($r = 0.87$, $P < 0.001$; bias: -0.16 l min^{-1}), 95% CI: -1.97 to 1.65).

Conclusion:

In a representative population of patients under investigation for PAH, ICG showed insufficient qualitative and quantitative value in the measurement of resting and exercise cardiac output when compared with TD and CMR.

IMPORTANT NOTE FROM THE MANUFACTURER:

This study was performed with an older generation PhysioFlow Enduro which was equipped with a built in amplifier that was underperforming in such "difficult" patient population. The study below shows good performance in a similar population, with an upgraded device featuring the current amplifier.

Accuracy of impedance cardiography to measure cardiac output at rest in pulmonary hypertension

European Respiratory Journal 2015 46: PA3782; DOI: 10.1183/13993003.congress-2015.PA3782

Authors:

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- Fabien Pillard,
- Daniel Rivière,
- Alain Didier

Abstract:

Introduction: Cardiac output (CO) is one of the most important prognostic factor in PH and is required for the assessment of treatment response. CO is measured invasively by right heart catheterization by thermodilution or the Fick method. Impedance cardiography (IP) measures CO and is noninvasive, simple and provides immediate results.

Objectives: The main objective of this feasibility study was to assess the accuracy of of CO measures performed IP compared to the Fick method in selected patients treated for PH (Group 1 or 4). Secondary objectives were to evaluate the accuracy of CO evaluation by IP compared to thermodilution and to determine the factors that may affect the measures.

Methods: Patients were recruited from the cohort of the Competence Center PH of Midi-Pyrenees, France. The three techniques (Fick, thermodilution and IP) were realized at the same time during right heart catheterization performed in the patient follow up. All patients had confirmed PH from Group 1 or group 4.

Results: We had recruited 37 subjects in the study. (31 patients group 1 and 6 patients group 4). The CO measured by IP correlates with the CO measured by the Fick method: $\rho=0.62$ CI 95% [0.3064; 0.8124] ($P<0.001$) and $\rho^2= 0.385$. The CO measured by IP correlates with the CO measured by thermodilution: $\rho=0.7468$ CI 95% [0.5578; 0.8622] ($p<0.0001$) and $\rho^2= 0.56$. In PH patients CO changes observed during the test was related to stroke volume variation and predominantly in patients known to have intracardiac shunt.

Conclusion:

This pilot study validates the measurement of CO by IP in patients with PH (group 1 or 4). This suggests a potential role of the non-invasive IP in the follow up of PH patients.

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Cardiac output measurement during exercise in COPD: A comparison of dye dilution and impedance cardiography

Clin Respir J 2019 Apr;13

Authors:

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Abstract:

Introduction:

Impedance cardiography (IC) derived from morphological analysis of the thoracic impedance signal is now commonly used for noninvasive assessment of cardiac output (CO) at rest and during exercise. However, in Chronic Obstructive Pulmonary Disease (COPD), conflicting findings put its accuracy into question.

Objectives:

We therefore compared concurrent CO measurements captured by IC (PhysioFlow: CO_{IC}) and by the indocyanine green dye dilution method (CO_{DD}) in patients with COPD.

Methods:

Fifty paired CO measurements were concurrently obtained using the two methods from 10 patients (FEV₁: 50.5 ± 17.5% predicted) at rest and during cycling at 25%, 50%, 75% and 100% peak work rate.

Results:

From rest to peak exercise CO_{IC} and CO_{DD} were strongly correlated ($r = 0.986$, $P < 0.001$). The mean absolute and percentage differences between CO_{IC} and CO_{DD} were 1.08 L/min (limits of agreement (LoA): 0.05-2.11 L/min) and $18 \pm 2\%$, respectively, with IC yielding systematically higher values. Bland-Altman analysis indicated that during exercise only 7 of the 50 paired measurements differed by more than 20%. When data were expressed as changes from rest, correlations and agreement between the two methods remained strong over the entire exercise range ($r = 0.974$, $P < 0.001$, with no significant difference: 0.19 L/min; LoA: -0.76 to 1.15 L/min). Oxygen uptake (VO₂) and CO_{DD} were linearly related: $r = 0.893$ ($P < 0.001$), $CO_{DD} = 5.94 \times VO_2 + 2.27$ L/min. Similar results were obtained for VO₂ and CO_{IC} ($r = 0.885$, $P < 0.001$, $CO_{IC} = 6.00 \times VO_2 + 3.30$ L/min).

Conclusion:

These findings suggest that IC provides an acceptable CO measurement from rest to peak cycling exercise in patients with COPD.

Stroke volume and cardiac output measurement in cardiac patients during a rehabilitation program: comparison between tonometry, impedancemetry and echocardiography

2020 Mar;36(3):447-455 10554-019-01738-y. Epub 2019 Dec 16.

Authors:

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Abstract:

Given the increasing use of noninvasive techniques for the assessment of cardiac function in clinical practice, the aim of this study was to evaluate if stroke volume (SV) and cardiac output (CO) measurements obtained by PhysioFlow impedance cardiography or HDI CR-2000 pulse wave analysis (Pulse) are interchangeable with measurements obtained by echocardiography in patients with coronary artery disease (CAD) or heart failure (HF). The study involved 48 men with heart disease (CAD or HF). We compared SV and CO measurements with the three devices at rest, as well as relative changes in SV and CO derived from a rehabilitation program. SV and CO measurements were carried out first by echocardiography and immediately after using tonometry and impedancemetry techniques simultaneously. The Bland-Altman analysis showed a significant bias in the measurement of absolute SV and CO values with Pulse and PhysioFlow. Four quadrant plot and polar plot analysis of relative change SV between Pulse and echocardiography show a rate of concordance of 77% (95% CI 60-88%) and 79% (95% CI 63-89%) respectively. The polar plot analysis showed a mean polar angle of $34^{\circ} \pm 22^{\circ}$, and a 30° radial sector containing 52% of the data points. Both Pulse and PhysioFlow devices overestimate absolute SV and CO values compared to values recorded using echocardiography. Similarly, neither Pulse nor PhysioFlow reliably track SV or CO changes after a rehabilitation program compared with echocardiography.

1.3 REPRODUCIBILITY/ELECTRODE PLACEMENT

Measurement of Cardiac Output Using PhysioFlow® with Different Positions of Electrode Placement

Singapore Med J 2006; 47(11): 967

Authors:

- Tan K H,
- Lai F O,
- Hwang N C

Abstract:

PhysioFlow is a non-invasive impedance cardiograph device that measures cardiac output. Recommended electrode placements involve six electrodes, including two near the xiphisternum (Z3 and Z4/EcG3/neutral). This study aims to evaluate if changing the positions of these two leads to the left fourth and fifth intercostal spaces along the mid- axillary line results in a change in the cardiac output measurement.

Keywords:

- *Electrode placements*
- *Impedance*
- *Non-invasive cardiac output monitoring* , • *PhysioFlow®*

Methods:

This was a prospective, controlled, crossover, paired study of 30 patients where electrodes were placed in the recommended positions and cardiac output (CO1) obtained after two minutes. The second cardiac output (CO2) was then obtained with the electrodes Z3 and Z4/EcG3/neutral repositioned at the left mid- axillary line at the fourth and fifth intercostal spaces. The final step involved switching the Z3 and Z4/EcG3/neutral leads back to the recommended position and the cardiac output (CO3) was measured. Results: the average of the initial and third readings (COave) was compared with the measured CO2 and analyzed. The regression equation was: CO at the proposed site (CO2) = COave at the recommended site + 0.058. The paired samples correlation was 0.995. Within the 95 percent limits of agreement, the bias with CO measured at the proposed site of electrode placement was 0.046 L/min with the limits at - 0.24 L/min and 0.34 L/min. the mean difference was 0.86% of the average CO.

Reproductibility of cardiac monitoring in men using impedance cardiography during Müller maneuver.

[Pneumologia](#). 2011 Oct-Dec;60(4):213-5.

Authors:

- [Aron A](#)¹,
- [Zedalis D](#),
- [Herbert WG](#).

1 Department of Human Nutrition, Food and Exercise, Virginia Tech, Blacksburg, VA, USA. aaron@radford.edu

Abstract:

Obstructive sleep apnea hypopnea syndrome (OSAHS) is a form of sleep-disordered breathing highlighted by recurrent episodes of upper airway collapse during sleep. OSAHS contributes to an increased risk of cardiac arrhythmias, cardiovascular disease, and altered immune function. Measuring cardiac function in OSAHS patients can provide information that can help delineate clinical treatment efficacy. Cardiac function has been widely tested using electrical bioimpedance.

AIM:

The aim of this study was to determine the reproducibility of cardiac functional parameters in subjects performing Müller maneuver.

METHODS:

Fifteen apparently healthy males were tested on three different days in a protocol requiring their performance of forced and sustained inspiratory efforts against a closed epiglottis (Müller maneuver-MM). On each day, the protocol included performance of two simulated apneas of 30 seconds, with at least 3 minutes of normal breathing in between.

Results:

Changes from a normal breathing baseline for cardiac output, heart rate and stroke volume were comparable during both MM in all three days. The coefficient of variation was similar on all three trials.

Conclusion:

This new contemporary bioimpedance cardiography device provided reliable measures of dynamic cardiac responses during a simulated apnea event

PMID: 22420171

Intrarater reliability and agreement of the Physioflow bioimpedance cardiography device during rest, moderate and high-intensity exercise

Kinesiology 50(2018) Suppl.1:140-149
Original scientific paper, UDC: 796.012:519.2

Authors:

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4 Allied Health Department, Fiona Stanley Hospital, 11 Robin Warren Drive, Murdoch, Western Australia, 6150, AUS

Abstract:

The PhysioFlow bioimpedance cardiography device provides key measures of central systolic and diastolic and peripheral vascular function. Many of these variables have not been assessed for intrarater reliability and agreement during rest, submaximal exercise and high-intensity interval exercise. Twenty healthy adults (age: 26±4 years) completed two identical trials beginning with five minutes of rest followed by two 5-minute submaximal cycling bouts at 50% and 70% of peak power output. Subjects then completed ten 30-second cycling intervals at 90% of peak power output interspersed with 60 s of passive recovery. Bioimpedance cardiography (PhysioFlow; Manatec Biomedical, France) monitored heart rate, stroke volume, cardiac output, stroke volume index, cardiac index, ventricular ejection time, contractility index, ejection fraction, left cardiac work index, end diastolic volume, early diastolic filling ratio, systemic vascular resistance and systemic vascular resistance index continuously throughout both trials. Intraclass correlation coefficients (ICC), standard errors of measurement and minimal detectable differences were calculated for all variables. Heart rate, stroke volume, cardiac output, left cardiac work index and end diastolic volume demonstrated a good level of reliability (ICC>.75) at rest, during submaximal exercise and high-intensity interval exercise. All other variables demonstrated inconsistent reliability across activity types and intensities. When using the PhysioFlow device, heart rate, stroke volume, cardiac output, left cardiac work index and end diastolic volume were deemed acceptable for use regardless of exercise type (continuous vs. interval) or intensity (low, moderate, or high). However, other variables measured by this device appear less reliable.

Keywords:

- bioimpedance cardiography,*
- exercise,*
- reliability,*
- high-intensity interval exercise,*
- cardiac output,*
- minimal detectable differences,*
- central haemodynamics,*
- peripheral haemodynamics*

Results:

No differences were observed between trial one and trial two for urine specific gravity (1.008±0.006 vs. 1.007±0.005; p=.37). Similarly, no differences were observed for oxygen consumption at rest (0.31±0.06 vs. 0.31±0.08 L·min⁻¹; p=.92), during 50% steady-state cycling (2.02±0.45 vs. 2.05±0.50 L·min⁻¹; p=.33), 70% steady-state cycling (2.86±0.67 vs. 2.88±0.70 L·min⁻¹; p=.56), or during high-intensity interval cycling (1.87±0.46 vs. 1.82±0.46 L·min⁻¹; p=.24). The intrarater reliability and agreement of the PhysioFlow-derived variables for central systolic function (Table 1), central diastolic function (Table 2) and peripheral vascular function (Table 3) at rest, during steady-state cycling and interval cycling are presented. HR and LCWi were greater during the high-intensity interval exercise in trial one compared with trial two (p=.04 and p=.03, respectively). Additionally, EDV was greater during trial one compared with trial two during rest (p=.02), 50% steady-state (p=.03), 70% steady-state (p=.03) and during the high-intensity interval exercise (p=.02). No other significant differences were observed for any other variables between trial one compared to trial two.

IMPORTANT NOTE FROM THE MANUFACTURER:

This study, although looking acceptable from the methodological standpoint, yields completely absurd results: The non indexed parameters (CO, SV) are considered reproducible while the indexed ones are not (CI, SVi). The only adjustment between indexed and non indexed parameters comes from the body surface area, which does not change between tests.

Reproducibility of Impedance Cardiography Hemodynamic Measures in Clinically Stable Heart Failure Patients

February 2000 / *Congestive Heart Failure* 6(2):74-80

Authors:

- Barry Greenberg
- Denise D. Hermann
- Maryann F. Pranulis
- Lucia Lazio
- University of California, San Diego

Abstract:

This study demonstrated that ICG is a useful technology for evaluating the status of heart failure patients in an outpatient setting. The technology is noninvasive with minimal risk, provides real time hemodynamic data, and is easy to use. Further, the BioZ® provides trended data, which facilitates evaluating changes over time. The finding that measures SI, contractility, and workload are more stable indices (less influenced by environmental conditions and/or neurohormonal responses to activity rest or postural changes) than HR, arterial pressures, and CO which encourages the use of these measures over time to evaluate responses to treatment and disease progression. Previously, these measures were available only through the use of invasive technologies or complex, noninvasive technologies, such as echocardiography. Because those operator dependent procedures involve either risk for patient safety or are costly, their use in routine patient evaluation has been limited. Thus, changes in clinical signs and symptoms become the main criteria for evaluating patient and disease progress in the outpatient setting. It is known that there is a substantial (but unclear duration) time lag between structural changes at the cellular level, and functional changes at the organic level, and further time lags between functional changes and the onset of clinical signs and symptoms of deterioration. Thus, sole reliance on clinical signs and symptoms produces a deleterious, and perhaps irreparable, delay in appropriately modifying the treatment program and the course of the disease. Obtaining important, real time data about hemodynamic functional status may improve the response time to indications of deterioration. Modifications in treatment may be initiated earlier in the disease trajectory and may improve the outcomes.

Repeatability of impedance cardiography in the measurement of cardiovascular hemodynamics during exercise

April 2017

Authors:

•Lindsey Marie Rodriguez • James Madison University - Harrisonburg State of Virginia

https://www.google.fr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwimqPnmz_zsAhWnDGMBHUKwBksQFjADegQIBRAC&url=https%3A%2F%2Fpdfs.semanticscholar.org%2F5e25%2F7728eca59db8b149d67e7faf93860ae2ba4a.pdf&usq=AOvVaw3lo_Bi-H4_rEDwlS5ARozdT

Abstract:

Purpose:

To analyze the day to day repeatability of cardiac hemodynamic measurements using a PhysioFlow 07 Enduro during treadmill submaximal exercise.

Methods:

21 male subject ages 18 and older were studied. Two graded treadmill exercise tests consisting of two 5-minute steady state stages (Moderate and Vigorous intensity) were performed using the PhysioFlow device at least 48 hours apart. Cardiac hemodynamic measurements were compared between stages and trials using repeated measures ANOVA, intraclass correlations, and Bland-Altman plots.

Results:

Oxygen consumption (VO₂) and respiratory exchange ratio (RER), were not different between the two trials for either Moderate or Vigorous intensities. There was a main effect for intensity for all variables with the exception early diastolic filling ratio (EDFR) and ejection fraction (EF%). Intraclass correlation coefficients between exercise trials were > 0.7 for all hemodynamic variables except for ventricular ejection time (VET) (Moderate and Vigorous Intensity stages), and EDFR (Moderate Intensity Stage). Coefficient of Variation between exercise trials were <12.5% for all hemodynamic variables and <8% for primary hemodynamic variables. Bland-Altman analysis showed good agreement (P >0.05) for all hemodynamic measures except heart rate (HR) (P = 0.018 and 0.019 for Moderate Intensity Stage and Vigorous Intensity Stage, respectively), left cardiac work index (LCWi) (Vigorous Intensity Stage, P = 0.000), and systemic vascular resistance index (SVRi) (Vigorous Intensity Stage, P = 0.000).

Conclusion:

Measurements from the PhysioFlow was repeatable, with no statistical differences across trials and reasonably strong reliability coefficients for most relevant hemodynamic variables, apart from VET and Low Intensity Stage EDFR, during moderate and vigorous intensity treadmill exercise.

2

APPLICATION STUDIES

2.1 CARDIOLOGY

2016 focused update: clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations.

[Eur Heart J](#). 2016 May 2. pii: ehw180
DOI: 10.1093/eurheartj/ehw180

Authors:

- Guazzi M,
- Arena R,
- Halle M,
- Piepoli MF,
- Myers J,
- Lavie CJ.

Abstract:

Noninvasive Determination of CO

Because peak Vo_2 is strongly related to the CO response to exercise, peak Vo_2 is often considered a surrogate for CO. In fact, one reason that peak Vo_2 is such a strong prognostic marker is that it closely parallels cardiac function with exercise. However, peak Vo_2 can be influenced by many other factors

(including age, sex, motivation, obesity, deconditioning, and localized muscle fatigue).⁸⁵ Thus, it has been of interest to study whether the noninvasive determination of CO may enhance the prognostic power of CPX. A number of studies have been useful in assessing the complementary value of CO responses to exercise, along with CPX indexes, for evaluating other hemodynamic responses (eg, exercise EF, stroke work index, and other indexes of contractility) and for assessing submaximal hemodynamic responses to exercise. Studies have demonstrated that noninvasively determined peak CO provides an independent predictor of outcomes that enhances the prognostic utility of peak Vo_2 .^{86–90} More recent reports suggest that noninvasively determined peak cardiac index complements indexes of ventilatory inefficiency and peak Vo_2 and that combining these markers provides the most powerful stratification of risk.^{91,92} Although the Fick and thermodilution methods remain the gold standards for the measurement of CO,⁹³ several rebreathing methods that use CPX are available. Bioelectric impedance has also experienced a renewed interest in recent years, and along with a number of validation studies, cardiac hemodynamics with these techniques have been shown to have prognostic value in patients with HF.^{91,92,94–96}

IMPORTANT NOTE FROM THE MANUFACTURER:

These recommendations highlight the necessity to measure CO independently from VO_2 in Heart Failure patients in order to considerably increase the predictive value of a cardiopulmonary exercise test. By far the most important study supporting these recommendations comes from Stanford University (Pr. Jonathan Myers), a research and clinical center using PhysioFlow. It is most likely that any other device would not have yield similar results as they are known for underperforming during exercise.

Best Detection of Coronary Artery Disease using a New Generation Impedance Cardiography: Comparison to Exercise Thallium 201 Scintigraphy

Authors:

•JM Dupuis, •Ph Pezard,
•F Prunier, •F Bour,
•W Abi-Khalil, •Ph Geslin,

Department of cardiology, C.H.U. Angers
France.

Abstract:

During exercise in patients with ischemia, contractility is impeded before electrical signs or angina appear. Therefore, measurement of contractility impairment could provide a highly sensitive approach to the detection of an ischemia. The protocol was designed to determine if a new, non invasive cardiac output measuring device (Physio Flow®: PF03, Manatec France) whose measurements are based on analysis of instant thoracic impedance (ICG) variations could be helpful to detect ischemia during exercise thallium scintigraphy.

Methods:

The efficiency of ICG in detecting myocardial ischemia was compared to treadmill exercise/redistribution thallium-201 scintigraphy. During exercise, patients had simultaneous measurement of stroke volume with ICG. ICG was considered abnormal if stroke volume at the peak of exercise was lower than another stroke volume measured before, and separated by at least 1 min from peak. Clinical was considered as positive if typical angina occurred and an abnormal ECG if ST-segment horizontal or descending depression > 1 mV lasting for at least 30 seconds. Ischemia was affirmed by a mismatch between exercise/redistribution thallium-201 scintigraphy.

Results:

36 patients (30 men, age 62+/-11 years), 30 with proved CAD were submitted to treadmill exercise/redistribution thallium-201 scintigraphy. Stroke volume profile alteration always occurred earlier in exercise than ECG ST segment depression and angina. The sensitivity (Se), specificity (Sp), positive (PPV) and negative (NPV) predictive values are summarized in the following table.

	Se	Sp	PPV	NPV
Angina	46%	74%	50%	71%
ECG(+)	31%	65%	33%	63%
ECG(+) and/or Angina	41%	66%	41%	66%
ECG(+) and Angina	33%	76%	43%	68%
ICG(-)	100%	74%	67%	100%

Conclusion:

Use of ICG during exercise allows for the estimation of stroke volume changes over time. These preliminary results show that it is a promising technique compared to ECG or other criteria for the detection of ischemia during exercise test with an excellent NPV.

Detection of Coronary Artery Disease (CAD) during Bicycle Exercise, using New Generation Impedance Cardiography

Heart Journal, June 2000 Volume 83 supplement II

Authors:

•J.M. Dupuis, •P Abraham,
•J. Bour, •K. Kalife.

C.H.U. Angers France.

Abstract:

During exercise in patients with CAD, contractility is impeded before electrical signs or angina appear. Therefore, measurement of contractility impairment could provide a highly sensitive approach to the detection of CAD. The protocol was designed to determine if a new, non-invasive cardiac output measuring device (Physio Flow® : PF03, Manatec France) whose measurements are based on analysis of instant thoracic impedance (ICG) variations that does not use average impedance baseline values could be helpful to detect CAD.

Methods:

On a 12 months period, subjects suspected of CAD had been submitted to an incremental bicycle exercise test (30 W / 2 min). Those who presented either an interpretable and abnormal ECG : [ECG(+)] ST-segment horizontal or descending depression > 1 mV lasting for at least 30 seconds, or typical angina during the exercise test were submitted to coronarography (n=29. 18 men/11 women, age = 57+/-10 years. Weight = 80+/-12 Kg. Height = 170+/-9 cm). Coronarography, considered as the gold standard for comparison, were performed and analyzed by independent observers and quoted abnormal for at least 50% stenosis of the coronary arteries : coro(+). During exercise, patients had simultaneous measurement of stroke volume with ICG. ICG was considered abnormal if stroke volume at the peak of exercise was lower than another stroke volume measured before, and separated by at least 1 min from peak.

Results:

Number of patients in each group are summarized in the table. Stroke volume profile alteration always occurred earlier in exercise than ECG ST segment depression. The sensitivity, specificity, positive and negative predictive values were respectively: 63, 20, 60, 22% for ECG alone; 68, 20, 62, 25 for angina alone; 84, 10, 64, 25% for ECG or angina; 100, 50, 79, 100% for ICG.

	coro(+) n=19	coro(-) n=10
ECG(+)	12	8
Angina	13	8
ECG(+) and Angina	9	7
ECG(+) and/or Angina	16	9
ICG SV depression	19	5

Conclusion:

Use of ICG during exercise allows for the estimation of stroke volume changes over time. As such, these preliminary results show that it is a promising technique for the non-invasive diagnosis of CAD.

Changes in Transthoracic Impedance Signal Predict Outcome of 70° Head-up Tilt Test

Accepted by Clinical Science October 21st 2002

Authors:

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Abstract:

We determined if the early changes in central hemodynamics determined by transthoracic impedance induced by head-upright tilt test (70°HUT) could predict syncope. Heart rate, arterial blood pressure and central hemodynamics (pre-ejection period and rapid left ventricular ejection time (T1), slow ejection time (T2) and dZ/dtmax, assessed by the transthoracic impedance technique), were recorded during supine rest and 45 min 70°HUT in 68 patients (40±2 years) with history of unexplained recurrent syncope. Thirty-eight patients (42 ±3 years) had a symptomatic outcome to 70°HUT (fainters) and 30 (39±2 years) had a negative outcome (non-fainters). Between the 5th and 10th minutes of 70°HUT, T2 increased significantly only in the fainters and a change of T2 >40 ms from baseline predicted a positive outcome with a sensitivity of 68% and a specificity of 70%. During supine rest, fainters exhibited a shorter T2 than non-fainters (183±10 ms vs. 233±14 ms, p<0.01). A T2 <199ms predicted a positive 70°HUT outcome with a sensitivity of 68% and a specificity of 63%. The combination to the changes from rest to 70°HUT of the other hemodynamic variables (heart rate >11 bpm, systolic <2 mmHg, diastolic <7 mmHg and pulse <-3 mmHg pressures) increased the specificity to 97% as well as the positive predictive value (93%). Transthoracic impedance could detect differences between fainters and non-fainters in central hemodynamics during supine rest and the initial period of 70°HUT with a consistent sensitivity and specificity when combined with peripheral hemodynamic variables.

[Clin Sci \(Lond\)](#). 2003 Feb;104(2):119-26.
DOI: 10.1042/CS20020169

Head-upright Tilt Test with Sublingual Nitroglycerin Predicts Hemodynamic Abnormalities in 70° Head upright Tilt

European Journal of Physiology (2002, 444, R49, S3 26) (Physiomed 2002 Société de Physiology Abstracts of the 70th Annual Meeting 18-20 Septembre 2002, Québec, Canada)

Authors:

- Bellard Elisabeth, •Victor Jacques,
- Fortrat Jacques-Olivier, •Lefthériotis
- Dupuis Jean-Marc, Georges

Pflugers Arch - Eur J Physiol (2002) 444: R49,S3 26.

Abstract:

We aimed to determine if the outcome to a head upright tilt test (70°HUT) with sublingual nitroglycerin (NTG) could retrospectively help to determine abnormal changes in central and peripheral hemodynamics to a standard (STD) 45 min 70°HUT without NTG in patients with unexplained syncope. 32 patients with negative outcome to a 70°HUT-STD were submitted to consecutive 70°HUT+NTG. Heart rate, arterial blood pressure (BP) and central hemodynamic assessed by transthoracic impedance variables (pre ejection +rapid left ventricular ejection time (T1, ms) and peak of first derivative of signal (dZ/dtmax) were recorded during supine rest, initial 5 min and 40-45 min of a 70°HUT-STD. Changes from rest value of these variables (mean+/-SEM) were retrospectively compared (unpaired T test) between patients with a negative (n=15,NTG-) and positive (n=17,NTG+) outcome to a 70°HUT+NTG. Differences were only observed during 40-45 min of 70°HUT-STD: systolic (NTG+:-18+/-4 vs NTG-:-2+/-4 mmHg;p<0.01), mean BP (-1+/-2 vs 6+/-2 mmHg;p<0.05) and dZ/dtmax (-51+/-30 vs 35+/-21 Ohm.s-1;p<0.05). A drop of systolic BP >10mmHg and/or dZ/dtmax >13 Ohm.s-1 predicted positive outcome to 70°HUT+NTG with a sensitivity of 82% and a specificity of 60% suggesting that abnormal response to a 70°HUT+NTG was linked to 70°HUT-STD outcome.

Impedance Cardiography and Quantitative Tissue Doppler Echocardiography for Evaluating the Effect of Cardiac Resynchronization Therapy

Japanese Journal of Cardiology, reprinted from 2003 July, Vol. 42 n°1 : 37-42 (Japanese College of Cardiology)

Authors:

• Hitoshi Adachi, MD; Tomoya Hiratsuji, MD ; Shigeki Sakurai, MD; Hiroshi Tada, MD; Takuji Tomoya, Koichi MD FJCC; Shigeto Naito, MD; Hiroshi Hoshizaki, MD; Shigeru Oshima, MD FJCC ; Taniguchi, MD FJCC.

From Division of Cardiology, Gunma Prefectural Cardiovascular Center Gunma

Abstract:

An 83-year-old woman presented with dilated cardiomyopathy. Cardiac resynchronization therapy was performed. Two weeks later, cardiac output and ventricular wall motion were estimated using impedance cardiography and tissue Doppler echocardiography with and without pacing. Cardiac output increased from 3.5 to 4.5 l/m during biventricular pacing with a 120 msec atrioventricular interval. Intraventricular phase difference for contraction decreased from 190 to 150 msec. When the atrioventricular interval was 180 msec, cardiac output and phase difference became 4.6 l/m and 170 msec. These assessments were performed rapidly and non-invasively. New impedance cardiography and tissue Doppler echocardiography are useful to evaluate the effect of cardiac resynchronization therapy

Conclusion:

The present case demonstrates usefulness of impedance cardiography and tissue Doppler echocardiography in the evaluation of the effect of cardiac resynchronization therapy on cardiac function. Using impedance cardiography, the cardiac output could be assessed easily and non-invasively. Impedance cardiography and tissue Doppler are useful for evaluating the beneficial effect of cardiac resynchronization therapy and determined the optimal AV delay interval.

References:

- 1/ Hochleitner M, Hortnagl H, Ng CK, Gschnitzer F, Zechmann W : Usefulness of physiologic dual-chamber pacing in drug-resistant idiopathic dilated cardiomyopathy. *Am J Cardiol* 1990 ; 66 : 198 – 202
- 2/ Brecker SJ, Xiao HB, Sparrow J, Gibson DG : Effects of dual-chamber pacing with short atrioventricular delay in dilated cardiomyopathy. *Lancet* 1992 ; 340 : 1308 – 1312
- 3/ Abraham WT, Fischer WG, Smith AL, Delurgio DB, Leon AR, Loh E, Kocovic DZ, Packer M, Clavell AL, Hayes DL, Ellestad M, Trupp RJ, Underwood J, Pickering F, Truex C, McAtee P, Messenger J, MIRACLE Study Group : Multicenter InSync Randomized Clinical Evaluation : Cardiac resynchronization in chronic heart failure. *N Engl J Med* 2002 ; 346 : 1845 – 1853
- 4/ Gras D, Leclercq C, Tang AS, Bucknall C, Luttikhuis HO, Kirstein-Pedersen A : Cardiac resynchronization therapy in advanced heart failure the multicenter InSync clinical study. *Eur J Heart Fail* 2002 ; 4 : 311 – 320
- 5/ Charloux A, Lonsdorfer-Wolf E, Richard R, Lampert E, Oswald-Mammosser M, Mettauer B, Geny B, Lonsdorfer J : A new impedance cardiograph device for the non-invasive evaluation of cardiac output at rest and during exercise : Comparison with the “direct” Fick method. *Eur J Appl Physiol* 2000 ; 82 : 313 – 320
- 6/ Pianosi PT : Impedance cardiography accurately measures cardiac output during exercise in children with cystic fibrosis. *Chest* 1997 ; 111 : 333 – 337
- 7/ Miyatake K, Yamagishi M, Tanaka N, Uematsu M, Yamasaki N, Mine Y, Sano A, Hirama M : New method for evaluating left ventricular wall motion by color-coded tissue Doppler imaging : In vitro and in vivo studies. *J Am Coll Cardiol* 1995 : 25 : 717 – 724
- 8/ Yu CM, Chau E, Sanderson JE, Fan K, Tang MO, Fung WH, Lin H, Kong SL, Lam YM, Hill MR, Lau CP : Tissue Doppler echocardiographic evidence of reverse remodeling and improved synchronicity by simultaneously delaying regional contraction after biventricular pacing therapy in heart failure. *Circulation* 2002 ; 105 : 438 – 445

Impedance Cardiography a Rapid and Cost effective Screening Tool for Cardiac Disease

European Journal of Heart Failure, October 2005 (Vol. 7, Issue 6, Pages 974-983)

Authors:

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- John Gale Kellett, MD

Abstract:

Impedance cardiography (ICG) charts the rises and falls of thoracic impedance as the fluid content of the chest changes with each heartbeat. Breathing, arrhythmia, movements and posture interfere with the ICG. Modern pattern recognition software can now produce a composite Signal Averaged ICG, which considerably simplifies interpretation.

The first derivative velocity waveform shows a smooth S wave that corresponds with systole, while the second derivative acceleration waveform (dZ/dt) contains several reference points that outline the A-wave, S and O-wave. Normally the A-wave follows atrial contraction and occurs in late diastole. It can, therefore, be abnormal in both atrial and ventricular arrhythmias, and is abnormally increased when there is diastolic dysfunction. The S-wave reflects ventricular contractility, and is deformed by ventricular dyssynchrony. The O-wave is associated with mitral valve opening and is abnormally enlarged in heart failure.

These different patterns of ICG waveform are relatively easy to recognise and can be cost-effectively and quickly obtained to reliably distinguish between normal and abnormal cardiac function.

Keywords:

- Impedance*
- Cardiography*,
- Heart failure*
- Diastolic dysfunction*
- Dyssynchrony*

Isolated Left Ventricular Diastolic Dysfunction: Implications for Exercise Left ventricular Performance in Patients without Congestive Heart Failure

Journal of the American Society of Echocardiography, Volume 19, Issue 5, Pages 491 - 498

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Abstract-Objective:

Clinical relevance of left ventricular (LV) diastolic dysfunction in the absence of congestive heart failure (CHF) and LV systolic dysfunction is not fully established.

Methods:

Asymptomatic outpatients, sedentary, with cardiovascular risk factors but no history of cardiovascular events, underwent echocardiographic evaluation of LV structure and function by standard Doppler, color M-mode, and Doppler tissue methods, and exercise testing with simultaneous noninvasive assessment of LV stroke index and cardiac index. LV ejection fraction less than 50% and significant valvular disease or stress test suggestive of coronary disease were additional exclusion criteria.

Results:

In 70 patients selected (40 ± 10 years old, 63% men, 34% hypertensive, 34% diabetic, 4% diabetic and hypertensive, 11% with LV hypertrophy), LV diastolic dysfunction was detected in 26%, which was associated with hypertension, higher LV mass index, lower systolic function, lower peak exercise heart rate, and chronotropic reserve (all P < .05), and with lower peak exercise stroke index and cardiac index (both covariates adjusted P < .05), but not with lower peak exercise metabolic equivalents (P > .5). Abnormal LV relaxation was independently correlated with lower peak exercise cardiac index and stroke index (both P < .05). Peak exercise systolic and cardiac indices were comparable between patients with CHF risk factors (74%) versus those without.

Conclusion:

Isolated LV diastolic dysfunction was independently associated with lower peak exercise LV systolic performance in patients without CHF. Its diagnosis may provide a target for aggressive CHF risk management.

Thoracic Bioimpedance for Optimizing Atrioventricular and Intraventricular Delays after Cardiac Resynchronization Therapy

Authors:

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Abstract-Background:

The lack of easy and fast method for optimizing AV and VV delay after cardiac resynchronization therapy (CRT), is a major deficiency of two-dimensional echocardiography combined with tissue Doppler imaging (TDI). The aim of our human study was to test a new non-invasive system for optimizing cardiac resynchronization.

Keywords:

•Bioimpedance
•Echocardiography
•Systolic dysfunction
•Heart failure •Resynchronization therapy

Methods-Results

Six to 12 months before bioimpedance and 2D echocardiographic study, 10 patients with symptomatic systolic heart failure were resynchronized with CRT device. At the subsequent session, a total of 78 different steady-state hemodynamic conditions were studied by serially changing the pacemaker delays. 2D echocardiography with TDI capability was used as gold standard for optimal cardiac resynchronization.

A validated system was employed for measuring the thoracic electrical bioimpedance (TEB). Physioflow TEB signals were recorded on a computer and left ventricular stroke volume was determined online by morphological analysis of the impedance waveforms. Optimal AV and VV delays by Physioflow TEB were defined when stroke volume was maximal. Optimal VV and AV delays obtained by echocardiography averaged 0 ± 10 ms and 129 ± 18 ms. Those obtained by bioimpedance averaged 0 ± 21 ms and 133 ± 28 ms, respectively. Bland-Altman analysis showed a good agreement between the echocardiography-obtained optimal delays and bioimpedance (mean difference, 2 ± 22 ms).

Conclusion:

The Physioflow thoracic electrical bioimpedance system provided an accurate approach for adjusting AV and VV delays, suggesting an important application in cardiac resynchronization therapy.

Evaluation of a New Noninvasive, Thoracic Bioimpedance Monitor for Hemodynamic Monitoring in Pediatric Patients



Evaluation of a New Noninvasive, Thoracic Bioimpedance Monitor for Hemodynamic Monitoring in Pediatric Patients
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Introduction

Hemodynamic monitoring with a pulmonary artery catheter is a common practice in adults, but anesthesiologists and surgeons rarely use invasive monitoring routinely in pediatric patients because of the technical difficulties and associated risks. A reliable, non-invasive method for determining cardiac output and hemodynamic values may be useful in pediatric patients for optimal management. We report preliminary data evaluating a new thoracic bioimpedance (TBI) system for determination of hemodynamic values in pediatric patients in a prospective, observational study.

Methods

Following Institutional Board Review approval and parental informed consent, we studied 38 patients presenting for diagnostic cardiac catheterization. Enrollment was not restricted. All procedures were performed under general anesthesia or moderate sedation. Patients had cardiac output measured by either a) a modified Fick principle application where oxygen content of arterial and pulmonary artery blood was measured directly and oxygen uptake was estimated or b) measured with thermoflution (TD) catheters. TBI determinations of cardiac output were made with the PhysioFlow PF-35 (Mammatec, Inc, Paris, FR). Cardiac index determinations (Fick or TD versus TBI) were analyzed using the Bland-Altman analysis. 1

Results

Enrollment: N = 38

	Mean	Std Dev	Max	Min
Age (year)	9.0	7.8	24.8	2
Weight (Kg)	24.5	34.6	4.3	76
BSA (M ²)	0.87	0.58	1.96	0.26
BMI (Kg/M ²)	11.9	24	31.6	26

Males - 18
Females - 20

Results

Cardiac structure	Cardiac pathophysiology
Normal 21	No shunt 36
Anomaly 22	Left-to-right 7
	Right-to-left 3
Completed studies	PCL-Fick 21
Incomplete studies	PCL-TD 22

Fig. 1. Bland-Altman analysis and correlation comparing cardiac output by TBI versus thermoflution in pediatric cardiology patients (N=12).

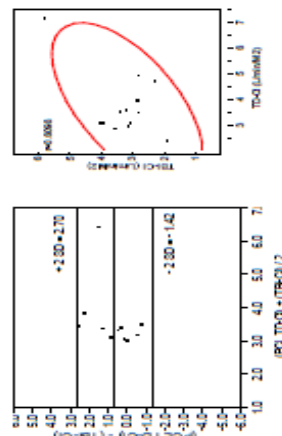
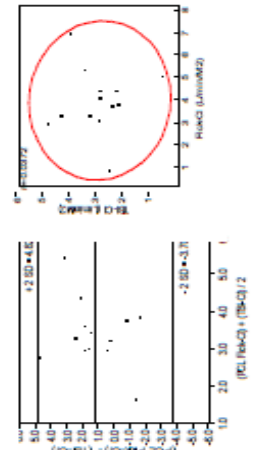


Fig. 1. Bland-Altman analysis and correlation comparing cardiac output by TBI versus cardiologist's Fick estimate in pediatric cardiology patients (N=13).



Discussion

TBI determines CO by measuring the change in an electrical impedance signal. Z. This is measured by attaching skin electrodes at the base of the neck and sternum. Some devices use the absolute value of the signal (Zo), which has been described as a limiting factor in the usefulness of TBI. We evaluated a new monitor that uses relative values of the impedance signal rather than absolute values. This system has good agreement with the TD method for measuring CI in adults. 2

The data provided by this monitor has good agreement with values obtained by thermoflution. Difficulties in obtaining simultaneous TBI readings while obtaining blood samples for the modified Fick and using estimates for oxygen uptake instead of measuring oxygen consumption accounts for the greater difference between TBI and Fick CI values. TBI may be a useful method for the noninvasive monitoring pediatric hemodynamics.

References

1. Bland JM, Altman DG (1986) Statistical method for assessing agreement between two methods of clinical measurement. The Lancet, i, 307-310.
2. Haynes GR, Moreau X, Rousseau JM et al. Cardiac output with a new bioimpedance monitor: comparison with thermoflution methods. Anesthesiology 2006:A470.

● New Non Invasive Marker of Heart Failure with Pulmonary Congestion: Thoracic Electrical Bioimpedance

Heart Failure Congress, Milan 2008

DOI: 10.1016/S1567-4215(08)60123-X

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Abstract-Objective:

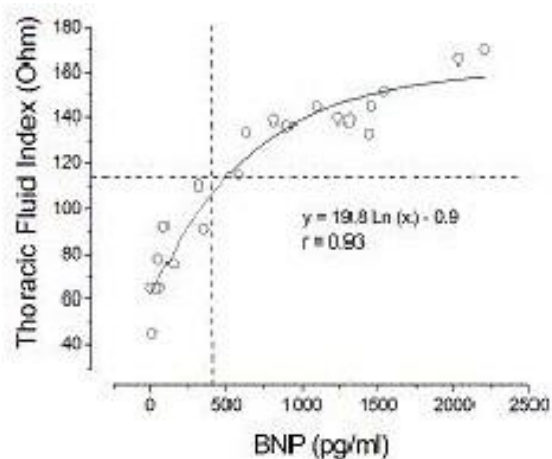
Brain Natriuretic Peptide (BNP) is usually utilized to diagnose heart failure. However, BNP is expensive, measured invasively and is not specific to the left ventricle. The aim of this study was to calculate the thoracic fluid index (TFI, ohm), a new marker of pulmonary congestion measured using the electrical bioimpedance, and to correlate it to BNP level in normals and patients with heart failure.

Methods-Results:

6 normals and 15 patients with EF < 35% were investigated. The BNP level was measured with the Triage assay (Biosite). A commercially available system for measuring the thoracic bioimpedance (Physioflow, FR) was used for calculating TFI from 4 electrodes (2 at the upper chest and 2 in front of the xyphoid process) connected to a computer interfacing with a dedicated platform. Both BNP level and TFI were measured simultaneously. Mean BNP concentration and TFI were 777 ± 700 pg/ml (range from 5 to 2038 pg/ml) and 114 ± 37 ohm (range from 45 to 170 ohm), respectively. Multiple regression analyses showed a good correlation and agreement between the BNP and TFI ($r=0.93$, figure. Cut-offs are in represented by dashed lines). Measurement of TFI was obtained in less than 2 minutes.

Conclusion:

The Thoracic Fluid Index provided good estimation of heart failure, suggesting an important application of this new parameter and bioimpedance method to detect heart failure.



Patients with Systolic Heart Failure Show Improvement with Long-Acting, Cardioselective Beta-Blocker Nebivolol when Others Fail

ESC Congress 2007

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Abstract-Purpose:

β-blockers are highly effective by reducing morbimortality in patients with systolic heart failure (SHF). However, failure to (re-)start or to titrate β-blockers is frequent, occurring in 10% of these patients. We hypothesized that β-blockers intolerance is attributable to persistent elevated afterload and that nebivolol would efficiently normalize it

Patients-Methods:

We selected 20 SHF patients intolerant to β-blockers. Reasons for intolerance were worsening heart failure and symptomatic peripheral hypoperfusion during up-titration. Using commercially available bioimpedancemeter (Physioflow, FR), we measured cardiac index (CI), total intrathoracic fluid (TIF), blood pressure, heart rate and NYHA functional class with the first β-blocker and after substituting it to equidose nebivolol. Systemic vascular resistance index (SVRi) was calculated along with left cardiac work index (LCWi) using validated equations.

Results-Discussion:

Patients aged 63±15y. Both mean arterial pressure and heart rate significantly decreased with nebivolol from 106±12 to 99±7 mm Hg (p=0.002) and 74±14 to 71±12 (p=0.05), respectively. Effects of replacing the β-blocker to nebivolol are shown in the table. There was a significant improvement in NYHA functional class from 2.9±0.5 to 2.1±0.9 (p=0.001)

CONCLUSION: Patients with systolic heart failure, intolerant to β-blockers, exhibit persistent elevated systemic vascular resistance. By reducing the systemic vascular resistances, nebivolol enhances cardiac output, decreases intrathoracic fluid, and therefore improves NYHA functional class.

Conclusion:

Patients with systolic heart failure, intolerant to β-blockers, exhibit persistent elevated systemic vascular resistance. By reducing the systemic vascular resistances, nebivolol enhances cardiac output, decreases intrathoracic fluid, and therefore improves NYHA functional class

Hemodynamic Data by Bioimpedance

	With the first β-blocker	Under nebivolol	p
CI (l/min/m ²)	2,7±0,6	2,9±05	0.02
SVRi (Dynesxs/cm5/m ²)	3028±540	2564±470	0.00002
LCWi (J ules)	3,96±1,16	3,93±0,82	NS
TIF (1/ohm)	129±27	113±22	0.0003

CI: Cardiac Index TIF: Total Intrathoracic Fluid SVRi: Systemic Vascular Resistance index LCWi: Left Cardiac Work index

Central hemodynamic responses during high-intensity interval exercise and moderate continuous exercise in patients with chronic heart failure

Citation: *The European Journal of Cardiovascular Prevention and Rehabilitation* (April 2011) 18 (Supplement 1), S90

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Topic(s) : Heart Failure (Rehabilitation & Implementation)

Purpose:

We have previously proposed an optimized high-intensity interval exercise (HIIE) protocol in patients with chronic heart failure (CHF). However, central hemodynamic response during HIIE has not been studied in patients with CHF. The aim of this study was to compare central hemodynamic responses during our optimized HIIE protocol compared to that of an isocaloric moderate-intensity interval exercise (MICE) session.

Methods:

Thirteen CHF patients (59±6 years, NYHA I-III, LVEF 27 %) performed in random order a single session of HIIE (2×8min) consisting in 30s at 100% of maximal aerobic power (MAP) alternating with 30s of passive recovery or an isocaloric MICE (22min) at 60% of MAP. Gas exchange, central hemodynamic measured by cardiac bioimpedance, ECG and blood pressure were monitored continuously. Mean pulmonary VO₂ uptake, cardiac output and arterio-venous differences as well as kinetics of those variables were compared during MICE and HIIE.

Results:

See Table 1. A mode effect was noted for pulmonary VO₂ and C(a-v)O₂ kinetics (p<0.0001) with lower values measured during HIIE compared to MICE. A mode effect was noted for cardiac output kinetics (p<0.01) with higher values measured during HIIE vs. MICE.

Conclusion:

Compared to MICE, optimized HIIE elicited a greater central hemodynamic response in patients with CHF associated with a lower pulmonary VO₂ uptake and arterio-venous difference. HIIE may be an interesting complementary exercise training modality that could favorably improve central hemodynamic responses during exercise training intervention in patients with CHF

Central hemodynamic responses during MICE and HIIE:

Parameters	MICE	HIIE	ANOVA
	22min	16 min	P value
VO ₂ (ml/min)	1052±300	977±276	<0.0001
Cardiac output (l/min)	9.25±2.33	9.89±4.29	0.0007
C(a-v)O ₂ (ml/100 ml)	11.57±3.42	10.55±3.42	<u><0.0001</u>
Mean power (Watts)	58±17	48±14	<0.0001
Total exercise time	22	8	---



Am J Physiol Heart Circ Physiol. 2009 Nov;297(5):H1720-8. Epub 2009 Sep 4.

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Abstract:

Impaired muscle blood flow at the onset of heavy-intensity exercise may transiently reduce microvascular O₂ pressure and decrease the rate of O₂ transfer from capillary to mitochondria in chronic heart failure (CHF). However, advances in the pharmacological treatment of CHF (e.g., angiotensin-converting enzyme inhibitors and third-generation beta-blockers) may have improved microvascular O₂ delivery to an extent that intramyocyte metabolic inertia might become the main locus of limitation of O₂ uptake (V_{O₂}) kinetics. We assessed the rate of change of pulmonary V_{O₂} (V_{O₂}(p)), (estimated) fractional O₂ extraction in the vastus lateralis (approximately Δ[deoxy-Hb+Mb] by near-infrared spectroscopy), and cardiac output (Qt) during high-intensity exercise performed to the limit of tolerance (T_{lim}) in 10 optimally treated sedentary patients (ejection fraction = 29 ± 8%) and 11 controls. Sluggish V_{O₂}(p) and Qt kinetics in patients were significantly related to lower T_{lim} values (P < 0.05). The dynamics of Δ[deoxy-Hb+Mb], however, were faster in patients than controls [mean response time (MRT) = 15.9 ± 2.0 s vs. 19.0 ± 2.9 s; P < 0.05] with a subsequent response "overshoot" being found only in patients (7/10). Moreover, τV_{O₂}/MRT-[deoxy-Hb+Mb] ratio was greater in patients (4.69 ± 1.42 s vs. 2.25 ± 0.77 s; P < 0.05) and related to Qt kinetics and T_{lim} (R = 0.89 and -0.78, respectively; P < 0.01). We conclude that despite the advances in the pharmacological treatment of CHF, disturbances in "central" and "peripheral" circulatory adjustments still play a prominent role in limiting V_{O₂}(p) kinetics and tolerance to heavy-intensity exercise in nontrained patients.

Cardiopulmonary and Noninvasive Hemodynamic Responses to Exercise Predict Outcomes in Heart Failure

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Abstract-Background:

An impaired cardiac output response to exercise is a hallmark of chronic heart failure (HF). We determined the extent to which noninvasive estimates of cardiac hemodynamics during exercise in combination with cardiopulmonary exercise test (CPX) responses improved the estimation of risk for adverse events in patients with HF.

Keywords:

- Exercise testing
- Oxygen uptake
- Cardiac Output
- Mortality

Methods-Results:

CPX and impedance cardiography were performed in 639 consecutive patients (mean age 48 ± 14 years), evaluated for HF. Clinical, hemodynamic, and CPX variables were acquired at baseline and subjects were followed for a mean of 460 ± 332 days. Patients were followed for the composite outcome of cardiac-related death, hospitalization for worsening HF, cardiac transplantation, and left ventricular assist device implantation. Cox proportional hazards analyses including clinical, noninvasive hemodynamic, and CPX variables were performed to determine their association with the composite endpoint. There were 113 events. Among CPX variables, peak oxygen uptake (VO₂) and the minute ventilation (VE)/carbon dioxide production (VCO₂) slope were significant predictors of risk for adverse events (age-adjusted hazard ratio [HR] 1.08, 95% confidence interval [CI] 1.05–1.11 for both; $P < .001$). Among hemodynamic variables, peak cardiac index was the strongest predictor of risk (HR 1.08, 95% CI 1.0–1.16; $P = .01$). In a multivariate analysis including CPX and noninvasively determined hemodynamic variables, the most powerful predictive model included the combination of peak VO₂, peak cardiac index, and the VE/VCO₂ slope, with each contributing significantly and independently to predicting risk; an abnormal response for all 3 yielded an HR of 5.1 ($P < .001$).

Conclusion:

These findings suggest that noninvasive indices of cardiac hemodynamics complement established CPX measures in quantifying risk in patients with HF.

Cardiopulmonary Responses and Prognosis in Hypertrophic Cardiomyopathy: A Potential Role for Comprehensive Noninvasive Hemodynamic Assessment.

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Objectives:

The study sought to discover the key determinants of exercise capacity, maximal oxygen consumption (oxygen uptake [VO₂]), and ventilatory efficiency (ventilation/carbon dioxide output [VE/VC₀₂] slope) and assess the prognostic potential of metabolic exercise testing in hypertrophic cardiomyopathy (HCM).

Background:

The intrinsic mechanisms leading to reduced functional tolerance in HCM are unclear.

Methods:

The study sample included 156 HCM patients consecutively enrolled from 2007 to 2012 with a complete clinical assessment, including rest and stress echocardiography and cardiopulmonary exercise test (CPET) with impedance cardiography. Patients were also followed for the composite outcome of cardiac-related death, heart transplant, and functional deterioration leading to septal reduction therapy (myectomy or septal alcohol ablation).

Results:

Abnormalities in CPET responses were frequent, with 39% (n = 61) of the sample showing a reduced exercise tolerance (VO₂ max <80% of predicted) and 19% (n = 30) characterized by impaired ventilatory efficiency (VE/VC₀₂ slope >34). The variables most strongly associated with exercise capacity (expressed in metabolic equivalents), were peak cardiac index (r = 0.51, p < 0.001), age (r = -0.25, p < 0.01), male sex (r = 0.24, p = 0.02), and indexed right ventricular end-diastolic area (r = 0.31, p = 0.002), resulting in an R² of 0.51, p < 0.001. Peak cardiac index was the main predictor of peak VO₂ (r = 0.61, p < 0.001). The variables most strongly related to VE/VC₀₂ slope were E/E₀ (r = 0.23, p = 0.021) and indexed left atrial volume (LAVI) (r = 0.34, p = 0.005) (model R² = 0.15). The composite endpoint occurred in 21 (13%) patients. In an exploratory analysis, 3 variables were independently associated with the composite outcome (mean follow-up 27 ± 11 months): peak VO₂ <80% of predicted (hazard ratio: 4.11; 95% confidence interval [CI]: 1.46 to 11.59; p = 0.008), VE/VC₀₂ slope >34 (hazard ratio: 3.14; 95% CI: 1.26 to 7.87; p = 0.014), and LAVI >40 ml/m² (hazard ratio: 3.32; 95% CI: 1.08 to 10.16; p = 0.036).

Conclusion:

In HCM, peak cardiac index is the main determinant of exercise capacity, but it is not significantly related to ventilatory efficiency. Peak VO₂, ventilatory inefficiency, and LAVI are associated with an increased risk of major events in the short-term follow-up. (J Am Coll Cardiol HF 2015;:-:---) © 2015 by the American College of Cardiology Foundation.

Exercise Cardiac Output Limitation in Pectus Excavatum

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- Ruddy Richard, MD, PhD

Abstract:

Indication of pectus excavatum (PE) surgical treatment is a much-debated subject, especially regarding functional impact of the deformation. The pulmonary consequences of PE have been found not to be the limiting factor in exercise for these patients. On the other hand, the hemodynamic consequences of PE have been sparingly studied, because of the difficulty to secure reliable exercise cardiac output (CO). Opinions, therefore, differ greatly as to the scope and the reversibility of hemodynamic exercise limitations for these patients (1,2).

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Usefulness of stroke volume monitoring during upright ramp incremental cycle exercise in young patients with Fontan circulation

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Abstract:

Background: Aerobic capacity (VO₂ max) of patients with Fontan circulation (FC) is lowest within patients with congenital heart disease. The reasons have not been completely elucidated.

Methods: Twenty five young patients with non-failing FC underwent a cardiopulmonary test during an upright ramp cycling. By using a signal morphology impedance cardiography device (physioflow®), stroke volume (SV) was evaluated along with effort. The results were compared with paired healthy controls.

Results: FC patients had lower VO₂max (24 vs 32ml/Kg/min) and maximal cardiac index (CI) (6.4 vs 9.9 l/min/m²) than controls, due to impaired maximal SV (42 vs 54 ml/m²) and maximal Heart Rate (HR) (154 vs 184/min) (p < 0.001). No correlation between SV and HR at peak was found. At ventilatory threshold, SV continued to rise in a part of FC patients. Other FC patients showed an almost a “plateau” as in controls. The more maximal CI was impaired, the more was maximal arterio-venous difference (r = -0.6, p = 0.001). Compared to controls, stroke work was lower in FC patients (p < 0.01) even though maximal vascular resistance was higher in them (p < 0.001).

Keywords:

- Congenital heart disease
- Fontan circulation
- Aerobic capacity
- Stroke volume
- Signal morphology impedance cardiography

Conclusion:

Impaired SV and chronotropic incompetence are both independently responsible for impaired CI at peak.

The increase in arteriovenous difference appeared to be an adaptive response. As the stroke work was low among FC patients, high systemic vascular resistance does not appear to be the cause of SV impairment but rather a consequence. SV monitoring at effort evidences heterogeneous SV profiles among FC patients that could be considered for the management of patients.

Cardiac output response to exercise in chronic cardiac failure patients.

Int Heart J. 2012;53(5):293-8.

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Abstract:

The purpose of this study was to investigate the precise pattern of stroke volume (SV) response during exercise in patients with chronic heart failure (CHF) compared with age-matched controls. Fourteen patients with CHF and 7 controls performed symptom-limited bicycle exercise testing with respiratory gas exchange measurement. Patients were classified into group A (n = 7) with peak VO₂ ≥ 18.0 mL/kg/minute and group B (n = 7) with peak VO₂ < 18.0 mL/kg/minute. SV and cardiac output (CO) were continuously measured during exercise using a novel thoracic impedance method (Physioflow). CO and SV were lower in the group B patients than those in controls at peak exercise [CO: 11.3 ± 1.0 (SE) versus 15.6 ± 0.9 L/minute, P < 0.05, SV: 89 ± 6 versus 110 ± 6 mL, P < 0.05]. SV reached its peak levels during submaximal exercise and remained close to the peak value until peak exercise in 6 of 7 group B patients (86%). On the other hand, it progressively increased until peak exercise in 6 of 7 controls (86%) and 5 of 7 group A patients (71%). In all subjects, CO at peak exercise was more closely correlated with SV at peak exercise (r = 0.86, P < 0.001) than with peak heart rate (r = 0.69, P < 0.001). CHF patients with impaired exercise capacity had attenuated increment of CO during exercise, and SV reached its peak levels during submaximal exercise.

Reliability of peak exercise stroke volume assessment by impedance cardiography in patients with residual right outflow tract lesions after congenital heart disease repair

Original Article

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Abstract:

Global ventricular response to exercise may be useful in follow-up of patients with residual right outflow tract lesions after congenital heart disease repair. In this context, impedance cardiography is considered accurate for stroke volume (SV) measurement during exercise testing, however, to date, only partial assessment of its reliability has been reported. We retrospectively evaluated relative and absolute reliability of peak SV by impedance cardiography during exercise using intraclass correlation (ICC) and standard error of measurement (SEM) in this population. Peak SV was measured in 30 young patients (mean age 14.4 years \pm 2.1) with right ventricular outflow tract reconstruction who underwent two cardiopulmonary exercise tests at a mean one-year interval. SV was measured using a signal morphology impedance cardiography analysis device (PhysioFlow) and was indexed to body surface area. ICC of peak indexed SV measurement was 0.80 and SEM was 10.5%. High heterogeneity was seen when comparing patients according to peak indexed SV; in patients with peak SV < 50 ml/m (15 patients), ICC rose to 0.95 and SEM dropped to 2.7%, while in patients with a peak SV > 50 ml/m relative and absolute reliability decreased (ICC = 0.45, SEM = 12.2%). Peak exercise SV assessment by a PhysioFlow device represents a highly reliable method in patients with residual right outflow tract lesions after congenital heart disease repair, especially in patients with peak SV < 50 ml/m. In this latter group, a peak SV decrease > 7.3% (corresponding to the minimum “true” difference) should be considered a clinically-relevant decrease in global ventricular performance and taken into account when deciding whether to perform residual lesion removal.

Keywords:

- Congenital heart disease
- Reliability
- Cardiopulmonary exercise test
- Stroke volume
- Signal morphology impedance cardiography

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Vasoconstrictive Response in the Vascular Beds of the Non-Exercising Forearm during Leg Exercise in Patients with Mild Chronic Heart Failure

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Circ J. 2007 Jun;71(6):922-8.

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Abstract:

Background reduced exercise capacity may be related to decreased redistribution of blood flow from the non-exercising tissues to the exercising skeletal muscle in patients with mild chronic heart failure (CHF). Methods and Results In the present study 14 patients with mild CHF and 10 healthy subjects (N) underwent symptom-limited multistage-ergometer exercise, during which forearm vascular resistance (FVR), cardiac index (CI), systemic vascular resistance index (SVRI), and oxygen uptake (VO₂) were measured non-invasively using the plethysmograph, impedance, and respiratory gas analysis methods, respectively. The VO₂ and CI at peak exercise were lower ($p < 0.01$ each), and SVRI and FVR at both rest and peak exercise were higher in the CHF group than in N. However, both the percent increase in FVR and percent decrease in SVRI from the resting state to peak exercise were lower in CHF than N, and both of them correlated with not only peak VO₂, but also the corresponding resting value of FVR and SVRI ($p < 0.01$ each). Conclusions Redistribution of blood flow from the non-exercising tissues to the working skeletal muscles, which may participate in exercise capacity, can be blunted in CHF. The decreased vasoconstrictive response in the non-exercising tissues is intimately related to the increased resting vascular tone in CHF.

Conclusion:

Not only an impaired reduction in SVRI, mainly because of attenuated reduction of working vascular resistance, but also blunted redistribution of blood flow from non-working to exercising muscles, which is expected from the attenuation of the % increase in FVR, may play a role in the exercise intolerance of CHF patients. The development of a new strategy for alleviating these abnormalities in the nonexercising vascular bed, as well as the impaired vascular relaxation in exercising skeletal muscle, is recommended to ameliorate the decreased exercise capacity of CHF patients.

Effects of obstructive sleep apnea on hemodynamic parameters in patients entering cardiac rehabilitation.

[J Cardiopulm Rehabil Prev](#). 2015 May-Jun;35(3):181-5. doi: 10.1097/HCR.000000000000102.

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Abstract:

PURPOSE:

Obstructive sleep apnea (OSA) is a prevalent form of sleep-disordered breathing. Evidence suggests that OSA may lead to cardiac remodeling, although the literature is equivocal. Previous literature suggests a high percentage of individuals entering a cardiac rehabilitation (CR) program also have OSA. The objective of this study was to determine whether resting hemodynamic variables were altered in OSA subjects entering CR compared with those without OSA, as determined by impedance cardiography.

METHODS:

Subjects entering an early outpatient CR program were screened for OSA using an at-home screening device and verified by a sleep physician. Subjects were divided into an OSA group (n = 48) or a control group (n = 25) on the basis of the screening results. Hemodynamic variables were measured during supine rest using impedance cardiography. A 6-minute walk test was performed to assess functional capacity.

Results:

The proportion of cardiac diagnoses was similar between groups. Overall, 66% of the subjects were positive for OSA. Subject groups did not differ by age, body mass index, heart rate, diastolic blood pressure, or functional capacity. Cardiac output, cardiac index, stroke volume, contractility index, and left cardiac work index were all significantly decreased in the OSA group compared with the control group ($P < .05$).

Conclusion:

Findings suggest that OSA results in decreased cardiac function in patients entering CR, likely because of pressure and volume changes associated with apneic events. This may place those individuals at a disadvantage in recovering from their cardiac event, and place them at increased risk for secondary complications.

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Reliability of Peak Exercise Stroke Volume Assessment by Impedance Cardiography in Patients with Residual Right Outflow Tract Lesions After Congenital Heart Disease Repair

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Abstract:

Global ventricular response to exercise may be useful in follow-up of patients with residual right outflow tract lesions after congenital heart disease repair. In this context, impedance cardiography is considered accurate for stroke volume (SV) measurement during exercise testing, however, to date, only partial assessment of its reliability has been reported. We retrospectively evaluated relative and absolute reliability of peak SV by impedance cardiography during exercise using intraclass correlation (ICC) and standard error of measurement (SEM) in this population. Peak SV was measured in 30 young patients (mean age 14.4 years \pm 2.1) with right ventricular outflow tract reconstruction who underwent two cardiopulmonary exercise tests at a mean one-year interval. SV was measured using a signal morphology impedance cardiography analysis device (PhysioFlow) and was indexed to body surface area. ICC of peak indexed SV measurement was 0.80 and SEM was 10.5%. High heterogeneity was seen when comparing patients according to peak indexed SV; in patients with peak SV \leq 50 ml/m² (15 patients), ICC rose to 0.95 and SEM dropped to 2.7%, while in patients with a peak SV $>$ 50 ml/m² relative and absolute reliability decreased (ICC = 0.45, SEM = 12.2%). Peak exercise SV assessment by a PhysioFlow device represents a highly reliable method in patients with residual right outflow tract lesions after congenital heart disease repair, especially in patients with peak SV \leq 50 ml/m². In this latter group, a peak SV decrease \geq 7.3% (corresponding to the minimum “true” difference) should be considered a clinically-relevant decrease in global ventricular performance and taken into account when deciding whether to perform residual lesion removal.

Keywords:

- Congenital heart disease
- Reliability
- Cardiopulmonary exercise test
- Stroke volume
- Signal morphology impedance cardiography

Conclusion:

The aim of this study was to provide an exhaustive assessment of the reliability of peak indexed SV and peak cardiac index in patients with right ventricular outflow tract lesions, in order to demonstrate its clinical usefulness in the context of pulmonary valve replacement. Taken together, our results show that both measures represent highly reliable methods of assessment in patients with residual right outflow tract lesions after CHD repair. The good absolute reliability allows implementation of these measures in clinical practice to detect abnormal decreases in global ventricular performance in overloading conditions. Further prospective studies are needed to clarify the role of this parameter in therapeutic decision-making for pulmonary valve replacement.

Changes in exercise capacity of frailest patients with heart failure treated with standard exercise recommendations versus stroke volume response to exercise: a pilot study.

Authors:

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Abstract:

Background

Peak exercise oxygen uptake (VO_{2peak}) and exercise capacity are strong factors for predicting mortality in heart failure patients (HF). Although considerable heterogeneity in the nature of exercise intolerance was found in HF patients, one third of them presented a central hemodynamic exercise limitation induced by the impairment to augment stroke volume (SV) during a cardiopulmonary exercise testing (CPET). Among the frailest HF subjects ($VO_{2peak} < 18.0 \text{ mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$), SV moreover reached its peak levels at a submaximal exercise intensity (pSV_{max}) in 86 % of patients. To improve exercise capacity of the frailest HF patients, the international guidelines recommended to prescribe moderate continuous intensity exercise (MICE) based on the heart rate value (HR) associated with the anaerobic threshold (VT_1). However, the β -blockers interactions on ventilatory adaptations and the attenuated HR response to exercise generally observed in HF patients would induce a dissociation between VT_1 and pSV_{max} . This might be taken into consideration for the exercise intensity prescription.

Purpose The aims of the study were, in HF patients: 1) to examine whether VT_1 is concomitant with pSV_{max} , 2) to compare the effects of 4 weeks of exercise cardiac rehabilitation based on VT_1 or pSV_{max} on cardiorespiratory responses.

Methods Twelve HF patients ($VO_{2peak}: 15.1 \pm 3.6 \text{ mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$) performed a CPET with respiratory gas analysis and simultaneous assessment of SV, using a thoracic impedance method, before and after an exercise-based cardiac rehabilitation. Maximal tolerated power (MTP), VO_{2peak} and VT_1 were determined in accordance with the international standards. Peak SV values and pSV_{max} were estimated by a third-order curvilinear regression method. During 4 weeks, all subjects performed, 5 times per week, 20-50-min cycling exercise at the power associated to VT_1 (GVT₁, n=6) or pSV_{max} (GpSV_{max}, n=6). Exercise session duration was regulated to maintain similar training load between both groups using session rating of perceived exertion.

Results:

Baseline medication, anthropometric and exercise characteristics did not differ between groups. For all HF patients, pSV_{max} was lower than VT_1 before (60.3 ± 12.6 vs. 63.6 ± 14.5 w, $p = 0.004$) and after (73.3 ± 18.9 vs. 76.0 ± 19.6 w, $p = 0.02$) training. MICE significantly improved MTP ($p = 0.01$) without any difference between GVT₁ and GpSV_{max} ($p = 0.12$). MICE based on VT_1 did not improve VO_{2peak} , but 2 dropouts were found among GVT₁ patients. In contrast, a significant VO_{2peak} increase occurred after MICE based on pSV_{max} . Changes in VO_{2peak} were related to SV change to training ($r = 0.77$, $p = 0.05$) in GpSV_{max}.

Conclusion:

Changes in VO_{2peak} with training suggested a greater effect of MICE based on pSV_{max} compared to MICE based on VT_1 . Further investigation is required to confirm our results and the interest of SV monitoring in order to prescribe exercise intensity in heart failure

Cardiopulmonary Exercise Testing, Impedance Cardiography, and Reclassification of Risk in Patients Referred for Heart Failure Evaluation

2019 Dec;25(12):961-968. doi: 10.1016/j.cardfail.2019.08.013. Epub 2019 Aug 24

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Abstract:

Background

An impaired cardiac output response to exercise is a hallmark of chronic heart failure (HF). We determined the extent to which impedance cardiography (ICG) during exercise in combination with cardiopulmonary exercise test (CPX) responses reclassified risk for adverse events in patients with HF.

Methods and results

CPX and ICG were performed in 1236 consecutive patients (48±15 years) evaluated for HF. Clinical, ICG and CPX variables were acquired at baseline and subjects were followed for the composite outcome of cardiac-related death, hospitalization for worsening HF, cardiac transplantation, and left ventricular assist device implantation. Cox proportional hazards analyses including clinical, noninvasive hemodynamic, and CPX variables were performed to determine their association with the composite endpoint. Net reclassification improvement (NRI) was calculated to quantify the impact of adding hemodynamic responses to a model including established CPX risk markers on reclassifying risk. There were 422 events. Among CPX variables, peak VO₂ and indices of ventilatory inefficiency (VE/VCO₂ slope, oxygen uptake efficiency slope) were significant predictors of risk for adverse events. Among hemodynamic variables, change in cardiac index, peak cardiac time interval, and peak left cardiac work index were the strongest predictors of risk. Having 5 impaired CPX and ICG responses to exercise yielded a sevenfold higher risk for adverse events compared with having no abnormal responses. Combining ICG responses to CPX resulted in NRIs ranging between 0.34 and 0.89, attributable to better reclassification of events.

Conclusion:

Cardiac hemodynamics determined by ICG complement established CPX measures in reclassifying risk among patients with HF.

Cardiac performance assessment during cardiopulmonary exercise test can improve the management of children with repaired congenital heart disease

j.ijcard.2019.10.032. Epub 2019 Oct 21.

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Abstract:

Background

Children with repaired congenital heart disease (CHD) have impaired maximal aerobic capacity (VO₂max). Determining the causes of their VO₂max alteration remains challenging. Cardiac output measure using thoracic impedancemetry during cardiopulmonary exercise tests (CPET) can help to understand the determinants of VO₂max in children with open-heart repaired CHD.

Method

We analyzed CPET in 77 children with repaired CHD. Among them, 55 patients had residual lesions. Patients with repaired CHD were compared with 44 age-matched healthy individuals. Maximal oxygen content brought to capillaries (QO₂max) and oxygen muscle diffusion capacity (DO₂) were assessed using cardiac output measure, Fick principle and simplified Fick law.

Results

In the 55 patients with residual lesion, VO₂max, QO₂max and DO₂ were lower than those of controls (76.1 vs 86% of theoretical value, $p < 0.01$; 2.15 vs 2.81 L/mn, $p < 0.001$; 24.7 vs 28.8 ml/min/mmHg, $p < 0.05$). Decrease in QO₂max was due to both impaired stroke volume and chronotropic insufficiency (48 vs 53 ml/m² and $p < 0.05$; 171 vs 185/min $p < 0.001$). Patients without residual lesion (22/77) had normal VO₂max with lower maximal heart rate compensated by higher SV ($p < 0.05$).

Conclusion:

Aerobic capacity was normal in children without residual lesions after CHD repair. Patients with residual lesion have impaired VO₂max due to both lower central and peripheral determinants. Measuring cardiac performance during CPET allowed a better selection of patients with altered cardiac reserve that can benefit from residual lesion treatment and find the good timing for intervention. Detection of peripheral deconditioning can lead to a rehabilitation program.

Noninvasive investigation of the cardiodynamic response to 6MWT in people after stroke using impedance cardiography


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Abstract:

This is a cross-section observational study that investigated the cardiodynamic response to a 6-minute walk test (6MWT) in patients after stroke using impedance cardiography (ICG). Patients diagnosed with stroke were invited to participate in a 6MWT on consecutive days. Heart rate (HR), cardiac output (CO), stroke volume (SV) and cardiac index (CI) were measured by ICG using the PhysioFlow® PF07 Enduro™ at 1-second intervals for 10 minutes prior to, during and for 10 minutes after each 6MWT. Oxygen saturation, perceived exertion score (modified Borg scale) and the distance covered at the end of each 6MWT were recorded. Twenty-nine patients (mean age 55.6±10.9 years) completed the study. The mean duration of stroke after diagnosis was 14.4±19.1 months. There were no differences in the measured data between the first and second 6MWT (mean intraclass correlation coefficient (ICC) range: 0.87-0.95). The 6 minute walk distance (6MWD) covered in the two 6MWTs was 246±126 and 255±130m respectively (p>0.05). Mean measured data for each subject at rest, and at the end of the better performed 6MWT were, respectively: HR 78±11 and 100±18 bpm; CO 5.5±1.2 and 8.9±2.6 l/min, SV 71.3±16 and 89.3±18.6 ml/beat and CI 3.0±0.6 and 4.9±1.3 l/min/m². After commencement of the 6MWT, the increase in SV took 30 sec before the rise approaching a plateau, whereas HR, CO and CI continued to rise steeply for 90 sec before leveling off to a steady rise. After completion of the 6MWT, all parameters had returned to baseline by a mean of 3.5 min. Sub-group analysis showed that the increase in cardiac output was predominantly contributed by an increase in heart rate in participants diagnosed with stroke for less than 1 year, whereas both stroke volume and heart rate contributed similarly to the increase in cardiac output in participants with diagnosis of stroke for longer than 1 year. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) both returned to baseline within 2 minutes post 6MWT. HR recorded at the end of the 6MWT was 60.8±10.6% of the predicted maximal heart rate and perceived exertion score was 5±2. Correlations between 6MWD and HR, and between 6MWD and SV were weak, with correlation coefficients Spearman's rho (rs) =0.46, and 0.42, respectively (p<0.05). Correlation between 6MWD and CO and CI were higher (rs= 0.66 and 0.63, respectively (p<0.01)). This is the first study to report cardiac responses during a 6MWT in stroke patients. ICG is a reliable, non-invasive, repeatable method of measuring cardiodynamic data in stroke patients.

 **Nocturnal thoracic volume overload and post-discharge outcomes in patients hospitalized for acute heart failure**

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Abstract:

Aims

Volume overload and perturbations of pulsatile haemodynamics may precipitate acute heart failure (AHF). Nocturnal thoracic volume overload due to rostral fluid shift during recumbency undetected by daytime measures may impact nighttime haemodynamics and post-discharge outcomes.

Methods and results

A total of 63 patients (median 60 years, 79.4% men, and left ventricular ejection fraction 29.4%) hospitalized for AHF were enrolled. Once clinical euvolaemia was achieved, noninvasive pulsatile haemodynamics were assessed during daytime followed by circadian monitoring (6 p.m. to 5 a.m.) of thoracic fluid content and thoracic fluid content index (TFCi) using impedance cardiography, normalized electromechanical activation time ratio (EMAT%) using acoustic cardiography, and mean blood pressure using ambulatory blood pressure monitoring before discharge. The primary endpoints were composited of the first hospitalization for heart failure and death from any cause. Patients were also followed for the repeated heart failure hospitalizations. During a median follow-up duration of 16 months, 33 patients encountered primary composite endpoints (52.4%), and there were 42 hospitalizations developed among 25 patients. An overnight increase in TFCi along with persistently prolonged EMAT% and low mean blood pressure was observed in the eventful group. Overnight increase in TFCi (Δ TFCi, the difference between the measures at 4 a.m. and 6 p.m.) was an independent predictor of primary composite events (hazard ratio and 95% confidence interval: 1.58, 1.07-2.33; $P = 0.022$) and recurrent composite events (2.22, 1.51-3.26; $P < 0.001$), after adjusting for potential confounding factors. A high Δ TFCi ($\geq 0.5/\text{k}\Omega/\text{m}^2$) significantly correlated with higher post-discharge events (hazard ratio 6.25; 95% confidence interval 2.30-16.96; $P < 0.001$) in comparison with a low Δ TFCi ($< 0.5/\text{k}\Omega/\text{m}^2$). Δ TFCi was significantly associated with EMAT%, estimated glomerular filtration rate, and left ventricular ejection fraction, but not with parameters of pulsatile haemodynamics.

Conclusion:

Nocturnal thoracic volume overload in AHF before discharge, indicating the presence of residual volume overload unidentified by daytime measures, may predict post-discharge outcomes.

The Effect of Carotid Chemoreceptor Inhibition on Exercise Tolerance in Chronic Heart Failure

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Abstract:

Purpose

Chronic heart failure (CHF) is characterized by heightened sympathetic nervous activity, carotid chemoreceptor (CC) sensitivity, marked exercise intolerance and an exaggerated ventilatory response to exercise. The purpose of this study was to determine the effect of CC inhibition on exercise cardiovascular and ventilatory function, and exercise tolerance in health and CHF.

Methods

Twelve clinically stable, optimally treated patients with CHF (mean ejection fraction: $43 \pm 2.5\%$) and 12 age- and sex-matched healthy controls were recruited. Participants completed two time-to-symptom-limitation (TLIM) constant load cycling exercise tests at 75% peak power output with either intravenous saline or low-dose dopamine ($2 \mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; order randomized). Ventilation was measured using expired gas data and operating lung volume data were determined during exercise by inspiratory capacity maneuvers. Cardiac output was estimated using impedance cardiography, and vascular conductance was calculated as cardiac output/mean arterial pressure.

Results

There was no change in TLIM in either group with dopamine (CHF: saline 13.1 ± 2.4 vs. dopamine 13.5 ± 1.6 min, $p = 0.78$; Control: saline 10.3 ± 1.2 vs. dopamine 11.5 ± 1.3 min, $p = 0.16$). In CHF patients, dopamine increased cardiac output ($p = 0.03$), vascular conductance ($p = 0.01$) and oxygen delivery ($p = 0.04$) at TLIM, while ventilatory parameters were unaffected ($p = 0.76$). In controls, dopamine improved vascular conductance at TLIM ($p = 0.03$), but no other effects were observed.

Conclusion:

Our findings suggest that the CC contributes to cardiovascular regulation during full-body exercise in patients with CHF, however, CC inhibition does not improve exercise tolerance.

The non-invasive evaluation of heart function in patients with an acute myocardial infarction: The role of impedance cardiography

2019 Oct 23/CJ.a2019.0098. Online ahead of print.

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Abstract:

Background

The purpose of this study was to analyze hemodynamic changes in patients treated with percutaneous coronary intervention (PCI) at an early stage of acute myocardial infarction (AMI) and at one-month follow-up.

Methods

Patients with AMI (n = 27) who underwent PCI were analyzed using impedance cardiography (ICG). ICG data were collected continuously (beat by beat) during the whole PCI procedure and thereafter at every 60 s for the next 24 h. Blood pressure was taken every 10 min and stored for analysis. Additionally the following parameters were measured: cardiac index (CI), stroke volume index (SVi), left cardiac work index (LCWi), contractility index (CTi), ventricular ejection time (VET), systemic vascular resistance index (SVRi), thoracic fluid content index (TFCi) and heart rate (HR).

Results

In the first 24 h after PCI all the contractility parameters including CI, SVi, LCWi, CTi and VET significantly decreased, whereas HR, SVRi and TFCi increased compared to baseline. All of the parameters examined got normalized at one month. The CI, SVi, LCWi, CTi, SVRi did not significantly differ from baseline, however the HR and VET were significantly lower compared to first day after PCI.

Conclusion:

1. Cardiac performance deteriorates early after PCI and normalizes after one month in patients with an AMI. 2. ICG is useful for hemodynamic monitoring of AMI patients during and after invasive therapy.

The Effect of Carotid Chemoreceptor Inhibition on Exercise Tolerance in Chronic Heart Failure

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Abstract:

Purpose:

Chronic heart failure (CHF) is characterized by heightened sympathetic nervous activity, carotid chemoreceptor (CC) sensitivity, marked exercise intolerance and an exaggerated ventilatory response to exercise. The purpose of this study was to determine the effect of CC inhibition on exercise cardiovascular and ventilatory function, and exercise tolerance in health and CHF

Methods:

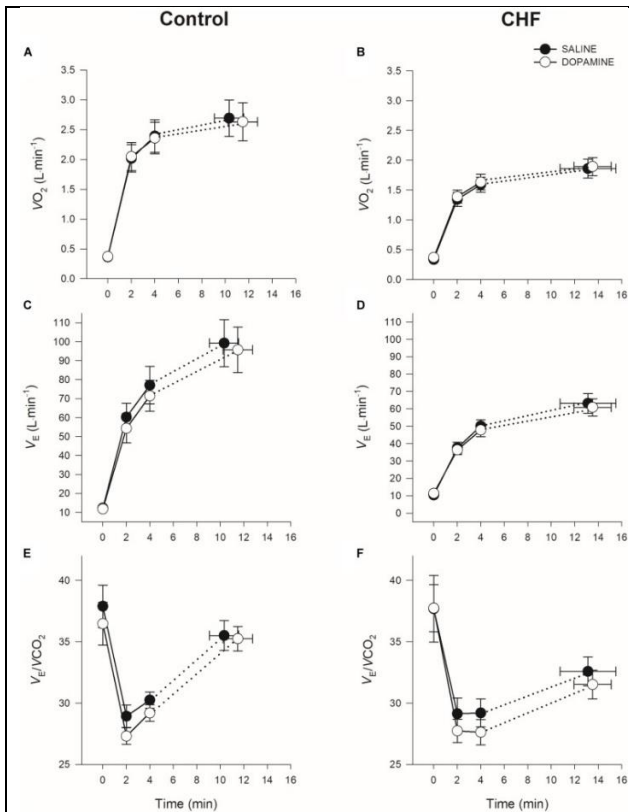
Twelve clinically stable, optimally treated patients with CHF (mean ejection fraction: $43 \pm 2.5\%$) and 12 age- and sex-matched healthy controls were recruited. Participants completed two time-to-symptom-limitation (TLIM) constant load cycling exercise tests at 75% peak power output with either intravenous saline or low-dose dopamine ($2 \mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; order randomized). Ventilation was measured using expired gas data and operating lung volume data were determined during exercise by inspiratory capacity maneuvers. Cardiac output was estimated using impedance cardiography, and vascular conductance was calculated as cardiac output/mean arterial pressure.

Results:

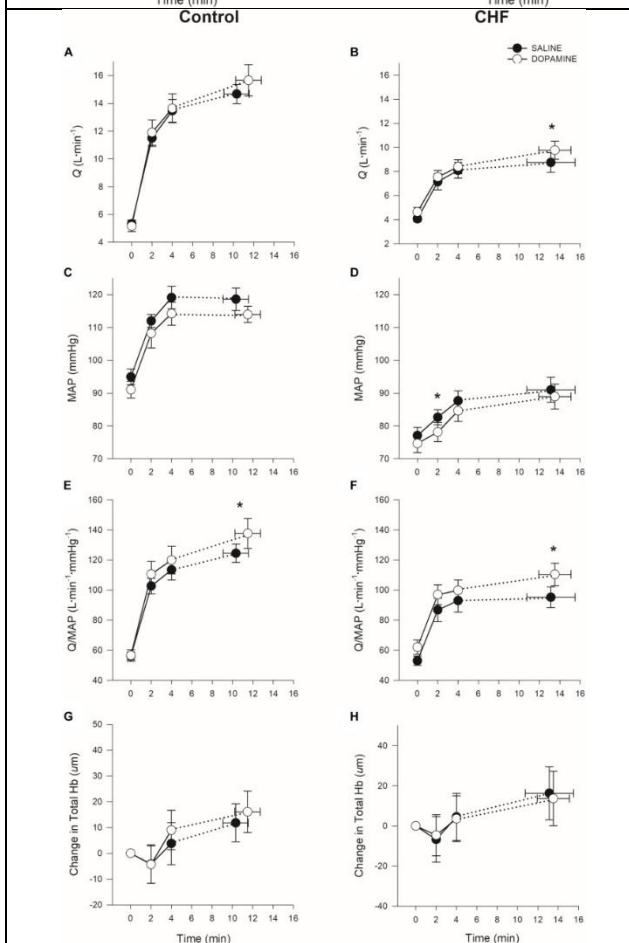
There was no change in TLIM in either group with dopamine (CHF: saline 13.1 ± 2.4 vs. dopamine 13.5 ± 1.6 min, $p = 0.78$; Control: saline 10.3 ± 1.2 vs. dopamine 11.5 ± 1.3 min, $p = 0.16$). In CHF patients, dopamine increased cardiac output ($p = 0.03$), vascular conductance ($p = 0.01$) and oxygen delivery ($p = 0.04$) at TLIM, while ventilatory parameters were unaffected ($p = 0.76$). In controls, dopamine improved vascular conductance at TLIM ($p = 0.03$), but no other effects were observed.

Conclusion:

Our findings suggest that the CC contributes to cardiovascular regulation during full-body exercise in patients with CHF, however, CC inhibition does not improve exercise tolerance.



Mean ± SEM oxygen consumption ($\dot{V}O_2$), minute ventilation (\dot{V}_E), and ventilatory efficiency ($\dot{V}_E/\dot{V}CO_2$) at rest and during constant-load cycle ergometry in controls (**A,C,E**) and CHF (**B,D,F**).



Mean ± SEM cardiac output (Q), mean arterial pressure (MAP), vascular conductance, and vastus lateralis tissue oxygenation [Total Hemoglobin (Hb)] at rest and during constant-load cycle ergometry in controls (**A,C,E,G**) and CHF (**B,D,F,H**). * $p < 0.05$ saline vs. dopamine within group.

🌀 **Epicardial adipose tissue is associated with cardiorespiratory fitness and hemodynamics among Japanese individuals of various ages and of both sexes.**

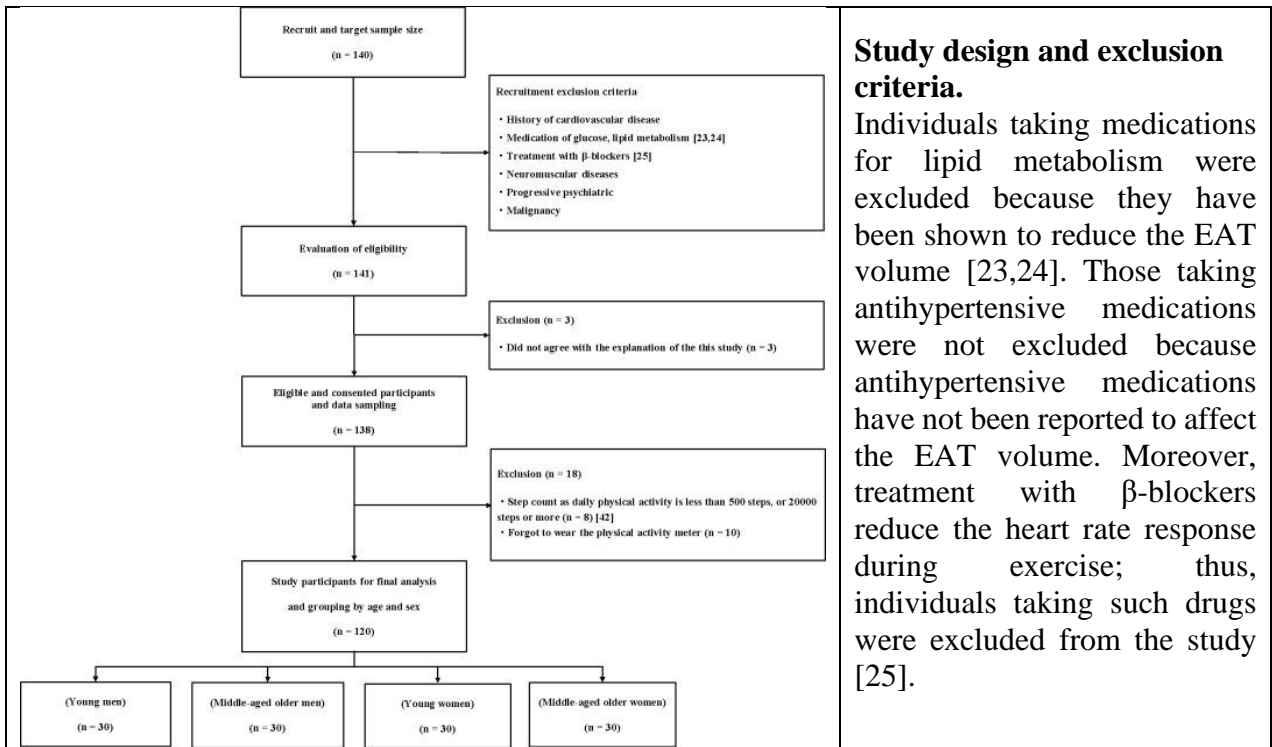
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Abstract:

Epicardial adipose tissue may affect hemodynamics and cardiorespiratory fitness as it is a metabolically active visceral adipose tissue and a source of inflammatory bioactive substances that can substantially modulate cardiovascular morphology and function. However, the associations between epicardial adipose tissue and hemodynamics and cardiorespiratory fitness remain unclear. This cross-sectional study aimed to examine the association between epicardial adipose tissue volume and hemodynamics, and cardiorespiratory fitness among Japanese individuals of various ages and of both sexes. Epicardial adipose tissue volume was measured in 120 participants (age, 21-85 years) by cardiac magnetic resonance imaging. To evaluate cardiorespiratory fitness, peak oxygen uptake was measured by cardiopulmonary exercise testing. Peak cardiac output and arteriovenous oxygen difference were calculated by impedance cardiography. The epicardial adipose tissue volume was significantly increased in middle-aged and older women. The epicardial adipose tissue volume was significantly and negatively correlated to peak cardiac output and peak oxygen uptake, regardless of age and sex; furthermore, epicardial adipose tissue showed a strong negative correlation with peak heart rate. Epicardial adipose tissue and peak cardiac output were significantly associated ($\beta = -0.359$, 95% confidence interval, -0.119 to -0.049, $p < 0.001$), even after multivariate adjustment ($R^2 = 0.778$). However, in the multiple regression analysis with peak oxygen uptake as a dependent variable, the epicardial adipose tissue volume was not an independent predictor. These data suggest that increased epicardial adipose tissue volume may be correlated with decreased peak oxygen uptake, which might have mediated the abnormal hemodynamics among Japanese people of various ages and of both sexes. Interventions targeting epicardial adipose tissue could potentially improve hemodynamics and cardiorespiratory fitness



Study design and exclusion criteria.

Individuals taking medications for lipid metabolism were excluded because they have been shown to reduce the EAT volume [23,24]. Those taking antihypertensive medications were not excluded because antihypertensive medications have not been reported to affect the EAT volume. Moreover, treatment with β -blockers reduce the heart rate response during exercise; thus, individuals taking such drugs were excluded from the study [25].

Proportional Assist Ventilation Improves Leg Muscle Reoxygenation After Exercise in Heart Failure With Reduced Ejection Fraction.

10.3389/fphys.2021.685274

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Abstract:

Background:

Respiratory muscle unloading through proportional assist ventilation (PAV) may enhance leg oxygen delivery, thereby speeding off-exercise oxygen uptake ($\dot{V}O_2$) kinetics in patients with heart failure with reduced left ventricular ejection fraction (HFrEF).

Methods:

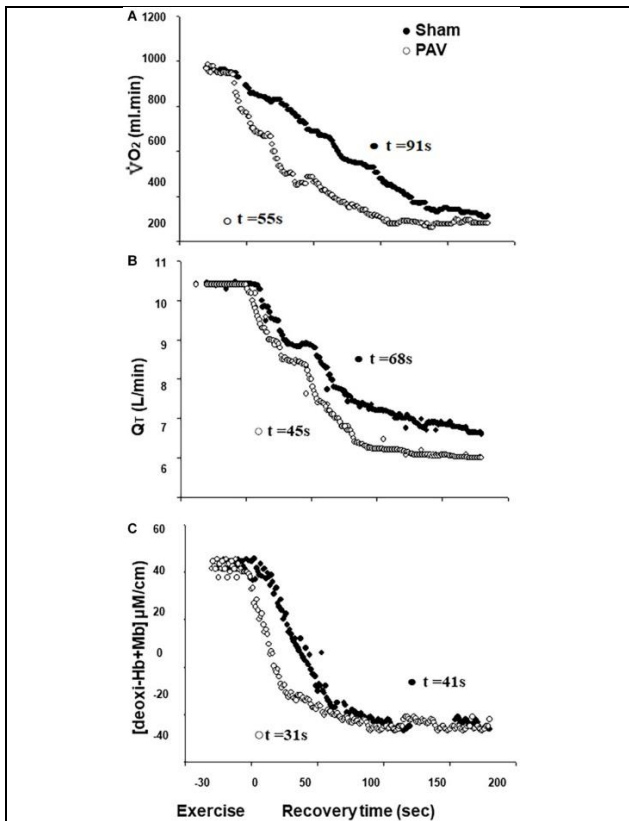
Ten male patients (HFrEF = $26 \pm 9\%$, age 50 ± 13 years, and body mass index 25 ± 3 kg m²) underwent two constant work rate tests at 80% peak of maximal cardiopulmonary exercise test to tolerance under PAV and sham ventilation. Post-exercise kinetics of $\dot{V}O_2$, vastus lateralis deoxyhemoglobin ([deoxy-Hb + Mb]) by near-infrared spectroscopy, and cardiac output (Q_T) by impedance cardiography were assessed.

Results:

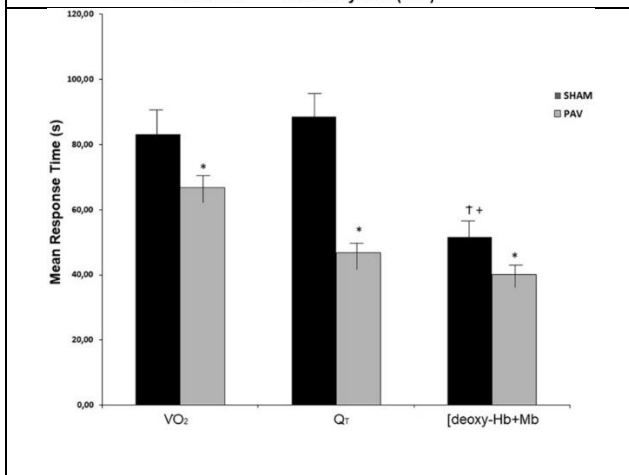
PAV prolonged exercise tolerance compared with sham (587 ± 390 s vs. 444 ± 296 s, respectively; $p = 0.01$). PAV significantly accelerated $\dot{V}O_2$ recovery ($\tau = 56 \pm 22$ s vs. 77 ± 42 s; $p < 0.05$), being associated with a faster decline in $\Delta[\text{deoxy-Hb} + \text{Mb}]$ and Q_T compared with sham ($\tau = 31 \pm 19$ s vs. 42 ± 22 s and 39 ± 22 s vs. 78 ± 46 s, $p < 0.05$). Faster off-exercise decrease in Q_T with PAV was related to longer exercise duration ($r = -0.76$; $p < 0.05$).

Conclusion:

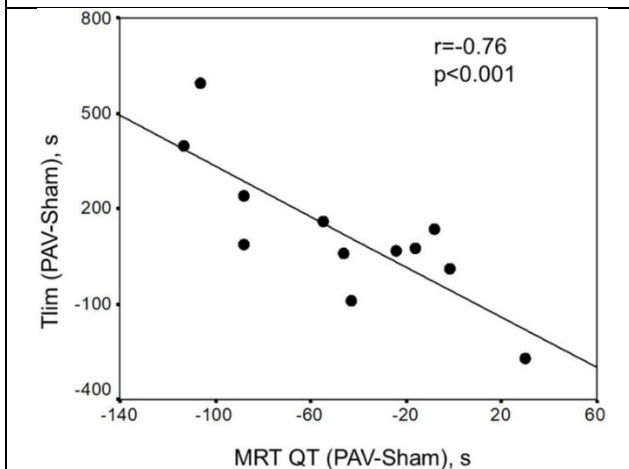
PAV accelerates the recovery of central hemodynamics and muscle oxygenation in HFrEF. These beneficial effects might prove useful to improve the tolerance to repeated exercise during cardiac rehabilitation.



Pulmonary O_2 uptake [$\dot{V}O_2p$, (A)], cardiac output [Q_T , (B)], and deoxy-hemoglobin concentration [deoxy-Hb + Mb, (C)] off-kinetics variables at high-intensity constant workload exercise test of a representative patient with HFrEF contrasting PAV (○) vs. Sham Ventilation (●).



Mean response time (MRT) of $\dot{V}O_2p$, Q_T , and deoxy-hemoglobin concentration ([deoxy-Hb + Mb]), on recovery of heavy-intensity exercise during Sham (open bars) and PAV (solid bars). Note that the dynamics of $\dot{V}O_2p$ and Q_T and [deoxy-Hb + Mb] recovery were faster during PAV ($p < 0.05$). In addition, [deoxy-Hb + Mb] kinetic was faster than Q_T and $\dot{V}O_2p$ only when Sham was administered in HFrEF patients. Values are means (SD). * $p < 0.05$ for between-intervention comparisons; [†] $p < 0.05$ for within-variables comparisons between [deoxy-Hb + Mb] vs. $\dot{V}O_2p$; and ⁺ $p < 0.05$ for within-group comparisons of [deoxy-Hb + Mb] vs. Q_T .



Significant inverse relationship between the difference of limit of tolerance with PAV-Sham vs. the difference of mean response time (MRT) of Q_T (PAV-Sham). These data suggest that the higher variation of T_{lim} with PAV, the faster lower “central” cardiovascular kinetics (Pearson correlation = 0.76, $p < 0.001$).

 **Predictors of low exercise cardiac output in patients with severe pulmonic regurgitation.**

10.1136/heartjnl-2020-317550

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Abstract:

Background and objectives:

Chronic pulmonic regurgitation (PR) following repair of congenital heart disease (CHD) impairs right ventricular function that impacts peak exercise cardiac index (pCI). We aimed to estimate in a non-invasive way pCI and peak oxygen consumption (pVO_2) and to evaluate predictors of low pCI in patients with significant residual pulmonic regurgitation after CHD repair.

Methods:

We included 82 patients (median age 19 years (range 10-54 years)) with residual pulmonic regurgitation fraction >40%. All underwent cardiac MRI and cardiopulmonary testing with measurement of pCI by thoracic impedancemetry. Low pCI was defined <7 L/min/m².

Results:

Low pCI was found in 18/82 patients. Peak indexed stroke volume (pSV_i) tended to compensate chronotropic insufficiency only in patients with normal pCI ($r=-0.31$, $p=0.01$). Below 20 years of age, only 5/45 patients had low pCI but near-normal (≥ 6.5 L/min/m²). pVO_2 (mL/kg/min) was correlated with pCI ($r=0.58$, $p=0.0002$) only in patients aged >20 years. Left ventricular stroke volume in MRI correlated with pSV_i only in the group of patients with low pCI ($r=0.54$, $p=0.02$). No MRI measurements predicted low pCI. In multivariable analysis, only age predicted a low pCI (OR=1.082, 95% CI 1.035 to 1.131, $p=0.001$) with continuous increase of risk with age.

Conclusion:

In patients with severe PR, pVO_2 is a partial reflection of pCI. Risk of low pCI increases with age. No resting MRI measurement predicts low haemodynamic response to exercise. Probably more suitable to detect ventricular dysfunction, pCI measurement could be an additional parameter to take into account when considering pulmonic valve replacement.

 **Responses to exercise training in patients with heart failure. Analysis by oxygen transport steps**

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Abstract:

Background

Exercise training (ET) increases exercise tolerance, improves quality of life and likely the prognosis in heart failure patients with reduced ejection fraction (HFrEF). However, some patients do not improve, whereas exercise training response is still poorly understood. Measurement of cardiac output during cardiopulmonary exercise test might allow ET response assessment according to the different steps of oxygen transport.

Methods

Fifty-three patients with HFrEF (24 with ischemic cardiomyopathy (ICM) and 29 with dilated cardiomyopathy (DCM) had an aerobic ET. Before and after ET program, peak oxygen consumption (VO_{2peak}) and cardiac output using thoracic impedancemetry were measured. Oxygen convection (QO_{2peak}) and diffusion (DO_2) were calculated using Fick's principle and Fick's simplified law. Patients were considered as responders if the gain was superior to 10%.

Results

We found 55% VO_{2peak} responders, 62% QO_{2peak} responders and 56% DO_2 responders. Four patients did not have any response. None baseline predictive factor for VO_{2peak} response was found. QO_{2peak} response was related to exercise stroke volume ($r = 0.84$), cardiac power ($r = 0.83$) and systemic vascular resistance (SVR_{peak}) ($r = -0.42$) responses. Cardiac power response was higher in patients with ICM than in those with DCM ($p < 0.05$). Predictors of QO_{2peak} response were low baseline exercise stroke volume and ICM etiology. Predictors of DO_2 response were higher baseline blood creatinine and prolonged training.

Conclusion:

The analysis of the response to training in patients with HFrEF according to the different steps of oxygen transport revealed different phenotypes on VO_{2peak} responses, namely responses in either oxygen convection and/or diffusion.

The Role of 6-Minute Walk Test Guided by Impedance Cardiography in the Rehabilitation Following Knee Arthroplasty: A Randomized Controlled Trial

2021 Nov 18;8:736208.doi: 10.3389/fcvm.2021.736208

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Abstract:

Objective

To explore the effect of the 6-minute walk test (6MWT) guided by non-invasive cardiac output on the rehabilitation of patients with knee osteoarthritis following artificial total knee arthroplasty.

Methods

About 66 patients with knee osteoarthritis planned to undergo artificial total knee arthroplasty were included from March 2019 to October 2019, and randomly assigned to the intervention group or control group. Under the guidance of a clinical rehabilitation physician, orthopedic physician, and cardiologist, a home rehabilitation exercise program based on 6MWT and non-invasive cardiac output was formulated for patients with knee osteoarthritis. The participants of the intervention group conducted full rehabilitation training supervision and guidance through the WeChat platform to ensure their rehabilitation pieces of training were completed safely and effectively. As for the control group, patients were just given rehabilitation training manuals at the time of discharge and completed the training by themselves.

Results

At 6 months post-operatively, 6-minute walk distance (413.88 ± 44.61 vs. 375.00 ± 40.53 m, $P < 0.05$), active metabolic equivalent (4.13 ± 0.29 vs. 3.88 ± 0.27 , $P < 0.05$), stroke volume after 6MWT (114.97 ± 12.05 vs. 98.38 ± 16.43 ml, $P < 0.05$), and cardiac output (11.92 ± 1.68 vs. 9.79 ± 1.82 l/min, $P < 0.05$) of the intervention group were significantly higher than those of the control group. The symptom evaluation scores of the intervention group were also better than those of the control group.

Conclusion:

The multidisciplinary post-operative rehabilitation exercise training program is beneficial to the recovery of lower limb function and the improvement of exercise capacity after knee replacement, and it also helps to improve the non-invasive hemodynamic indicators related to the cardiac function of the patient.

Examination of the Relationship and Dissociation Between Minimum Minute Ventilation/Carbon Dioxide Production and Minute Ventilation vs. Carbon Dioxide Production Slope

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Abstract:

Background

Minute ventilation/carbon dioxide production ($\dot{V}E/\dot{V}CO_2$) is a variable of cardiopulmonary exercise testing (CPET), which is evaluated by arterial CO_2 pressure and ventilation-perfusion mismatch via invasive methods. This study evaluated substitute non-invasively obtained variables for minimum $\dot{V}E/\dot{V}CO_2$ (Min) and $\dot{V}E$ vs. $\dot{V}CO_2$ slope (Slope) and the relationship between Min and Slope. Methods and Results: This study enrolled 1,052 patients with heart disease who underwent CPET and impedance cardiography simultaneously. At first, the correlations between the end-tidal CO_2 pressure (PETCO₂), tidal volume/respiratory rate (TV/RR) ratio, $\dot{V}E$ and $\dot{V}CO_2$ Y-intercept (Y-int), and cardiac index (CI) and the Min and Slope were investigated. Second, the correlation between Min and Slope was investigated. PETCO₂ showed the largest correlation value among the 4 variables. These 4 variables could reveal 84.2% and 81.9% of Min and Slope, respectively. Although Slope correlated with Min (R=0.868) and predicted 78.9% of Min, considering these 4 variables, Slope+Y-int was more strongly correlated with Min (R=0.940); the Slope+Y-int revealed 90.6% of the Min relationship in the multiple regression analysis.

Conclusion:

Over 80% of the Min and Slope values were revealed with the above-mentioned 4 variables collected non-invasively. The formula, $Min \propto Slope + Y-int$, can reveal >90% of the Min/Slope relationships, and the Y-int may be a crucial factor to clarify the relationship between Min and Slope.

 **Cardiopulmonary exercise testing and impedance cardiography in the assessment of exercise capacity of patients with coronary artery disease early after myocardial revascularization**

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Abstract:

Background

Patients with coronary artery disease (CAD) are characterized by different levels of physical capacity, which depends not only on the anatomical advancement of atherosclerosis, but also on the individual cardiovascular hemodynamic response to exercise. The aim of this study was evaluating the relationship between parameters of exercise capacity assessed via cardiopulmonary exercise testing (CPET) and impedance cardiography (ICG) hemodynamics in patients with CAD.

Methods

Exercise capacity was assessed in 54 patients with CAD (41 men, aged 59.5 ± 8.6 years) within 6 weeks after revascularization by means of oxygen uptake (VO_2), assessed via CPET, and hemodynamic parameters [heart rate (HR), stroke volume, cardiac output (CO), left cardiac work index (LCWi)], measured by ICG. Correlations between these parameters at anaerobic threshold (AT) and at the peak of exercise as well as their changes ($\Delta_{\text{peak-rest}}$, $\Delta_{\text{peak-AT}}$) were evaluated.

Results

A large proportion of patients exhibited reduced exercise capacity, with 63% not reaching 80% of predicted peak VO_2 . Clinically relevant correlations were noted between the absolute peak values of VO_2 versus HR, VO_2 versus CO, and VO_2 versus LCWi ($R = 0.45$, $p = 0.0005$; $R = 0.33$, $p = 0.015$; and $R = 0.40$, $p = 0.003$, respectively). There was no correlation between AT VO_2 and hemodynamic parameters at the AT time point. Furthermore ΔVO_2 (peak-AT) correlated with ΔHR (peak-AT), ΔCO (peak-AT) and $\Delta LCWi$ (peak-AT) ($R = 0.52$, $p < 0.0001$, $R = 0.49$, $p = 0.0001$; and $R = 0.49$, $p = 0.0001$, respectively). ΔVO_2 (peak-rest) correlated with ΔHR (peak-rest), ΔCO (peak-rest), and $\Delta LCWi$ (peak-rest) ($R = 0.47$, $p < 0.0001$; $R = 0.41$, $p = 0.002$; and $R = 0.43$, $p = 0.001$, respectively).

Conclusion:

ICG is a reliable method of assessing the cardiovascular response to exercise in patients with CAD. Some ICG parameters show definite correlations with parameters of cardiovascular capacity of proven clinical utility, such as peak VO_2 .

Noninvasive Hemodynamic Monitoring in Advanced Heart Failure Patients: New Approach for Target Treatments

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Abstract:

Using bio-impedance to deduce some hemodynamic parameters combined with some short-term ECG temporal dispersion intervals, and measuring myocardial depolarization, intraventricular conduction, and repolarization. A total of 65 in-hospital patients (M/F:35/30) were enrolled, 39 with HFrEF and 26 HFpEF, in New York Heart Association (NYHA) class IV. Stroke volume (SVI), cardiac indexes (CI), left ventricular ejection fraction (LVEF_{BIO}), end diastolic volume (LV-EDV), and other systolic and diastolic parameters were noninvasively obtained at enrollment and at hospital discharge. At the same time, QR, QRS, QT, ST, Tpeak-Tend (Te) interval mean, and standard deviation (SD) from 5 min ECG recordings were obtained. At baseline, HFrEF patients reported significantly lower SVI ($p < 0.05$), CI ($p < 0.05$), and LVEF ($p < 0.001$) than HFpEF patients; moreover, HFrEF patients also showed increased LV-EDV ($p < 0.05$), QR, QRS, QT, ST, and Te means ($p < 0.05$) and standard deviations ($p < 0.05$) in

comparison to HFpEF subjects. Multivariable logistic regression analysis reported a significant correlation between hospital mortality and Te mean (odds ratio: 1.03, 95% confidence limit: 1.01-1.06, p : 0.01). Fifty-seven percent of patients were considered responders to optimal medical therapy and, at discharge, they had significantly reduced NT-proBNP, (p < 0.001), heart rate (p < 0.05), and Te_{SD} (p < 0.001). LVEF, obtained by transthoracic echocardiography, and LVEF_{BIO} were significantly related (r : 0.781, p < 0.001), but these two parameters showed a low agreement limit. Noninvasive hemodynamic and ECG-derived parameters were useful to highlight the difference between HFrEF and HFpEF and between responders and nonresponders to the optimal medical therapy. Short-period bioimpedance and electrocardiographic data should be deeply evaluated to determine possible advantages in the therapeutic and prognostic approach in severe CHF.

Rightward imbalanced pulmonary perfusion predicts better exercise stroke volume in children after Fallot repair

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Abstract:

Background

Residual lesions following Fallot repair are primarily pulmonary regurgitation and right ventricular outflow tract obstruction. These lesions may impact exercise tolerance, particularly because of a poor increase in left ventricular stroke volume. Pulmonary perfusion imbalance is also common, but its effect on cardiac adaptation to exercise is not known.

AIM

To assess the association between pulmonary perfusion asymmetry and peak indexed exercise stroke volume (pSVi) in young patients.

Methods


We retrospectively studied 82 consecutive patients with Fallot repair (mean age 15.2±3.8 years) who underwent echocardiography, four-dimensional flow magnetic resonance imaging and cardiopulmonary testing with pSVi measurement by thoracic bioimpedance. Normal pulmonary flow distribution was defined as right pulmonary artery perfusion between 43 and 61%.

Results

Normal, rightward and leftward flow distributions were found in 52 (63%), 26 (32%) and four (5%) patients, respectively. Independent predictors of pSVi were right pulmonary artery perfusion ($\beta=0.368$, 95% confidence interval [CI] 0.188 to 0.548; $P=0.0003$), right ventricular ejection fraction ($\beta=0.205$, 95% CI 0.026 to 0.383; $P=0.049$), pulmonary regurgitation fraction ($\beta=-0.283$, 95% CI -0.495 to -0.072; $P=0.006$) and Fallot variant with pulmonary atresia ($\beta=-0.213$, 95% CI -0.416 to -0.009; $P=0.041$). The pSVi prediction was similar when the categorical variable right pulmonary artery perfusion >61% was used ($\beta=0.210$, 95% CI 0.006 to 0.415; $P=0.044$).

Conclusion:

In addition to right ventricular ejection fraction, pulmonary regurgitation fraction and Fallot variant with pulmonary atresia, right pulmonary artery perfusion is a predictor of pSVi, in that rightward imbalanced pulmonary perfusion favours greater pSVi.

 **Exercise training affects hemodynamics and exercise capacity in cases of heart failure with preserved ejection fraction: a non-randomized controlled trial in individuals aged 65-80 years**

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Abstract:

Introduction

Exercise training is an established intervention method for improving exercise capacity and survival rates in patients with heart failure with preserved ejection fraction (HFpEF). However, most reports have focused on European and American patients, with limited data regarding the effects of exercise training on cardiac function, hemodynamics, and exercise capacity in East Asian patients. This study investigated the effects of exercise training on cardiac function, hemodynamics, and exercise capacity in Japanese patients aged 65-80 years with HFpEF.

Methods

This single-center, open-label, non-randomized, controlled trial prospectively enrolled 99 outpatients. Eligibility criteria for HFpEF patients were an HFA score ≥ 5 in addition to clinical symptoms of heart failure and left ventricular diastolic dysfunction. Exercise training in the intervention group consisted of aerobic exercise and strength training thrice weekly for 5 months. Patients in the control group continued the usual treatment for 5 months. Resting cardiac function was evaluated using echocardiography. Peak oxygen uptake (peakVO₂), ventilatory equivalent (VE) vs. carbon dioxide output (VCO₂) slope, peak cardiac output index, and arteriovenous oxygen difference were calculated using cardiopulmonary exercise testing combined with impedance cardiography.

Results

After 5 months of exercise training, remarkable interactions were observed, with peakVO₂ as the primary outcome. Additionally, significant interactions were observed between hemodynamic indices and some echocardiographic parameters. The mean percentage change in peakVO₂ from baseline was 8.3% in the intervention group. Fifteen study participants (30.1%) in the intervention group achieved a clinically meaningful change of 3.0 ml/min/kg (10% improvement) in peakVO₂ from baseline. The group with 3.0 ml/min/kg or 10% improvement in peakVO₂ from baseline had a considerably lower prevalence of diabetes mellitus and VE vs. VCO₂ slope and considerably higher left atrial-global longitudinal strain values than the group without any notable improvements.

Conclusion:

Although exercise training can help improve exercise intolerance in Japanese patients aged 65-80 years with HFpEF, its benefits are limited. Our results suggest that HFpEF, complicated by diabetes mellitus and decreased ventilatory efficiency during exercise, may require reconsideration of intervention strategies. This trial was registered with the University Hospital Medical Information Network, a trial registry in Japan (registration number: UMIN000045474).

Non-Invasive Assessment of Cardiodynamics by Impedance Cardiography during the Six-Minute Walk Test in Patients with Heart Failure

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Abstract:

Background

Central Illustration: Non-Invasive Assessment of Cardiodynamics by Impedance Cardiography during the Six-Minute Walk Test in Patients with Heart Failure. The six-minute walk test (6MWT) is commonly used to evaluate heart failure (HF) patients. However, several clinical factors can influence the distance walked in the test. Signal-morphology impedance cardiography (SM-ICG) is a useful tool to noninvasively assess hemodynamics.

Methods

This is a cross-sectional observational study. CO, HR, SV and cardiac index (CI) were evaluated before, during, and after the 6MWT assessed by SM-ICG. The level of significance adopted in the statistical analysis was 5%.

Results

Twenty-seven participants were included (13 HFrEF and 14 healthy controls). CO and HR acceleration significantly differed between groups ($p < 0.01$; $p = 0.039$, respectively). We found significant differences in SV, CO and CI between groups ($p < 0.01$). Linear regression showed an impaired SV contribution to CO change in HFrEF group (22.9% versus 57.4%).

Conclusion:

The main finding of the study was that individuals with HFrEF showed lower CO and HR acceleration values during the submaximal exercise test compared to healthy controls. This may indicate an imbalance in the autonomic response to exercise in this condition.

Hemodynamic Response to Exercise Training in Heart Failure With Reduced Ejection Fraction Patients

PMID: 38464706 PMCID: PMC10923260 DOI: 10.14740/cr1591

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Abstract:

Background

Supervised exercise training decreases total and cardiac mortality and increases quality of life of heart failure with reduced ejection fraction (HFrEF) patients. However, response to training is variable from one patient to another and factors responsible for a positive response to training remain unclear. The aims of the study were to compare cardiac hemodynamic changes after an exercise training program in responders (R) versus non-responders (NR) HFrEF patients, and to compare different discriminators used to assess response to training.

Methods


Seventy-six HFrEF patients (86% males, 57 ± 12 years) completed an exercise training program for 4 weeks. Patients underwent cardiopulmonary exercise testing (CPET) on a cycle ergometer before and after training. Cardiac hemodynamics were measured by impedance cardiography during CPET. The R and NR groups were classified using the median change in peak oxygen uptake ($\dot{V}O_{2peak}$).

Results

There were statistically significant differences in $\dot{V}O_{2peak}$ (+35% vs. -1%, $P < 0.0001$) and in peaks of ventilation (+30% vs. +2%, $P < 0.0001$), cardiac output (CO_{peak}) (+25% vs. +4%, $P < 0.01$), systolic blood pressure (+12% vs. +2%, $P < 0.05$), diastolic blood pressure (+9% vs. +4%, $P < 0.05$) and heart rate (+8% vs. +1%, $P < 0.01$) between R and NR after the training program. $\dot{V}O_{2peak}$ was the best discriminator between R and NR (receiver operating characteristic (ROC) area under the curve (AUC) = 0.83, $P < 0.0001$), followed by CO_{peak} (ROC AUC = 0.77, $P < 0.0001$).

Conclusion:

$\dot{V}O_{2peak}$ is the best discriminator between HFrEF R and NR patients after the training program. Responders showed improvements in peak hemodynamic parameters. These results pave the way for other studies to determine how the individualization of exercise training programs and peak hemodynamic parameters potentially linked to a better positive response status.

 **Cardiac hemodynamics phenotypes and individual Cardiac hemodynamics phenotypes and individual responses to training in coronary heart disease patients**

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Abstract:

Background

In patients with coronary heart disease (CHD), individualized exercise training (ET) programs are strongly recommended to optimize peak oxygen uptake ($\dot{V}O_{2\text{peak}}$) improvement and prognosis. However, the cardiac hemodynamic factors responsible for a positive response to training remain unclear. The aim of this study was to compare cardiac hemodynamic changes after an ET program in responder (R) versus non-responder (NR) CHD patients.

Methods

A total of 72 CHD patients completed a 3-month ET program and were assessed by cycle ergometer cardiopulmonary exercise test (CPET: $\dot{V}O_{2\text{peak}}$ assessment) with impedance cardiography (ICG) for hemodynamic measurements before and after training. Cardiac hemodynamics (e.g., CO, CI, SV, ESV, EDV, and SVR) were measured by ICG during CPET. The R and NR groups were classified using the median change in $\dot{V}O_{2\text{peak}}$ ($>$ the median for R and \leq the median for NR).

Results

In the R group, $\dot{V}O_{2\text{peak}}$ (+17%, $p < 0.001$), CO, CI, SV, and HR increased by 17%, 17%, 13%, and 5%, respectively ($p < 0.05$) after the training program. In the NR group, $\dot{V}O_{2\text{peak}}$, CO, CI, and SV increased by 0.5%, 5%, 8%, and 6%, respectively ($p < 0.01$). The SVR decreased in both groups (-19% in R and -11% in NR, $p < 0.001$).

Conclusion:

Among CHD patients, the R group showed a better improvement in peak cardiac output via an increase in peak stroke volume and heart rate and a reduced systemic vascular resistance than the NR group. Different cardiac phenotype adaptations and clinical individual responses were identified in CHD patients according to the aerobic fitness responder's status.

Determinants of $\dot{V}+O_2$ peak Changes After Aerobic Training in Coronary Heart Disease Patients

<https://doi.org/10.1055/a-2253-1807>

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Abstract:

This study aimed to highlight the ventilatory and circulatory determinants of changes in $\dot{V}O_{2peak}$ after exercise-based cardiac rehabilitation (ECR) in patients with coronary heart disease (CHD). Eighty-two CHD patients performed, before and after a 3-month ECR, a cardiopulmonary exercise testing (CPET) on a bike with gas exchanges measurements ($\dot{V}O_{2peak}$, minute ventilation, i. e., $\dot{V}E$), and cardiac output ($Q\dot{c}$). The arteriovenous difference in O_2 ($C(a-v)O_2$) and the alveolar capillary gradient in O_2 (PA_i-aO_2) were calculated using Fick's laws. Oxygen uptake efficiency slope (OUES) was calculated. A 5.0% cut off was applied for differentiating non- (NR: $\dot{V}O_2 < 0.0\%$), low (LR: $0.0 \leq \Delta \dot{V}O_2 < 5.0\%$), moderate (MR: $5.0 \leq \Delta \dot{V}O_2 < 10.0\%$), and high responders (HR: $\Delta \dot{V}O_2 \geq 10.0\%$) to ECR. A total of 44% of patients were HR (n=36), 20% MR (n=16), 23% LR (n=19), and 13% NR (n=11). For HR, the $\dot{V}O_{2peak}$ increase ($p < 0.01$) was associated with increases in $\dot{V}E$ ($+12.8 \pm 13.0$ L/min, $p < 0.01$), $C(a-v)O_2$ ($+1.0 \pm 0.9$ L/min, $p < 0.01$), and PA_i-aO_2 ($+2.3 \pm 2.5$ mL O_2 /100 mL, $p < 0.01$). MR patients were characterized by $+6.7 \pm 19.7$ L/min increase in $\dot{V}E$ ($p = 0.04$) and $+0.7 \pm 1.0$ L/min of $Q\dot{c}$ ($p < 0.01$). ECR induced decreases in $\dot{V}E$ ($p = 0.04$) and $C(a-v)O_2$ ($p < 0.01$) and a $Q\dot{c}$ increase in LR and NR patients ($p < 0.01$). Peripheral and ventilatory responses more than central adaptations could be responsible for the $\dot{V}O_{2peak}$ change with ECR in CHD patients.

2.2 LUNG DISEASE AND INTERNAL MEDICINE

Haemodynamics during Exercise are a Better Measure of Vasodilator Response in Human Subjects with Pulmonary Hypertension

Accepted for the British Thoracic Society winter meeting

Authors:

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Abstract:

Patients with pulmonary hypertension (PHT) are deemed 'non-responders' (NR) if they show no response to vasodilators at rest. We therefore decided to investigate the effects of vasodilators on pulmonary haemodynamics during exercise

Methods:

We investigated 4 patients, (2 female, 2 male) with PHT to determine pressure and flow changes over a range of flows. Flow was changed by straight leg raising. A micromanometer tipped continuous pulmonary artery pressure (PAP) catheter was inserted. All 4 were non-responders to a vasodilator challenge (defined as a reduction of >20% in pulmonary vascular resistance). Resting pressure was measured and then 3 mins of supine alternate straight leg raising was performed, whilst the subjects inhaled air or nitric oxide (NO, 40-80 ppm) and oxygen (O₂, 15L min). Cardiac Output (CO) was measured by non-invasive impedance cardiography. Subject data was pooled using the method described by Poon (J. Appl Physiol. 1998; 64:854-9). The best-fit line for Pressure Flow (P-Q) plots was determined by linear regression. An adjusted two paired student t-test was used to compare the line gradients.

Results

We found that although total pulmonary vascular resistance (as defined as mean PAP/CO) showed no change at rest, the slope of the P-Q plots decreased with vasodilators during exercise ($p < 0.0005$).

Conclusion:

In each of these 4 subjects, whilst there was no vasodilator response at rest, there was an improving relationship between pressure and flow during exercise whilst receiving the vasodilators NO & O₂. In patients with PHT, the assessment of vasodilator response may be better performed during exercise than at rest.

Dynamic Monitoring during Exercise in Familial Amyloid Polyneuropathy (FAP) Type I

Respiration and Circulation (Japan), vol. 51 N°12, December 2003

Authors:

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- Takashi Nakamura,
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Abstract:

A 64-years-old man was admitted to our hospital with complaints of orthostatic faintness and occasional diarrhea. An echocardiogram of the left ventricle demonstrated a severe restrictive disorder and granular sparkling appearance in the thickened walls. Microscopic findings of the myocardial biopsy revealed massive intramuscular accumulation of eosinophilic exudates and severe atrophy of myocytes. Cardiac 99m Tc-pyrophosphate (PYP) findings showed diffuse marked uptake in both left and right ventricles. Cardiac 123I-meta-iodobenzylguanidine (MIBG) findings showed complete defect on both early and delayed images. Genetic analysis revealed a single amino acid substitution at codon 30 of transthyretine (TTR), named FAP type I. Dynamic monitoring of the cardiac index peripheral vascular resistance in postural positions and exercise was measured by non-invasive methods (PhysioFlow™ Lab-1). The results of analysis indicated that the fall in blood pressure during exercise in our case was markedly affected by the lowering of peripheral vascular resistance. The cardiac index showed almost the same value during monitoring.

These findings suggest that orthostatic hypotension without increase in heart rate and output in a denervated myocardium is markedly accelerated by peripheral vascular sympathetic denervation in FAP type I. The present case is considered to be the first one encountered in Shiga.

Keywords:

- FAP type I,
- Cardiac amyloidosis,
- PhysioFlow™
- Lab-1

Unique cardiac response during apneas in obstructive sleep apnea (OSA) patients

Authors:

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Introduction:

Negative intrathoracic pressure (NIP) is a defining feature of OSA that acutely augments demand on cardiac function during apneas. Previous studies have shown distinct hemodynamic changes in healthy subjects undergoing simulated apneas. We sought to investigate the cardiovascular effects of NIP during and after a simulated apnea in awake patients with OSA versus healthy subjects.

Methods:

Subjects included 15 healthy males (Mean \pm SD: age = 38.6 \pm 6.3 yr; BMI = 22.7 \pm 5.4; all low risk by Berlin questionnaire; neck circumference = 38.71 \pm 2.4) and 10 recently diagnosed OSA patients (age = 44.3 \pm 10.7 yr; BMI = 33.3 \pm 8.0; AHI = 45.4 \pm 37.1). Cardiac function was monitored by non-invasive bioimpedance at baseline and during and 3 minutes after two 30-second Mueller maneuvers (MM).

Results:

During simulated apneas, stroke volume (SV) decreased in both groups with no response difference between control and OSA groups (-5.4 \pm 6.5 % and -2.7 \pm 11.0 %, p=0.5, respectively). When compared on myocardial contractility index (MCI), the OSA group showed an increase (11.8 \pm 14.3 %) and controls a decrease (-7.5 \pm 4.9%; p<0.0001) during apnea. In the post-apnea period, SV in controls increased in a compensatory fashion and returned to baseline by the end of the 3 minutes. In contrast, SV declined in OSA patients to pre-apnea values 30 seconds after breathing was restored, suggesting a blunted response. Post-apnea, MCI was different only immediately after termination of the MM, when the OSA response was higher than for controls (18.9 \pm 27.5 % versus -8.5 \pm 11.9 %, p<0.004).

Conclusion:

NIP appears to provoke unique hemodynamic changes in patients with untreated OSA. This indicates possible chronic adaptations of left ventricle arising from repetitive nocturnal apneas in untreated OSA.

Support: Study supported by NeuMeDx Inc.

CHRONIC OBSTRUCTIVE PULMONARY DISEASE
Respiratory muscle unloading improves leg muscle oxygenation during exercise in patients with COPD

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Background:

Respiratory muscle unloading during exercise could improve locomotor muscle oxygenation by increasing oxygen delivery (higher cardiac output and/or arterial oxygen content) in patients with chronic obstructive pulmonary disease (COPD).

Methods:

Sixteen non-hypoxaemic men (forced expiratory volume in 1 s 42.2 (13.9)% predicted) undertook, on different days, two constant work rate (70–80% peak) exercise tests receiving proportional assisted ventilation (PAV) or sham ventilation. Relative changes ($\Delta\%$) in deoxyhaemoglobin (HHb), oxyhaemoglobin (O₂Hb), tissue oxygenation index (TOI) and total haemoglobin (Hbtot) in the vastus lateralis muscle were measured by near-infrared spectroscopy. In order to estimate oxygen delivery (DO_{2est}, l/min), cardiac output and oxygen saturation (SpO₂) were continuously monitored by impedance cardiography and pulse oximetry, respectively.

Results:

Exercise tolerance (T_{lim}) and oxygen uptake were increased with PAV compared with sham ventilation. In contrast, end-exercise blood lactate/T_{lim} and leg effort/T_{lim} ratios were lower with PAV (p<0.05). There were no between-treatment differences in cardiac output and SpO₂ either at submaximal exercise or at T_{lim} (ie, DO_{2est} remained unchanged with PAV; p>0.05). Leg muscle oxygenation, however, was significantly enhanced with PAV as the exercise-related decrease in $\Delta(O_2Hb)\%$ was lessened and TOI was improved; moreover, $\Delta(Hbtot)\%$, an index of local blood volume, was increased compared with sham ventilation (p<0.01).

Conclusion:

Respiratory muscle unloading during high-intensity exercise can improve peripheral muscle oxygenation despite unaltered systemic DO₂ in patients with advanced COPD. These findings might indicate that a fraction of the available cardiac output had been redirected from ventilatory to appendicular muscles as a consequence of respiratory muscle unloading.

 **Skeletal muscle reoxygenation after high-intensity exercise in mitochondrial myopathy.**

Eur J Appl Physiol. 2011 Sep 4.

Authors:

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Abstract:

This study addressed whether $\dot{V}O_2$ delivery during recovery from high-intensity, supra-gas exchange threshold exercise would be matched to $\dot{V}O_2$ utilization at the microvascular level in patients with mitochondrial myopathy (MM). Off-exercise kinetics of (1) pulmonary $\dot{V}O_2$ uptake [Formula: see text] (2) an index of fractional $\dot{V}O_2$ extraction by near-infrared spectroscopy ($\Delta[\text{deoxy-Hb} + \text{Mb}]$) in the vastus lateralis and (3) cardiac output ($\dot{Q} (T) (')$) by impedance cardiography were assessed in 12 patients with biopsy-proven MM (chronic progressive external ophthalmoplegia) and 12 age- and gender-matched controls. Kinetics of [Formula: see text] were significantly slower in patients than controls ($\tau = 53.8 \pm 16.5$ vs. 38.8 ± 7.6 s, respectively; $p < 0.05$). $\dot{Q} (T) (')$, however, declined at similar rates ($\tau = 64.7 \pm 18.8$ vs. 73.0 ± 21.6 s; $p > 0.05$) being typically slower than [Formula: see text] in both groups. Importantly, $\Delta[\text{deoxy-Hb} + \text{Mb}]$ dynamics (MRT) were equal to, or faster than, [Formula: see text] in patients and controls, respectively. In fact, there were no between-group differences in [Formula: see text]/MRT $\Delta[\text{deoxy-Hb} + \text{Mb}]$ (1.1 ± 0.4 vs. 1.0 ± 0.2 , $p > 0.05$) thereby indicating similar rates of microvascular $\dot{V}O_2$ delivery. These data indicate that the slower rate of recovery of muscle metabolism after high-intensity exercise is not related to impaired microvascular $\dot{V}O_2$ delivery in patients with MM. This phenomenon, therefore, seems to reflect the intra-myocyte abnormalities that characterize this patient population.

 **Haemodynamic effects of proportional assist ventilation during high-intensity exercise in patients with chronic obstructive pulmonary disease.**

Respirology. 2010 Nov;15(8):1185-91. doi: 10.1111/j.1440-1843.2010.01846.x.

Authors:

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Background & Objective:

Proportional assist ventilation (PAV) has been proposed as a more physiological modality of non-invasive ventilation, thereby reducing the potential for deleterious cardio-circulatory effects during exercise, in patients with COPD. We therefore evaluated whether PAV modulates the kinetic and 'steady-state' haemodynamic responses to exercise in patients with moderate-to-severe COPD.

Methods:


Twenty patients underwent constant-load (75-80% peak work rate) cycle ergometer exercise testing to the limit of tolerance (T(lim)), while receiving PAV or breathing spontaneously. Stroke volume (SV), heart rate (HR) and cardiac output (CO) were monitored by impedance cardiography.

Results:

Compared with unassisted breathing, PAV increased T(lim) in 8/20 patients (median improvement 113% (range 8 to 212) vs -20% (range -40 to -9)). PAV had no significant effects on 'steady-state' haemodynamic responses either in patients with or those without increased T(lim) (P > 0.05). However, at the onset of exercise, SV kinetics were slowed with PAV, in 13/15 patients with analysable data. HR dynamics remained unaltered or failed to accelerate sufficiently in nine of these patients, thereby slowing CO kinetics (T(1/2) 61 s (range 81-30) vs 89 s (range 100-47)). These deleterious effects were not, however, associated with PAV-induced changes in T(lim) (P > 0.05).

Conclusion:

PAV slowed the SV and CO kinetics at the onset of high-intensity exercise in selected patients with moderate-to-severe COPD. However, these adverse effects of PAV disappeared during the stable phase of exercise, and were not related to the ergogenic potential of PAV in this patient population.

 **Effects of hyperoxia on the dynamics of skeletal muscle oxygenation at the onset of heavy-intensity exercise in patients with COPD.**

Respir Physiol Neurobiol. 2010 Jun 30;172(1-2):8-14. Epub 2010 Apr 24.

Authors:

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Abstract:

This study addressed whether hyperoxia (HiOX=50% O₂), compared to normoxia, would improve peripheral muscle oxygenation at the onset of supra-gas exchange threshold exercise in patients with chronic obstructive pulmonary disease (COPD) who were not overtly hypoxemic (resting Pa O₂> 60 mmHg). Despite faster cardiac output and improved blood oxygenation, HiOX did not significantly change pulmonary O₂ uptake kinetics (VO_{2p}). Surprisingly, however, HiOX was associated with faster fractional O₂ extraction (approximately Delta[deoxy-Hb+Mb] by near-infrared spectroscopy) (p<0.05). In addition, an "overshoot" in Delta[deoxy-Hb+Mb] was found after the initial fast response only in HiOX (7/11 patients) thereby suggesting impaired intra-muscular O₂ delivery (Q'O_{2mv})-to-utilization. These data indicate that, despite improved "central" O₂ delivery, Q'O_{2mv} adapted at a slower rate than muscle VO₂ under HiOX in non-hypoxaemic patients with COPD. Our results question the rationale of using supplemental O₂ to improve muscle oxygenation during the transition to high-intensity exercise in this patient sub-population.

Influence of respiratory pressure support on hemodynamics and exercise tolerance in patients with COPD.

Eur J Appl Physiol. 2010 Jul;109(4):681-9. Epub 2010 Mar 6.

Authors:

- Oliveira CC,
- Carrascosa CR,
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Erratum in

Eur J Appl Physiol. 2010 Aug;109(6):1219. Alberto Neder, J [corrected to Neder, J Alberto].

Abstract:

Inspiratory pressure support (IPS) plus positive end-expiratory pressure (PEEP) ventilation might potentially interfere with the "central" hemodynamic adjustments to exercise in patients with chronic obstructive pulmonary disease (COPD). Twenty-one non- or mildly-hypoxemic males (FEV(1) = 40.1 +/- 10.7% predicted) were randomly assigned to IPS (16 cmH(2)O) + PEEP (5 cmH(2)O) or spontaneous ventilation during constant-work rate (70-80% peak) exercise tests to the limit of tolerance (T (lim)). Heart rate (HR), stroke volume (SV), and cardiac output (CO) were monitored by transthoracic cardiopulmonary impedance (Physioflow, Manatec, France). Oxyhemoglobin saturation was assessed by pulse oximetry (SpO(2)). At similar SpO(2), IPS(16) + PEEP(5) was associated with heterogeneous cardiovascular effects compared with the control trial. Therefore, 11 patients (Group A) showed stable or increased Delta "isotime" - rest SV [5 (0-29) mL], lower DeltaHR but similar DeltaCO. On the other hand, DeltaSV [-10 (-15 to -3) mL] and DeltaHR were both lower with IPS(16) + PEEP(5) in Group B (N = 10), thereby reducing DeltaCO (p < 0.05). Group B showed higher resting lung volumes, and T (lim) improved with IPS(16) + PEEP(5) only in Group A [51 (-60 to 486) vs. 115 (-210 to 909) s, respectively; p < 0.05]. We conclude that IPS(16) + PEEP(5) may improve SV and exercise tolerance in selected patients with advanced COPD. Impaired SV and CO responses, associated with a lack of enhancement in exercise capacity, were found in a sub-group of patients who were particularly hyperinflated at rest.

 **Inspiratory resistive loading after all-out exercise improves subsequent performance.**

Eur J Appl Physiol. 2009 May;106(2):297-303. Epub 2009 Mar 6.

Authors:


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Exercise Pathophysiology Research
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Abstract:

We have previously shown that post-exercise inspiratory resistive loading (IRL) reduces blood lactate ([Lac(b)(-)]). In this study, we tested the hypothesis that IRL during recovery could improve subsequent exercise performance. Eight healthy men underwent, on different days, two sequential 30-s, cycle ergometer Wingate tests. During the 10-min recovery period from test 1, subjects breathed freely or through an inspiratory resistance (15 cm H₂O) with passive leg recovery. Arterialized [Lac(b)(-)] values, perceptual scores (Borg), cardiac output by impedance cardiography (QT), and changes in the deoxygenation status of the M. vastus lateralis by near-infrared spectroscopy (DeltaHHb), were recorded. [Lac(b)(-)] was significantly reduced after 4 min of recovery with IRL (peak [Lac(b)(-)] 12.5 +/- 2.3 mmol l⁻¹ with free-breathing vs. 9.8 +/- 1.5 mmol l⁻¹ with IRL). Effort perception was reduced during late recovery with IRL compared with free-breathing. Cardiac work was increased with IRL, since heart rate and QT were elevated during late recovery. Peripheral muscle reoxygenation, however, was significantly impaired with IRL, suggesting that post-exercise convective O₂ delivery to the lower limbs was reduced. Importantly, IRL had a dual effect on subsequent performance, i.e., improvement in peak and mean power, but increased fatigue index (P < 0.05). Our data demonstrate that IRL after a Wingate test reduces post-exercise effort perception and improves peak power on subsequent all-out maximal-intensity exercise.

 **Effects of respiratory muscle unloading on leg muscle oxygenation and blood volume during high-intensity exercise in chronic heart failure.**


Am J Physiol Heart Circ Physiol. 2008 Jun;294(6):H2465-72. Epub 2008 Mar 28.

Authors:

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Abstract:

Blood flow requirements of the respiratory muscles (RM) increase markedly during exercise in chronic heart failure (CHF). We reasoned that if the RM could subtract a fraction of the limited cardiac output (QT) from the peripheral muscles, RM unloading would improve locomotor muscle perfusion. Nine patients with CHF (left ventricle ejection fraction = 26 +/- 7%) undertook constant-work rate tests (70-80% peak) receiving proportional assisted ventilation (PAV) or sham ventilation. Relative changes (Delta%) in deoxy-hemoglobin, oxi-Hb ([O2Hb]), tissue oxygenation index, and total Hb ([HbTOT], an index of local blood volume) in the vastus lateralis were measured by near infrared spectroscopy. In addition, QT was monitored by impedance cardiography and arterial O2 saturation by pulse oximetry (SpO2). There were significant improvements in exercise tolerance (Tlim) with PAV. Blood lactate, leg effort/Tlim and dyspnea/Tlim were lower with PAV compared with sham ventilation (P < 0.05). There were no significant effects of RM unloading on systemic O2 delivery as QT and SpO2 at submaximal exercise and at Tlim did not differ between PAV and sham ventilation (P > 0.05). Unloaded breathing, however, was related to enhanced leg muscle oxygenation and local blood volume compared with sham, i.e., higher Delta[O2Hb]% and Delta[HbTOT]%, respectively (P < 0.05). We conclude that RM unloading had beneficial effects on the oxygenation status and blood volume of the exercising muscles at similar systemic O2 delivery in patients with advanced CHF. These data suggest that blood flow was redistributed from respiratory to locomotor muscles during unloaded breathing.

 **Kinetics of muscle deoxygenation are accelerated at the onset of heavy-intensity exercise in patients with COPD: relationship to central cardiovascular dynamics.**

Am J Physiol Heart Circ Physiol. 2008 Jun;294(6):H2465-72. Epub 2008 Mar 28.

Authors:

<ul style="list-style-type: none"> •Borghesi-Silva A, •Carrascosa C, •Oliveira CC, •Berton DC, •Maia J, •Gimenes AC, 	<ul style="list-style-type: none"> •Chiappa GR, •Ferreira EM, •Nery LE, •Neder JA. •Queiroga F Jr 	Pulmonary Function and Clinical Exercise Physiology Unit, Division of Respiratory Diseases, Department of Medicine, Federal University of São Paulo-Paulista School of Medicine, Rua Professor Francisco de Castro 54, Vila Clementino, São Paulo, Brazil.
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Abstract:

Patients with chronic obstructive pulmonary disease (COPD) have slowed pulmonary O₂ uptake (Vo₂(p)) kinetics during exercise, which may stem from inadequate muscle O₂ delivery. However, it is currently unknown how COPD impacts the dynamic relationship between systemic and microvascular O₂ delivery to uptake during exercise. We tested the hypothesis that, along with slowed Vo₂(p) kinetics, COPD patients have faster dynamics of muscle deoxygenation, but slower kinetics of cardiac output (Qt) following the onset of heavy-intensity exercise. We measured Vo₂(p), Qt (impedance cardiography), and muscle deoxygenation (near-infrared spectroscopy) during heavy-intensity exercise performed to the limit of tolerance by 10 patients with moderate-to-severe COPD and 11 age-matched sedentary controls. Variables were analyzed by standard nonlinear regression equations. Time to exercise intolerance was significantly (P < 0.05) lower in patients and related to the kinetics of Vo₂(p) (r = -0.70; P < 0.05). Compared with controls, COPD patients displayed slower kinetics of Vo₂(p) (42 +/- 13 vs. 73 +/- 24 s) and Qt (67 +/- 11 vs. 96 +/- 32 s), and faster overall kinetics of muscle deoxy-Hb (19.9 +/- 2.4 vs. 16.5 +/- 3.4 s). Consequently, the time constant ratio of O₂ uptake to mean response time of deoxy-Hb concentration was significantly greater in patients, suggesting a slower kinetics of microvascular O₂ delivery. In conclusion, our data show that patients with moderate-to-severe COPD have impaired central and peripheral cardiovascular adjustments following the onset of heavy-intensity exercise. These cardiocirculatory disturbances negatively impact the dynamic matching of O₂ delivery and utilization and may contribute to the slower Vo₂(p) kinetics compared with age-matched controls.

Evaluation of intradialytic hypotension using impedance cardiography

Int Urol Nephrol. 2010 May 7. [Epub ahead of print]

Authors:

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Background:

Hypotension during hemodialysis is frequent in patients with cardiovascular disease who have a limited physiological compensatory response. Recent advances in technology allow non-invasive monitoring of cardiac output and derived hemodynamic parameters. This prospective study evaluated episodes of intradialytic hypotension using clinical data and continuous non-invasive hemodynamic monitoring by impedance cardiography.

Methods:

Forty-eight chronic hemodialysis patients, with prevalence for intradialytic hypotensive episodes, underwent evaluation with non-invasive impedance cardiography (Physioflow((R))) before, during and after a regular dialysis session.

Results:

During continuous non-invasive cardiac monitoring, a fall of systolic arterial blood pressure of 20% or more at least once during hemodialysis was detected in 18 patients (37.5%)-thereafter identified as the "Unstable" group. In 30 patients-thereafter called the "Stable" group, the blood pressure did not change significantly. During hypotension, a decrease in cardiac output was found in 11 of the 18 unstable patients, and a significant fall in peripheral resistance in the remaining 7. End-diastolic filling ratio was significantly lower in the unstable group. The most significant predictors associated with intradialytic hypotension were the presence of ischemic heart disease ($P = 0.05$), and medication with beta blockers ($P = 0.037$) and calcium channel blockers ($P = 0.018$).

Conclusion:

Hemodynamic changes in dialysis patients with hypotensive episodes included decreased cardiac output or decreased peripheral resistance. A lower end-diastolic filling ratio may be regarded as a marker for reduced preload in these patients. Non-invasive impedance cardiography may be used to evaluate risk factors for hypotension in dialysis patients.

PMID: 20449654 [PubMed - as supplied by publisher]

Use Of Bioimpedance To Assess Changes In Hemodynamics During Acute Administration Of Continuous Positive Airway Pressure

C44 CARDIOPULMONARY INTERACTIONS AND NON-PULMONARY CRITICAL CARE /
Thematic Poster Session / Tuesday, May
18/8:15 AM-4:00 PM / Area H, Hall G (First Level), Morial Convention Center

Authors:

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Rationale:

Attempts to investigate the mechanisms by which continuous positive airway pressure (CPAP) therapy improves heart function in patients with obstructive sleep apnea (OSA) have been limited by the lack of non-invasive methods to assess cardiac performance. Measurements using transthoracic electrical bioimpedance (TEB) correlate closely with cardiac output measurements obtained by pulmonary artery catheterization (PAC). We used TEB to assess acute hemodynamic changes including heart rate (HR), stroke volume (SV), cardiac output (CO) and cardiac index (CI) during PAP titration in (1) in post-operative cardiac surgery patients, (2) patients with severe OSA, and (3) normal healthy volunteers.

Methods:

Post-operative cardiac surgery patients were studied via TEB and PAC during acute titration of positive end-expiratory pressure (PEEP) while mechanically ventilated. Patients with severe OSA were studied non-invasively by TEB during acute CPAP titration in supine stage 2 sleep, and normal subjects while awake and recumbent.

Results:

In three post-operative cardiac surgery patients, increasing PEEP to 18 cmH₂O reduced SV by 13.8 +/- 2.0% (P = 0.0003) and CI by 12.0 +/- 1.9% (P = 0.0004)

Relative to baseline. There was no statistical difference between TEB and PAC in terms of ability to assess variations in hemodynamic parameters. In patients with severe OSA (n=3), CPAP titration to optimal pressure to alleviate obstructive apneas (median 8 cmH₂O, range 5-9 cmH₂O) reduced HR significantly from 71.9 +/- 3.9 min⁻¹ to 61.8 +/- 6.3 min⁻¹ (P < 0.0001); SV from 93.5 +/- 7.8 mL to 82.9 +/- 11.2 mL

(P < 0.0001), CO from 6.7 +/- 0.7 L/min to 5.1 +/- 0.8 L/min (P < 0.0001) and CI from 2.9 +/- 0.3 L/min/m² to 2.3 +/- 0.4 L/min/m² (P < 0.0001) compared to without CPAP but in the absence of apneas. In three healthy subjects, maximal tolerated CPAP (median 16 cmH₂O, range 14-18 cmH₂O) reduced SV and CO by 10.3% +/- 0.4% and 13.0% +/- 9.9% respectively when compared to baseline.

Conclusion:

Acute administration of CPAP causes a decrease in CO and CI, apparently a consequence of a reduction in SV. TEB appears to be an accurate and reproducible non-invasive method of detecting changes in hemodynamics, rendering it a suitable alternative to PAC in measuring hemodynamic parameters in patients on PAP therapy.

This abstract is funded by: No funding for project. Submitting author received the Heart & Stroke Foundation of Ontario (HSFO) Summer Medical Student Award for undertaking the project
Am J Respir Crit Care Med 181;2010:A4541

Resistant Hypertension Comparing Hemodynamic Management to Specialist Care

(Hypertension. 2002;39:982.)

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Abstract:


Although resistant hypertension affects a minority of all hypertensives, this group continues to experience disproportionately high cardiovascular event rates despite newer antihypertensive agents. Hypertension represents an imbalance of hemodynamic forces within the circulation, usually characterized by elevated systemic vascular resistance. We studied the utility of serial hemodynamic parameters in the selection and titration of antihypertensive medication in resistant hypertensive patients using highly reproducible noninvasive measurements by thoracic bioimpedance. Resistant hypertension patients (n=104) were randomized to drug selection based either on serial hemodynamic (HD) measurements and a predefined algorithm or on drug selection directed by a hypertension specialist (SC) in a 3-month intensive treatment program. Blood pressure was lowered by intensified drug therapy in both treatment groups (169±3/87±2 to 139±2/72±1 mm Hg HD versus 173±3/91±2 to 147±2/79±1 mm Hg SC, P<0.01 for systolic and diastolic BP), using similar numbers and intensity of antihypertensive medications. Blood pressures were reduced further for those treated according to hemodynamic measurements, resulting in improved control rates (56% HD versus 33% SC controlled to ≤140/90 mm Hg, P<0.05) and incremental reduction in systemic vascular resistance measurements. Although the number of patients taking diuretics did not differ between groups, final diuretic dosage was higher in the hemodynamic cohort. Our results demonstrate superior blood pressure control using a treatment algorithm and serial hemodynamic measurements compared with clinical judgment alone in a randomized prospective study. Our measurements of thoracic fluid volume support occult volume expansion as a mediator of antihypertensive drug resistance and use of impedance measurements to guide advancing diuretic dose and adjustment of multidrug antihypertensive treatment.

Keywords:

- Hypertension
- Resistant
- Hemodynamics
- Drug therapy
- Cardiography

IMPORTANT NOTE FROM THE MANUFACTURER:

The device used for this study was a standard impedance cardiograph device

 **Effects of sauna alone and post-exercise sauna baths on blood pressure and hemodynamic variables in patients with untreated hypertension.**

AQSAP, 19th March 2011

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Purpose:

The aim of our study was to measure the effects of sauna alone (S) vs. exercise and sauna (ES) on blood pressure (BP) and central hemodynamic variables during and after sauna exposure in patients with untreated hypertension.

Methods:

16 untreated hypertensive subjects (61±9 years) were randomly assigned to 3 conditions: a resting control period (C), ES (30-min ergocycle exercise at 75% HRmax followed by two successive saunas) and S (two successive 8 min-sauna). Manual BP and hemodynamic measurements (cardiac bioimpedance, PhysioFlow®) were performed at baseline, during the 2 saunas (for ES and S), 15 and 120 min after saunas. 24h-ambulatory BP (ABP, Spacelabs®) was installed 120 min after sauna.

Results:

ES decreased ABPM daytime SBP, 24h-SBP (-5 mmHg, $p<0.05$) and 24-h mean BP. During sauna, SBP decreased at 2nd min of the 1st sauna ($p<0.05$) for S and ES. During saunas, HR and cardiac output increased ($p<0.0001$) for S and ES conditions, whereas ventricular ejection time and total vascular resistance (TVR) decreased ($p<0.0001$). End-diastolic volume increased in S and ES after 120 min ($p<0.0001$). TVR was reduced after 15 and 120 min for S and ES compared to C ($p<0.0001$).

Conclusion:

Exercise and sauna have positive effects on daytime and 24h SBP in patients with untreated hypertension on contrary to sauna alone. Exercise and sauna or sauna alone reduces TVR, with positive effects lasting 120 min after heat exposure. Exercise and sauna could be recommended as a non-pharmacological intervention for hypertension.

 **On- and off-exercise kinetics of cardiac output in response to cycling and walking in COPD patients with GOLD Stages I-IV.**

Petite ligne d'où est tire l'abstract etc

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Abstract:

Exercise-induced dynamic hyperinflation and large intrathoracic pressure swings may compromise the normal increase in cardiac output (Q) in Chronic Obstructive Pulmonary Disease (COPD). Therefore, it is anticipated that the greater the disease severity, the greater would be the impairment in cardiac output during exercise. Eighty COPD patients (20 at each GOLD Stage) and 10 healthy age-matched individuals undertook a constant-load test on a cycle-ergometer (75% WR(peak)) and a 6min walking test (6MWT). Cardiac output was measured by bioimpedance (PhysioFlow, Enduro) to determine the mean response time at the onset of exercise (MRTon) and during recovery (MRToff). Whilst cardiac output mean response time was not different between the two exercise protocols, MRT responses during cycling were slower in GOLD Stages III and IV compared to Stages I and II (MRTon: Stage I: 45±2, Stage II: 65±3, Stage III: 90±3, Stage IV: 106±3s; MRToff: Stage I: 42±2, Stage II: 68±3, Stage III: 87±3, Stage IV: 104±3s, respectively). In conclusion, the more advanced the disease severity the more impaired is the hemodynamic response to constant-load exercise and the 6MWT, possibly reflecting greater cardiovascular impairment and/or greater physical deconditioning.

Hemodynamic parameters in preeclampsia measured by transthoracic cardiac impedancemetry in the third trimester of pregnancy: An observational pilot study

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Introduction:

During preeclampsia, symptoms and signs are often late in this disease's history, and the challenge is its early diagnostic, resulting early therapy, and consequently a lower morbidity and mortality. Nowadays, no per partum test is enough sensitive or specific to diagnose preeclampsia before the clinical signs appearance.

Transthoracic Cardiac impedancemetry (TCI) is a totally non invasive technique measuring systolic ejection volume (SEV), and calculating cardiac output (CO, cardiac index CI) and indexed systemic vascular resistances (ISVR), which could be interesting in the early detection of abnormal hemodynamic state in preeclampsia. The purpose of our study was to describe the variations of hemodynamic variables in preeclampsia during the third trimester of pregnancy using TCI in supine (S), left lateral (LL) and right lateral (RL) position, compared with non preeclamptic pregnant women, and non pregnant women.

Methods:

We conducted a prospective observational case control study. We included pregnant volunteer or with isolated pregnancy related hypertension women in the third trimester between the 32th and the 36th week of gestational age and divided them depending of their prognosis on term (preeclampsia, PE group, or eutocic birth, EUT group). We compared these patients, with 10 non pregnant women SUPINE, 15 minutes LEFT, 15 minutes RIGHT, 15min (TEM group). We measured by plethysmography and TCI (Physioflow®, Manatec) for every women, systolic blood pressure, diastolic and average blood pressure, CO, cardiac index (CI), ISVR. The measures were during 15 minutes in strict S, then the measures were repeated. We calculated the difference between each position sequence for every parameter. After the measures, the patients were followed until the 15 days postpartum and distributed according to their prognosis.

Results:

We included 10 patients per group. The TCI was performed at 35 SA for the EUT and PE group. The median term was 40 amenorrhea weeks (AW) in the EUT group and 36,6 AW in the PE group.

7 patients on 10 of the PE group had a negative cardiac index variation when changing from supine to lateral position (left or right) vs 2 in the EUT group. The principal hemodynamic variables between group is described in the following table (*= p<0,05). median [extremes]]

Parameter/position	EUT (n=10)	PREECLAMPSIA (n=10)	NON PREGNANT(n=10)
Indexed Cardiac output/ Supine	3,5 [2,7-4,5]	3 [1,6-3,6]	3,3 [2,8-4]
Cardiac output/ Left Lateral	3,4 [2,6-4,4]	* 2,4 [1,8-3,3]	2,9 [2,5-3,3]
Indexed Systemic vascular resistances/Supine	1894[1050-2790]	*3376[2523-7018]	2142 [1730-2409]
Indexed Systemic vascular resistances/Left Lateral	1687[1197-3617]	*3382 [2463-3971]	2345 [2128-2668]
Cardiac index variations between Supine and LL %[+- SEM] . p=0,3	0,98 [+4,31]	-7,39 [+7,3]	-10,9 [+ 4,92]

Conclusion:

In preeclampsia, high RVSI have already been described in several studies. These RVSI don't significantly change when the patient changes his position from SUPINE to LATERAL POSITION, but CO and CI do. Moreover, the CI and RVSI achieve the levels found in the litterature in preeclamptic patients. CO measurement with Physioflow© TCI device seems well correlated with CO measurement thermodilution technics (1) in the litterature. In our study, variation of cardiac index (measured with TIC) during changes of position between SUPINE to RIGHT OR LEFT position measured at 35 SA, could have a high prognosive power for an evolution toward preeclampsia. Our study is limited by our cohort's smallness. Further studies are needed to conclude discriminative power of the delta IC in the diagnostic of PE.

We have already started a new study comparing cardiac output correlation between transthoracic echocardiography and TCI in third trimester pregnant and non preeclamptic, which are nowadays, missing data, to validate TCI in these patients. Furthtermore we are still including patients in a larger cohort study, allowing more focused search on relations between known prognosis factors, prognosis and hemodynamic parameters measured by TCI.

Determination of Hemodynamic Parameters During 6-Minute Walk Test In Pulmonary Hypertension

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Background:

- Pulmonary hypertension (PH) is a disease, characterized by an increase in pulmonary pressures, ultimately leading to right heart failure and death.
- The diagnosis and management of PH requires right heart catheterization (RHC). Impedance cardiography is a noninvasive methodology that determines resting cardiac output with good accuracy and fair precision in patients with PH.
- Objective functional capacity in this disease is commonly assessed by the six-minute walk test (6MWT), at study that provides information on disease severity, prognosis and response to therapy.
- No previous studies have assessed the cardiac output response during 6MWT in PH using impedance cardiography.

Methods:


- Patients with PH, confirmed with RHC, were recruited at the time of their 6MWT.
- We used a new generation portable impedance cardiography device (Physioflow enduro, Manatec Biomedical, Paris, France) with real time wireless monitoring via a bluetooth USB adapter.
- Physioflow measures changes in transthoracic impedance in response to the administration of a high frequency and low-amperage alternating electrical current via skin electrodes.
- We determined heart rate (HR), stroke volume (SV), cardiac output (CO) and cardiac index (CI) before, during and for three minute after the 6MWT.

Results:

- We included 18 patients (61% female), mean (SD) age 51.4 (16) years.
- Pulmonary arterial hypertension was present in 78% of patients. The rest had chronic thromboembolic PH or PH associated with parenchymal lung disease. All but 3 patients were on PH-specific therapies.
- Baseline HR is inversely associated with SV at baseline ($r = -0.7$, $p < 0.001$) and at its peak ($r = -0.48$, $p = 0.04$).
- Similarly, maximum HR is inversely associated with SV at baseline ($r = -0.75$, $p < 0.001$) and at its peak ($r = -0.56$, $p = 0.017$).
- The CO acceleration slope is associated with peak CO ($r = 0.72$, $p < 0.001$) and distance walked in meters ($r = 0.49$, $p = 0.039$)
- Peak CO is significantly associated with maximal SV ($r = 0.66$, $p = 0.003$) but not maximal HR ($r = 0.2$, $p = 0.38$) on univariable linear regression analysis.

Conclusion:

- Real time wireless impedance cardiography allows the non-invasive determination of hemodynamic parameters in PH patients during 6MWT.
- SV, CO and CI increase with activity. CO acceleration slope is directly associated with the distance walked and peak CO.
- The addition of impedance cardiography to the 6MWT can potentially increase the value of this test and provide insight into the hemodynamic changes during exercise in PH.

 **Signal morphology impedance cardiography during incremental cardiopulmonary exercise testing in pulmonary arterial hypertension.**

Clin Physiol Funct Imaging

Clin Physiol Funct Imaging 2012 Sep 16;32(5):343-52. Epub 2012 Apr 16.

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Abstract:

Haemodynamic responses to exercise are related to physical impairment and worse prognosis in patients with pulmonary arterial hypertension (PAH). It is clinically relevant, therefore, to investigate the practical usefulness of non-invasive methods of monitoring exercise haemodynamics in this patient population.

Using a novel impedance cardiography (ICG) approach that does not require basal impedance estimations and relies on a morphological analysis of the impedance signal (Signal-Morphology-ICGTM), stroke volume (SV) and cardiac index (CI) were evaluated in 50 patients and 21 age-matched controls during a ramp-incremental cardiopulmonary exercise testing.

Technically unacceptable readings were found in 12 of 50 (24%) patients. In the remaining subjects, early decrease (N = 9) or a 'plateau' in SV (N = 8) and Δ (peak-unloaded exercise) SV <10 ml were markers of more advanced PAH (P<0.05). Δ CI \leq 1.5-fold and early estimated lactate threshold were the only independent predictors of a severely reduced peak oxygen uptake (VO₂) in patients (R² = 0.71, P<0.001). The finding of Δ CI \leq 1.5-fold plus peak VO₂ < 50% predicted was associated with a number of clinical and functional markers of disease severity (P<0.001). In addition, abnormal SV responses and Δ CI \leq 1.5-fold were significantly related to 1-year frequency of PAH-related adverse events (death and balloon atrial septostomy, N = 8; P<0.05).

'Qualitative' and 'semi-quantitative' signal-morphology impedance cardiographyTM (PhysioFlowTM) during incremental exercise provided clinically useful information to estimate disease severity and short-term prognosis in patients with PAH in whom acceptable impedance signals could be obtained.

Persistent elevation of central pulse pressure during postural stress in patients with type 2 diabetes mellitus

Journal of Human Hypertension (2012), 1–8

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Abstract:

An abnormal increase or decrease in blood pressure (BP) in response to postural stress is associated with increased risk of developing hypertension and stroke. However, the haemodynamic responses contributing to changes in central BP with postural stress are not well characterised. We aimed to determine this in controls compared to patients with type 2 diabetes mellitus (T2DM), whom we hypothesised would have an abnormal postural response. 41 participants (20 control, 21 T2DM) underwent measurement of brachial and central BP (by radial tonometry), with simultaneous bioimpedance cardiography (to determine stroke volume (SV) and cardiac output (CO)) and heart rate variability in seated and standing postures. Systemic vascular resistance (SVR; mean arterial pressure/CO), and arterial elastance (EA; end systolic pressure/SV) were calculated. Postural changes were defined as seated minus standing values. Central pulse pressure (PP) was higher in patients with T2DM and did not change from seated-to-standing positions, whereas there was a significant decrease upon standing in controls ($P < 0.05$). The change in central systolic BP (SBP) correlated with change in SVR and EA in controls ($r = 0.67$ and 0.68 , $P < 0.05$, respectively), but not in patients with T2DM ($r = 0.05$ and $r = 0.03$, $P > 0.05$, respectively). SV was the only significant correlate of change in central SBP in T2DM patients ($r = 0.62$, $P < 0.05$) and this was not observed in controls ($r = 0.08$, $P > 0.05$). We conclude that central haemodynamic responses to postural stress are altered in patients with T2DM and result in persistent elevation of central PP while standing. This may contribute to increased cardiovascular risk associated with T2DM.

Keywords:

- haemodynamics,
- type 2 diabetes,
- pulse wave analysis,
- posture.

 **Hemodynamic effects of high intensity interval training in COPD patients exhibiting exercise-induced dynamic hyperinflation.**

Respir Physiol Neurobiol. 2015 Oct;217:8-16. doi: 10.1016/j.resp.2015.06.006. Epub 2015 Jun 23.

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Abstract:

Dynamic hyperinflation (DH) has a significant adverse effect on cardiovascular function during exercise in COPD patients. COPD patients with (n=25) and without (n=11) exercise-induced DH undertook an incremental (IET) and a constant-load exercise test (CLET) sustained at 75% peak work (WR_{peak}) prior to and following an interval cycling exercise training regime (set at 100% WR_{peak} with 30-s work/30-s rest intervals) lasting for 12 weeks. Cardiac output (Q) was assessed by cardio-bio-impedance (PhysioFlow, enduro, PF-O7) to determine Q mean response time (QMRT) at onset (QMRTON) and offset (QMRTOFF) of CLET. Post-rehabilitation only those patients exhibiting exercise-induced DH demonstrated significant reductions in QMRTON (from 82.2±4.3 to 61.7±4.2s) and QMRTOFF (from 80.5±3.8 to 57.2±4.9s). These post-rehabilitation adaptations were associated with improvements in inspiratory capacity, thereby suggesting that mitigation of the degree of exercise-induced DH improves central hemodynamic responses in COPD patients.

Keywords:

- COPD
- Cardiac output
- Pulmonary rehabilitation

Effect of Pulmonary Rehabilitation on Cardiac Output Responses during Exercise in COPD

Conference: European Respiratory Society Annual Congress, 2012, At Vienna, Austria, Volume: Eur Respir J 2012; 40: Suppl. 56, 1904s

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Abstract:

Introduction: In patients with COPD pulmonary rehabilitation (PR) induces true physiological effects reflected by reduced ventilatory requirement and improved peripheral muscle function. The effect of PR on central hemodynamic responses during exercise remains largely unknown.

Aim: To examine the impact of PR on cardiac output (Q) responses during incremental (IE) and constant-load exercise (CLE).

Method: 60 COPD patients (GOLD stages II- IV) were studied (including 15 controls). PR consisted of interval cycling exercise 3 days/week for 10 weeks, with 30-s work periods/30-s rest periods for 30 min/day and intensity at 100% of peak work capacity (W_{peak}). Q was measured by bio-impedance (Physioflow PF-O7) during IE and CLE at 75% W_{peak} for 6-min during exercise and in recovery, prior to and following PR.

Results: At W_{peak} there was an increase in Q after PR (from 10.1±0.5 to 12.4±0.6, L/min, p=0.001) due to increased SV (from 90±3.2 to 105.1±4.42 ml/min, p=0.003). Post-rehabilitation at an identical work rate during IE, Q did not differ compared to pre-rehabilitation; however SV was higher (pre: 90±3.2; post 95±3.2 ml/min) and HR lower (pre: 113±3; post 106±3 beats/min, p=0.008). Postrehabilitation during CLE there were significant reductions in Q mean response time (MRT) at the onset and offset of exercise (pre: 79.8±4.4; post: 66.9±4.5sec, p=0.001) and (pre: 79.1±4.3, post: 66.1±4.2 sec, p=0.001), respectively.

Conclusion: Pulmonary rehabilitation induces an improvement in central hemodynamic function to incremental and constant-load exercise in patients with COPD across GOLD stages II to IV.

The Higher the Insulin Resistance the Lower the Cardiac Output in Men with Type 1 Diabetes During the Maximal Exercise Test

Metabolic Syndrome and related Disorders 2017, 15 (5): 252-257

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Abstract:

BACKGROUND: The aim of this study was to assess the hemodynamic parameters analyzed in bioimpedance cardiography during maximal exercise in patients with type 1 diabetes differing in insulin resistance.

METHODS: The study group consisted of 40 men with type 1 diabetes. Tissue sensitivity to insulin was assessed on the basis of the glucose disposal rate (GDR) analyzed during hyperinsulinemic-euglycemic clamp. Patients were divided into groups with GDR <4.5 mg/kg/min (G1 group-lower insulin sensitivity) and GDR ≥4.5 mg/kg/min (G2 group-higher insulin sensitivity). During the exercise test, the heart rate, systolic volume, cardiac output, cardiac index were measured by the impedance meter (PhysioFlow).

RESULTS: Compared with the G2 group, the G1 group had a lower cardiac output (CO): during exercise 8.6 (IQR 7.7-10.0) versus 12.8 (IQR 10.8-13.7) L/min; $P < 0.0001$, at the maximal effort 13.1 (IQR 12.2-16.7) versus 18.6 (IQR 16.9-20.2) L/min; $P = 0.001$, and during observation after exercise 8.4 (IQR 6.3-9.6) versus 11.9 (IQR 10.1-13.1) L/min; $P < 0.0001$. We noticed a positive correlation of GDR and cardiac output: during the exercise test ($r = 0.63$, $P = 0.0002$), at the maximal effort ($R_s 0.56$, $P = 0.001$), and during observation after the exercise test ($r = 0.72$, $P < 0.0001$). In multivariate logistic regression, cardiac output during exercise and during observation was associated with high GDR, regardless of the age and duration of diabetes [OR: 1.98 (95% CI 1.10-3.56), $P = 0.02$ and OR: 1.91 (95% CI 1.05-3.48), $P = 0.03$; respectively].

CONCLUSION: In nonobese subjects with type 1 diabetes, with good metabolic control, insulin resistance is associated with cardiac hemodynamic parameters assessed during and after exercise. The higher the insulin resistance the lower the cardiac output during maximal exercise in men with type 1 diabetes.

Management of an LCHADD Patient During Pregnancy and High Intensity Exercise

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Abstract:

In this report we describe a female Long-Chain 3- Hydroxyacyl-CoA Dehydrogenase Deficiency (LCHADD) patient who suffered from severe exercise intolerance. At age 34, the patient became pregnant for the first time. After an uneventful first 32 weeks of pregnancy she developed sinus tachycardia (resting heart rate 120–134 bpm) and lactate and creatinine kinase levels increased (3.3 mmol/L and 264 U/L, respectively). Increasing MCT supplementation (dose and frequency of administration) lowered heart rate and improved biochemical parameters. At 34 weeks the heart rate rose again and it was decided to deliver the child by caesarean section. Postpartum both mother and child did well. Prior to pregnancy, she performed exercise tests with different doses of medium chain triglycerides (MCTs) to establish a safe and effective exercise program (baseline test, second test with 10 g MCTs and third test with 20 g of MCTs). In the MCT supplemented tests the maximal power output was 23% (second test) and 26% (third test) higher, while cardiac output at maximal power output was the same in all three tests (~15.8 L/min). In conclusion, this is the first report of pregnancy in an LCHADD patient, with favourable outcome for both mother and child. Moreover, in the same patient, MCT supplementation improved cardiac performance and metabolic parameters during high intensity exercise. Using impedance cardiography, we got a clear indication that this benefit was due to improved muscle energy generation at high intensity exercise, since at the same cardiac output a higher power output could be generated.

Sildenafil restores the hemodynamic response during maximal exercise in patients with cystic fibrosis

Supported in part by a Vertex Pharmaceuticals IIS and NIH/NIDDK R21DK100783 (RAH).

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Abstract:

It is well established that patients with cystic fibrosis (CF) exhibit exercise intolerance; however, the mechanisms have yet to be elucidated. We have documented vascular dysfunction at rest in patients with CF and therefore, it is conceivable that the hemodynamic response is compromised during exercise in this patient population. Sildenafil is a phosphodiesterase type 5 inhibitor that promotes arterial vasodilation resulting in enhanced blood flow.

Purpose: To explore the hemodynamic response during maximal exercise in patients with CF and controls, and determine if a single dose of sildenafil improves this response in patients with CF.

Methods: Hemodynamic variables were collected in 19 patients with CF (20±2 years) and 15 controls (26±2 years old) at baseline and throughout a maximal exercise test on a cycle ergometer. Six of the patients also performed maximal exercise testing 1 hour following ingestion of a single dose of sildenafil (50 mg; CF-SIL). Hemodynamic parameters were assessed using Physioflow Enduro and included cardiac output (CO), left cardiac work index (LCWI), and systemic vascular resistance (SVR) among many others.

Results: Cardiac output (p=0.048) and LCWI (p=0.015) were significantly lower at baseline in patients with CF compared to controls. A significant group by time interaction (F_{1,32} =9.497; p=0.004) for SVR was observed. Specifically, SVR at baseline was significantly (p=0.018) higher in CF (1599±92 dyn.s/cm⁵) compared to controls (1307±60 dyn.s/cm⁵). Additionally, there was a greater drop (p=0.004) in SVR from baseline to maximal exercise in patients compared to controls (-924±72 vs. -639±51 dyn.s/cm⁵, respectively). Following sildenafil, no difference (p=0.332) in the change in SVR from baseline to maximal exercise was observed between CF-SIL (-549±65 dyn.s/cm⁵) and controls (-639±51 dyn.s/cm⁵). Additionally, baseline CO (p=0.382) and LCWI (p=0.717) were similar between CF-SIL and controls.

Conclusion:

These data indicate that patients with CF have compromised hemodynamic function at rest and exhibit an exaggerated reduction in systemic vascular resistance during maximal exercise. In addition, a single dose of sildenafil in CF appears to restore the systemic vascular resistance response to maximal exercise. Future studies are warranted to determine the contribution of the hemodynamic response to exercise intolerance in this patient population.

Cardiac output measurement during exercise in COPD: A comparison of dye dilution and impedance cardiography

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Abstract:

Introduction: Impedance cardiography (IC) derived from morphological analysis of the thoracic impedance signal is now commonly used for noninvasive assessment of cardiac output (CO) at rest and during exercise. However, in Chronic Obstructive Pulmonary Disease (COPD), conflicting findings put its accuracy into question.

Objectives: We therefore compared concurrent CO measurements captured by IC (PhysioFlow: COIC) and by the indocyanine green dye dilution method (CODD) in patients with COPD.

Methods: Fifty paired CO measurements were concurrently obtained using the two methods from 10 patients (FEV1: 50.5 ± 17.5% predicted) at rest and during cycling at 25%, 50%, 75% and 100% peak work rate.

Results:

From rest to peak exercise COIC and CODD were strongly correlated ($r = 0.986$, $P < 0.001$). The mean absolute and percentage differences between COIC and CODD were 1.08 L/min (limits of agreement (LoA): 0.05-2.11 L/min) and 18 ± 2%, respectively, with IC yielding systematically higher values. Bland-Altman analysis indicated that during exercise only 7 of the 50 paired measurements differed by more than 20%. When data were expressed as changes from rest, correlations and agreement between the two methods remained strong over the entire exercise range ($r = 0.974$, $P < 0.001$, with no significant difference: 0.19 L/min; LoA: -0.76 to 1.15 L/min). Oxygen uptake (VO_2) and CODD were linearly related: $r = 0.893$ ($P < 0.001$), $CODD = 5.94 \times VO_2 + 2.27$ L/min. Similar results were obtained for VO_2 and COIC ($r = 0.885$, $P < 0.001$, $COIC = 6.00 \times VO_2 + 3.30$ L/min)

Conclusion:

These findings suggest that IC provides an acceptable CO measurement from rest to peak cycling exercise in patients with COPD.

Keywords:

- central hemodynamics;
- exercise;
- lung diseases;
- noninvasive techniques;
- thoracic impedance

Limited usefulness of resting hemodynamic assessments in predicting exercise capacity in hypertensive patients

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Abstract:

Reliable assessments of reduced exercise capacity based on resting tests are one of the major challenges in clinical practice. The aim of this study was to evaluate the relationship between hemodynamic parameters obtained via resting tests (echocardiography and impedance cardiography (ICG)) and objective parameters of exercise capacity assessed via cardiopulmonary exercise testing and exercise ICG in patients with controlled arterial hypertension (AH). The left ventricular ejection fraction (LVEF), global longitudinal strain (GLS), diastolic function parameters (e' , E/A, E/e'), cardiac output (CO), stroke volume (SV), and systemic vascular resistance index were evaluated for any correlations with selected parameters of exercise capacity, such as peak oxygen uptake (VO_2) and peak CO in 93 people with AH (mean age 54 years, 47 women). Statistically relevant correlations occurred between indices of exercise capacity (peak VO_2 ; peak CO) and only the following hemodynamic parameters: diastolic blood pressure ($R = 0.23$, $p = 0.026$; $R = 0.24$, $p = 0.021$; respectively), e' ($R = 0.32$, $p = 0.002$; $R = 0.24$, $p = 0.027$), E/e' ($R = 0.35$, $p < 0.001$; ns), E/A ($R = 0.23$, $p = 0.030$; $R = 0.21$, $p = 0.047$), SV at rest (ns; $R = 0.24$, $p = 0.019$), and CO at rest (ns; $R = 0.21$, borderline $p = 0.052$). No significant correlations between the exercise capacity parameters and either LVEF or GLS were observed. No hemodynamic parameter proved to be an independent correlate of either peak VO_2 or peak CO. The association between hemodynamic parameters at rest and parameters of exercise capacity was weak and limited to selected parameters of diastolic function. Exercise capacity assessment in patients with AH based on resting tests alone is insufficiently reliable and should be supplemented with exercise tests.

Exercise impedance cardiography reveals impaired hemodynamic responses to exercise in hypertensives with dyspnea

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Abstract:

Patients with arterial hypertension (AH), especially women, often report exercise intolerance and dyspnea. However, these symptoms are not frequently reflected in standard assessments. The aim of the study was to evaluate the clinical value of impedance cardiography (ICG) in the hemodynamic assessment of patients with AH during exercise, particularly the differences between subgroups based on sex and the presence of dyspnea. Ninety-eight patients with AH (52 women; 54.5 ± 8.2 years of age) were evaluated for levels of N-terminal pro-B-type brain natriuretic peptide (NT-proBNP), exercise capacity (cardiopulmonary exercise testing (CPET) and the 6-min walk test (6MWT)), and exercise ICG. Patients with AH were stratified into the following four subgroups: males without dyspnea (MnD, $n = 38$); males with dyspnea (MD, $n = 8$); females without dyspnea (FnD, $n = 27$); and females with dyspnea (FD, $n = 25$). In comparison with the MnD subgroup, the FnD subgroup demonstrated significantly higher NT-proBNP levels; lower exercise capacity (shorter 6MWT distance, lower peak oxygen uptake (VO_2), lower O_2 pulse); higher peak stroke volume index (SVI); and higher SVI at the anaerobic threshold (AT). In comparison with the other subgroups, the FD subgroup walked a shorter distance during the 6MWT distance; had a steeper VE/ VCO_2 slope; had lower values of peak stroke volume (SV) and peak cardiac output (CO); and had a smaller change in CO from rest to peak. However, no other differences were identified (NT-proBNP, left ventricular diastolic dysfunction, or CPET parameters). Exercise impedance cardiography revealed an impaired hemodynamic response to exercise in hypertensive females with dyspnea. In patients with unexplained exercise intolerance, impedance cardiography may complement traditional exercise tests.

Multiparameter assessment of exercise capacity in patients with arterial hypertension

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Abstract:

Introduction:

Arterial hypertension (AH) can lead to the development of heart failure. **Aim:** Evaluating the relationship between parameters of exercise capacity assessed via a six-minute walk test (6MWT) and cardiopulmonary exercise test (CPET), with a hemodynamic assessment via impedance cardiography (ICG), in patients with AH.

Methods:

Exercise capacity was assessed in 98 hypertensive patients (54.5 ± 8.2 years) by means of oxygen uptake (VO_2) get from CPET, 6MWT distance (6MWTd) and hemodynamic parameters measured by ICG: heart rate (HR), stroke volume (SV), cardiac output (CO). Correlations between these parameters at rest, at anaerobic threshold (AT) and at peak of exercise as well as their changes ($\Delta_{\text{peak-rest}}$, $\Delta_{\text{peak-AT}}$, $\Delta_{\text{AT-rest}}$) were evaluated.

Results:

A large proportion of patients exhibited reduced exercise capacity, with 45.9% not reaching 80% of predicted peak VO_2 and 43.9% not reaching predicted 6MWTd. Clinically relevant correlations were noted between the absolute peak values and AT values of VO_2 vs HR and VO_2 vs CO. Furthermore $\Delta VO_2(\text{peak-AT})$ correlated with $\Delta HR(\text{peak-AT})$, $\Delta CO(\text{peak-AT})$ and $\Delta SV(\text{peak-AT})$; $\Delta VO_2(\text{peak-rest})$ with $\Delta HR(\text{peak-rest})$ and $\Delta CO(\text{peak-rest})$; $\Delta VO_2(\text{AT-rest})$ with $\Delta HR(\text{AT-rest})$ and $\Delta CO(\text{AT-rest})$. Stronger correlations between changes in the evaluated parameters were demonstrated in the subgroup of subjects with peak $VO_2 < 80\%$ of the predicted value; particularly $\Delta VO_2(\text{peak-AT})$ correlated with $\Delta SV(\text{peak-AT})$ and $\Delta CO(\text{peak-AT})$.

Conclusion:

The hemodynamic parameters show significant correlations with more measures of cardiovascular capacity of proven clinical utility. Impedance cardiography is a reliable method for assessing the cardiovascular response to exercise.

Exercise intolerance in comorbid COPD and heart failure: the role of impaired aerobic function

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Abstract:

Impaired aerobic function is a potential mechanism of exercise intolerance in patients with combined cardiorespiratory disease. We investigated the pathophysiological and sensory consequences of a low change in oxygen uptake (ΔV_{O_2})/change in work rate (ΔWR) relationship during incremental exercise in patients with coexisting chronic obstructive pulmonary disease (COPD) and systolic heart failure (HF). After clinical stabilisation, 51 COPD-HF patients performed an incremental cardiopulmonary exercise test to symptom limitation. Cardiac output was non-invasively measured (impedance cardiography) in a subset of patients (n=18). 27 patients presented with $\Delta V_{O_2}/\Delta WR$ below the lower limit of normal. Despite similar forced expiratory volume in 1 s and ejection fraction, the low $\Delta V_{O_2}/\Delta WR$ group showed higher end-diastolic volume, lower inspiratory capacity and lower transfer factor compared to their counterparts (p<0.05). Peak WR and peak V_{O_2} were ~15% and ~30% lower, respectively, in the former group: those findings were associated with greater symptom burden in daily life and at a given exercise intensity (leg discomfort and dyspnoea). The low $\Delta V_{O_2}/\Delta WR$ group presented with other evidences of impaired aerobic function (sluggish V_{O_2} kinetics, earlier anaerobic threshold) and cardiocirculatory performance (lower oxygen pulse, lower stroke volume and cardiac output) (p<0.05). Despite similar exertional hypoxaemia, they showed worse ventilatory inefficiency and higher operating lung volumes, which led to greater mechanical inspiratory constraints (p<0.05). Impaired aerobic function due to negative cardiopulmonary-muscular interactions is an important determinant of exercise intolerance in patients with COPD-HF. Treatment strategies to improve oxygen delivery to and/or utilisation by the peripheral muscles might prove particularly beneficial to these patients.

Left Ventricular Function Before and After Aerobic Exercise Training in Women With Pulmonary Arterial Hypertension

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Abstract:

Background:

Pulmonary arterial hypertension (PAH) is a chronic debilitating illness. The effects of vigorous aerobic exercise training (AET) on heart function in PAH are poorly understood.

Methods:

Eighteen women with PAH (aged 56.2 ± 8.8 yr, body mass index: 28.8 ± 7.3 kg/m) underwent 10 wk of vigorous AET. Cardiac function was observed at rest and peak exercise using bioelectrical impedance cardiography before and after the AET. Cardiac function was observed in a small PAH subset ($n = 7$) for 10 wk before beginning the AET. A cohort of sedentary women ($n = 19$) served as healthy controls.

Results:

Left ventricular ejection fraction (48 ± 9.2 vs $61.5 \pm 13.3\%$, $P = .034$) and the systemic vascular resistance index (2258 ± 419.1 vs 2939 ± 962.4 dyn·sec/cm·m, $P = .008$) were lower at supine rest in the baseline PAH group versus the healthy group, as were peak exercise heart rate (140 ± 13.3 vs 170 ± 13.8 beats/min, $P < .001$) and systemic vascular resistance index (828 ± 141.1 vs 824 ± 300.9 dyn·sec/cm·m, $P = .050$) after controlling for age and heart rate. Systemic vascular resistance index measured at peak exercise decreased in the PAH group after AET (828 ± 141.1 vs 766 ± 139.6 dyn·sec/cm·m, $P = .020$). Left ventricular early diastolic filling ratio worsened in the PAH subset prior to AET (95.9 ± 19.4 vs $76.2 \pm 18.9\%$, $P = .043$) and remained unchanged after AET.

Conclusion:

Vigorous AET was not associated with significant declines in left ventricular systolic or diastolic function in women with PAH. Aerobic exercise training may be beneficial for reducing afterload and may preserve left ventricular diastolic function.

Effects of lung deflation induced by tiotropium/olodaterol on the cardiocirculatory responses to exertion in COPD

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Abstract:

Background

Hyperinflation has been associated with negative cardiocirculatory consequences in patients with chronic obstructive pulmonary disease (COPD). These abnormalities are likely to worsen when the demands for O₂ increase, e.g., under the stress of exercise. Thus, pharmacologically-induced lung deflation may improve cardiopulmonary interactions and exertional cardiac output leading to higher limb muscle blood flow and oxygenation in hyperinflated patients with COPD.

Methods

20 patients (residual volume = 201.6 ± 63.6% predicted) performed endurance cardiopulmonary exercise tests (75% peak) 1 h after placebo or tiotropium/olodaterol 5/5 µg via the Respimat® inhaler (Boehringer Ingelheim, Ingelheim am Rhein, Germany). Cardiac output was assessed by signal-morphology impedance cardiography. Near-infrared spectroscopy determined quadriceps blood flow (indocyanine green dye) and intra-muscular oxygenation.

Results

Tiotropium/olodaterol was associated with marked lung deflation ($p < 0.01$): residual volume decreased by at least 0.4 L in 14/20 patients (70%). The downward shift in the resting static lung volumes was associated with less exertional inspiratory constraints and dyspnoea thereby increasing exercise endurance by ~50%. Contrary to our premises, however, neither central and peripheral hemodynamics nor muscle oxygenation improved after active intervention compared to placebo. These results were consistent with those found in a subgroup of patients showing the largest decrements in residual volume ($p < 0.05$).

Conclusion:

The beneficial effects of tiotropium/olodaterol on resting and operating lung volumes are not translated into enhanced cardiocirculatory responses to exertion in hyperinflated patients with COPD. Improvement in exercise tolerance after dual bronchodilation is unlikely to be mechanistically linked to higher muscle blood flow and/or O₂ delivery.

The physiological effect of early pregnancy on a woman's response to a submaximal cardiopulmonary exercise test

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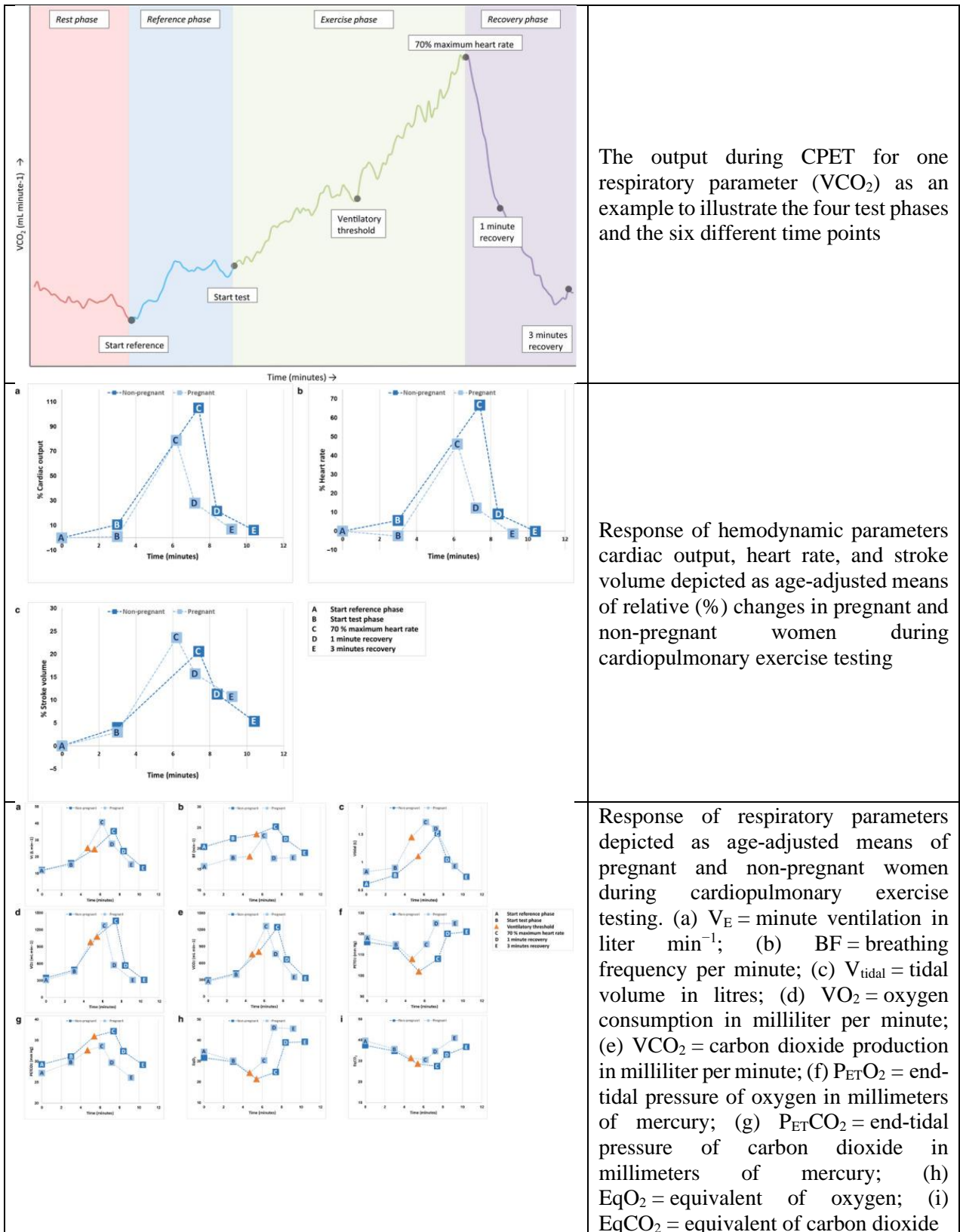
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Abstract:

Given all its systemic adaptive requirements, pregnancy shares several features with physical exercise. In this pilot study, we aimed to assess the physiological response to submaximal cardiopulmonary exercise testing (CPET) in early pregnancy. In 20 healthy, pregnant women (<13 weeks gestation) and 20 healthy, non-pregnant women, we performed a CPET with stationary cycling during a RAMP protocol until 70% of the estimated maximum heart rate (HR) of each participant. Hemodynamic and respiratory parameters were non-invasively monitored by impedance cardiography (PhysioFlow®) and a breath-by-breath analyzer (Oxycon™). To compare both groups, we used linear regression analysis, adjusted for age. We observed a similar response of stroke volume, cardiac output (CO) and HR to stationary cycling in pregnant and non-pregnant women, but a slightly lower 1-min recovery rate of CO (-3.9 [-5.5;-2.3] vs. -6.6 [-8.2;-5.1] L min⁻¹ min⁻¹; p = .058) and HR (-38 [-47; -28] vs. -53 [-62; -44] bpm/min; p = .065) in pregnant women. We also observed a larger increase in ventilation before the ventilatory threshold (+6.2 [5.4; 7.0] vs. +3.2 [2.4; 3.9] L min⁻¹ min⁻¹; p < .001), lower P_{ET} CO₂ values at the ventilatory threshold (33 [31; 34] vs. 36 [34; 38] mmHg; p = .042) and a larger increase of breathing frequency after the ventilatory threshold (+4.6 [2.8; 6.4] vs. +0.6 [-1.1; 2.3] breaths min⁻¹ min⁻¹;

$p = .015$) in pregnant women. In conclusion, we observed a slower hemodynamic recovery and an increased ventilatory response to exercise in early pregnancy.



The output during CPET for one respiratory parameter (V_{CO_2}) as an example to illustrate the four test phases and the six different time points

Response of hemodynamic parameters cardiac output, heart rate, and stroke volume depicted as age-adjusted means of relative (%) changes in pregnant and non-pregnant women during cardiopulmonary exercise testing

Response of respiratory parameters depicted as age-adjusted means of pregnant and non-pregnant women during cardiopulmonary exercise testing. (a) V_E = minute ventilation in liter min⁻¹; (b) BF = breathing frequency per minute; (c) V_{tidal} = tidal volume in litres; (d) VO_2 = oxygen consumption in milliliter per minute; (e) V_{CO_2} = carbon dioxide production in milliliter per minute; (f) $P_{ET}O_2$ = end-tidal pressure of oxygen in millimeters of mercury; (g) $P_{ET}CO_2$ = end-tidal pressure of carbon dioxide in millimeters of mercury; (h) EqO_2 = equivalent of oxygen; (i) $EqCO_2$ = equivalent of carbon dioxide

High-intensity exercise impairs extradiaphragmatic respiratory muscle perfusion in patients with COPD

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Abstract:

The study investigated whether high-intensity exercise impairs inspiratory and expiratory muscle perfusion in patients with chronic obstructive pulmonary disease (COPD). We compared respiratory local muscle perfusion between constant-load cycling[sustained at 80% peak work rate (WR_{peak})] and voluntary normocapnic hyperpnea reproducing similar work of breathing (WoB) in 18 patients [forced expiratory volume in the first second (FEV₁): 58 ± 24% predicted]. Local muscle blood flow index (BFI), using indocyanine green dye, and fractional oxygen saturation (%StiO₂) were simultaneously assessed by near-infrared spectroscopy (NIRS) over the intercostal, scalene, rectus abdominis, and vastus lateralis muscles. Cardiac output (impedance cardiography), WoB (esophageal/gastric balloon catheter), and diaphragmatic and extradiaphragmatic respiratory muscle electromyographic activity (EMG) were also assessed throughout cycling and hyperpnea. Minute ventilation, breathing pattern, WoB, and respiratory muscle EMG were comparable between cycling and hyperpnea. During cycling, cardiac output and vastus lateralis BFI were significantly greater compared with hyperpnea [by +4.2 (2.6-5.9) L/min and +4.9 (2.2-7.8)

nmol/s, respectively] ($P < 0.01$). Muscle BFI and %StiO₂ were, respectively, lower during cycling compared with hyperpnea in scalene [by -3.8 (-6.4 to -1.2) nmol/s and -6.6 (-8.2 to -5.1)%], intercostal [by -1.4 (-2.4 to -0.4) nmol/s and -6.0 (-8.6 to -3.3)%], and abdominal muscles [by -1.9 (-2.9 to -0.8) nmol/s and -6.3 (-9.1 to -3.4)%] ($P < 0.001$). The difference in respiratory (scalene and intercostal) muscle BFI between cycling and hyperpnea was associated with greater dyspnea (Borg CR10) scores ($r = -0.54$ and $r = -0.49$, respectively, $P < 0.05$). These results suggest that in patients with COPD, 1) locomotor muscle work during high-intensity exercise impairs extradiaphragmatic respiratory muscle perfusion and 2) insufficient adjustment in extradiaphragmatic respiratory muscle perfusion during high-intensity exercise may partly explain the increased sensations of dyspnea. **NEW & NOTEWORTHY** We simultaneously assessed the blood flow index (BFI) in three respiratory muscles during hyperpnea and high-intensity constant-load cycling sustained at comparable levels of work of breathing and respiratory neural drive in patients with COPD. We demonstrated that high-intensity exercise impairs respiratory muscle perfusion, as intercostal, scalene, and abdominal BFI increased during hyperpnea but not during cycling. Insufficient adjustment in respiratory muscle perfusion during exercise was associated with greater dyspnea sensations in patients with COPD.

Cardiac function and exercise capacity in patients with metabolic syndrome: A cross-sectional study

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Abstract:

Background

Metabolic syndrome is a pre-diabetes condition that is associated with increased cardiovascular morbidity and mortality. We aimed to explore how exercise capacity, cardiac structure, and function were affected in patients with metabolic syndrome.

Methods

Outpatients with echocardiography and exercise stress test combined with impedance cardiography (ETT + ICGG) results available from Nov 2018 to Oct 2020 were retrospectively enrolled. Echocardiographic, ETT + ICG profiles, and exercise performance were compared between patients with metabolic syndrome and the ones without. Sensitivity analyses were performed excluding patients without established coronary heart disease and further 1:1 paired for age and gender, respectively. Multiple linear regression was used to find out related predictors for maximal metabolic equivalents (METs).

Results

Three hundred and twenty-third patients were included, among whom 97 were diagnosed as metabolic syndrome. Compared to patients without metabolic syndrome, echocardiography showed that patients with metabolic syndrome had a significantly lower E/A ratio ($p < 0.001$). Besides, they have larger left atrium, larger right ventricle, and thicker interventricular septum (all $p < 0.001$), but similar left ventricular ejection fraction ($P = 0.443$). ICG showed that patients with metabolic syndrome had significantly higher stroke volume at rest and maximum ($p < 0.001$), higher left cardiac work index at rest and maximum ($p = 0.005$), higher systemic vascular resistance (SVR) at rest ($p < 0.001$), but similar SVI ($p = 0.888$). During exercise, patients with metabolic syndrome had lower maximal METs ($p < 0.001$), and a higher proportion suffering from ST-segment depression during exercise ($p = 0.009$). Sensitivity analyses yielded similar results. As for the linear regression model, 6 independent variables (systolic blood pressure, BMI, E/A ratio, the height of O wave, the peak value of LCWi, and the baseline of SVR) had statistically significant effects on the maximal METs tested in exercise ($R = 0.525$, $R^2 = 0.246$, $P < 0.001$).

Conclusion:

Patients with metabolic syndrome had significant structural alteration, apparent overburden of left ventricular work index, pre-and afterload, which may be the main cause of impaired exercise tolerance.

Repeated cardiopulmonary performance measurements in young competitive handball players with and without SARS-CoV-2 infection

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Abstract:

Background

The SARS-CoV-2 virus and its long-term consequences in adolescents have a global impact on upcoming medical issues. The aim of this study was to investigate the effects of a SARS-CoV-2 infection on cardiorespiratory parameters in young athletes.

Methods

In a cohort study involving repeated measurements during a six-month period, cardiorespiratory parameters were assessed in infected (SCoV) and non-infected (noSCoV) athletes. We evaluated handball players (17.2 ± 1.0 years) via performance diagnostics and a specific examination after a SARS-CoV-2 infection or without.

Results

We observed no significant differences between the two groups at the first visit. But between the first and second visit, the SCoV group's maximum power output was significantly lower than the noSCoV group's (-48.3 ± 12.5 ; $p \leq 0.01$ vs. -15.0 ± 26.0 W; $p = 0.09$). At the second visit, lung diffusion capacity (DLCO/VA, %predicted) did not differ between groups (111.6 ± 11.5 vs. $116.1 \pm 11.8\%$; $p = 0.45$). HR during comparative stress showed no group differences. The SCoV group's mean oxygen uptake during incremental exercise was lower (Two-way-ANOVA: 1912 vs. 2106 ml; $p \leq 0.01$; mean difference: - 194 ml; 95% CI - 317 to - 71); we also noted a significantly lower stroke volume course during exercise (Two-way-ANOVA: 147.5 vs. 169.5 ml; mean difference: - 22 ml; $p \leq 0.01$; 95% CI - 34.2 to - 9.9). The probability of premature ventricular complexes after a SARS-CoV-2 infection yielded an odds ratio of 1.6 (95% CI 0.24-10.81).

Conclusion:

The physical performance of young athletes infected with SARS-CoV-2 was impaired. This decreased performance is probably due to cardiac and/or peripheral deconditioning. Studies with larger cohorts are needed to make more profound conclusions.

Haemodynamic compensations for exercise tissue oxygenation in early stages of COPD: an integrated cardiorespiratory assessment study

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Abstract:

Background

Cardiovascular comorbidities are increasingly being recognised in early stages of chronic obstructive pulmonary disease (COPD) yet complete cardiorespiratory functional assessments of individuals with mild COPD or presenting with COPD risk factors are lacking. This paper reports on the effectiveness of the cardiocirculatory-limb muscles oxygen delivery and utilisation axis in smokers exhibiting no, or mild to moderate degrees of airflow obstruction using standardised cardiopulmonary exercise testing (CPET).

Methods

Post-bronchodilator spirometry was used to classify participants as 'ever smokers without' (n=88), with 'mild' (n=63) or 'mild-moderate' COPD (n=56). All underwent CPET with continuous concurrent monitoring of oxygen uptake ($\dot{V}O_2$) and of bioimpedance cardiac output (Q_c) enabling computation of arteriovenous differences ($a-vO_2$). Mean values of Q_c and $a-vO_2$ were mapped across set ranges of $\dot{V}O_2$ and Q_c isolines to allow for meaningful group comparisons, at same metabolic and circulatory requirements.

Results

Peak exercise capacity was significantly reduced in the 'mild-moderate COPD' as compared with the two other groups who showed similar pulmonary function and exercise capacity. Self-reported cardiovascular and skeletal muscle comorbidities were not different between groups, yet disease impact and exercise intolerance scores were three times higher in the 'mild-moderate COPD' compared with the other groups. Mapping of exercise Q_c and $a-vO_2$ also showed a leftward shift of values in this group, indicative of a deficit in peripheral O_2 extraction even for submaximal exercise demands. Concurrent with lung hyperinflation, a distinctive blunting of exercise stroke volume expansion was also observed in this group.

Conclusion:

Contrary to the traditional view that cardiovascular complications were the hallmark of advanced disease, this study of early COPD spectrum showed a reduced exercise O_2 delivery and utilisation in individuals meeting spirometry criteria for stage II COPD. These findings reinforce the preventive clinical management approach to preserve peripheral muscle circulatory and oxidative capacities.

Cardiac output and arteriovenous oxygen difference contribute to lower peak oxygen uptake in patients with fibromyalgia

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Abstract:

Background

Patients with fibromyalgia (FM) exhibit low peak oxygen uptake ($\dot{V}O_{2peak}$). We aimed to detect the contribution of cardiac output to $\dot{V}O_{2peak}$ and arteriovenous oxygen difference $\Delta a-vO_2$ to $\dot{V}O_{2peak}$ from rest to peak exercise in patients with FM.

Methods

Thirty-five women with FM, aged 23 to 65 years, and 23 healthy controls performed a step incremental cycle ergometer test until volitional fatigue. Alveolar gas exchange and pulmonary ventilation were measured breath-by-breath and adjusted for fat-free body mass (FFM) where appropriate. $\dot{V}O_{2peak}$ (impedance cardiography) was monitored. $\dot{V}O_{2peak}$ was calculated using Fick's equation. Linear regression slopes for oxygen cost ($\Delta \dot{V}O_2 / \Delta \text{work rate}$) and $\dot{V}O_{2peak}$

see text] to [Formula: see text] O_2 (Δ [Formula: see text]/ Δ [Formula: see text] O_2) were calculated. Normally distributed data were reported as mean \pm SD and non-normal data as median [interquartile range].

Results

[Formula: see text] $\text{O}_{2\text{peak}}$ was lower in FM patients than in controls (22.2 ± 5.1 vs. 31.1 ± 7.9 $\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$, $P < 0.001$; 35.7 ± 7.1 vs. 44.0 ± 8.6 $\text{mL}\cdot\text{min}^{-1}\cdot\text{kg FFM}^{-1}$, $P < 0.001$). [Formula: see text] and $\text{C(a-v)}\text{O}_2$ were similar between groups at submaximal work rates, but peak [Formula: see text] (14.17 [13.34-16.03] vs. 16.06 [15.24-16.99] $\text{L}\cdot\text{min}^{-1}$, $P = 0.005$) and $\text{C(a-v)}\text{O}_2$ (11.6 ± 2.7 vs. 13.3 ± 3.1 $\text{mL O}_2\cdot 100$ mL blood^{-1} , $P = 0.031$) were lower in the FM group. No significant group differences emerged in Δ [Formula: see text] O_2/Δ work rate (11.1 vs. 10.8 $\text{mL}\cdot\text{min}^{-1}\cdot\text{W}^{-1}$, $P = 0.248$) or Δ [Formula: see text]/ Δ [Formula: see text] O_2 (6.58 vs. 5.75 , $P = 0.122$) slopes.

Conclusion:

Both [Formula: see text] and $\text{C(a-v)}\text{O}_2$ contribute to lower [Formula: see text] $\text{O}_{2\text{peak}}$ in FM. The exercise responses were normal and not suggestive of a muscle metabolism pathology.

Cardiorespiratory fitness in women after severe pre-eclampsia

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Abstract:

Aims

To objectively study cardiorespiratory fitness (CRF) and physical activity (PA) and to evaluate limiting factors of exercise intolerance associated with poor CRF after severe pre-eclampsia.

Methods


In this single-centre, cross-sectional study, CRF was measured as peak oxygen uptake (VO₂peak) during a cardiopulmonary exercise test (CPET) on a treadmill in women 7 years after severe pre-eclampsia. Ninety-six patients and 65 controls were eligible to participate. Cardiac output (CO) was measured by impedance cardiography. PA was measured using accelerometers.

Results

In 62 patients and 35 controls (mean age 40 ± 3 years), the VO₂peak (in mL·kg⁻¹·min⁻¹) values were 31.4 ± 7.2 and 39.1 ± 5.4, respectively (p<0.01). In the patients, the CO_{peak} was (9.6 L·min⁻¹), 16% lower compared to controls (p<0.01). Twelve patients (19%) had a cardiac limitation to CPET. Twenty-three (37%) patients and one (3%) control were classed as unfit, with no cardiopulmonary limitations. The patients demonstrated 25% lower PA level (in counts per minute; p<0.01) and 14% more time being sedentary (p<0.01), compared with the controls. Twenty-one patients (34%) compared with four (17%) controls did not meet the World Health Organization's recommendations for PA (p=0.02). Body mass index and PA level accounted for 65% of the variability in VO₂peak.

Conclusion:

Significantly lower CRF and PA levels were found in patients on long-term follow-up after severe pre-eclampsia. CPET identified cardiovascular limitations in one third of patients. One third appeared unfit, with adiposity and lower PA levels. These findings highlight the need for clinical follow-up and exercise interventions after severe pre-eclampsia.

 **Greater exercise tolerance in COPD during acute intermittent compared to continuous shuttle walking protocols: A proof-of-concept study**

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Abstract:

Objectives

Ground-based walking is a simple training modality which would suit pulmonary rehabilitation (PR) settings with limited access to specialist equipment. Patients with COPD are, however, unable to walk uninterruptedly at a relatively fast walking pace to optimise training benefits. We compared an intermittent (IntSW) to a continuous (CSW) shuttle walking protocol. **Methods:** In 14 COPD patients (mean \pm SD. FEV₁: 45 \pm 21% predicted) we measured walking distance, cardiac output (CO), arterial oxygen saturation (SpO₂), and symptoms during (a) an IntSW protocol, consisting of 1-min walking alternating with 1-min rest, and (b) a CSW protocol, both sustained at 85% of predicted VO₂ peak to the limit of tolerance (Tlim). **Results:** Median (IQR) distance was greater ($p = 0.001$) during the IntSW protocol (735 (375-1107) m) than the CSW protocol (190 (117-360) m). At iso-distance (distance at Tlim during CSW) the IntSW compared to the CSW protocol was associated with lower CO (8.6 \pm 2.6 vs 10.3 \pm 3.7 L/min; $p = 0.013$), greater SpO₂ (92 \pm 6% versus 90 \pm 7%; $p = 0.002$), and lower symptoms of dyspnoea (2.8 \pm 1.3 vs 4.9 \pm 1.4; $p = 0.001$) and leg discomfort (2.3 \pm 1.7 vs 4.2 \pm 2.2; $p = 0.001$). At Tlim symptoms of dyspnoea and leg discomfort did not differ between the IntSW (4.4 \pm 1.9 and 3.6 \pm 2.1, respectively) and the CSW protocol. **Conclusions:** The IntSW protocol may provide important clinical benefits during exercise training in the PR settings because it allows greater work outputs compared to the CSW.

2.3 INTENSIVE CARE

Advances in Non-invasive Cardiac Output Monitoring

Annals of Cardiac Anaesthesia 2002 ;5 :141-148

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Abstract:

In EIC (Electrical Impedance Cardiographs) devices using Z_0 baseline impedance, large amounts of thoracic fluid may interfere with the impedance signal, making haemodynamic data unattainable or unreliable.⁵²⁻⁵⁴ Severe pulmonary oedema may decrease the signal-to-noise ratio, damp the dZ/dt waveform, and inhibit haemodynamic data acquisition.

The latest methods of EIC (PhysioFlow®) are baseline impedance independent and use more advanced forms of impedance waveform morphology analysis.⁴³⁻⁴⁶ New noninvasive impedance monitors are able to provide continuous trend monitoring of HR and SV giving derived CO and index parameters without the need for baseline impedance measurement. They use stroke waveform morphology analysis to determine SV and then calculate all the derived parameters.

Preload assessment is essential in any patient who may be at a risk of hypoperfusion. Assessment and management of preload catheter can be a challenge for clinicians. The insertion of a CVP catheter may help decision making but isolated measurements of CVP are not very informative. The trend of the CVP and in particular its response to a fluid challenge is far more valuable in planning the therapy. In PA catheterisation, the PAOP indirectly measures LV end-diastolic pressure and is related to LV end-diastolic volume, or preload.

However, many factors affect the extrapolation of the PAOP to LV preload, such as reduced L V compliance, pulmonary hypertension or mechanical ventilation.

A simple manoeuvre using EIC to assess intravascular volume is to give a fluid challenge using the patient's own circulating volume as the fluid bolus. By elevating the legs or placing the patient in the "head down" position, fluid moves from the lower extremities, increasing venous return. In a normal heart, the SV will increase. Patients who are hypovolaemic may show a significant increase in SV and would benefit from volume administration.

Patients with LV dysfunction or fluid overload may have minimal or no change in SV in response to a physiologic fluid bolus. These individuals do not have adequate cardiac reserve and cannot tolerate additional fluid. These patients may require treatment with inotropes or agents that reduce preload and afterload. Use of EIC to assess preload with a fluid affords valuable information regarding the patient's ability to tolerate additional fluids. The latest methods of EI use advanced waveform morphology analysis to determine a filling index (FI) for the heart. Where CVP measurements are available the information can be used to supplement the FI data. The trend of the FI is likely to be of more value than isolated measurements particularly for monitoring response to interventions or planning therapy.

Conclusion:

Recent technological advances have allowed the development of noninvasive methods of measuring CO with continuous on-line measurement and trending of SV and HR. Derived parameters such as SVI, CI, SVR, LCWI and EF can also be shown and recorded continuously. The new noninvasive technology is safe, reliable and relatively inexpensive and is increasingly being used in clinical practice and research. Completely noninvasive CO monitoring by modern EIC technology is suitable for continuous on-line and trend monitoring of SV, HR and derived parameters; and echocardiography, mainly TEE in the ICU, should be used for structural and functional evaluation of the heart as well as confirmation of SV and EF.

Hemodynamic Responses of a Spontaneous Breathing Trial Monitoring by an Impedance Cardiograph

Accepted by the American Thoracic Society, May 17-22, 2002

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Introduction:

Left ventricular insufficiency is a common cause of ventilator weaning failure. We evaluated the hemodynamic parameters during a T-piece trial.

Methods

We conducted a prospective, open study in an intensive care unit. Heart rate (Hr), stroke volume (SV) and cardiac index (Ci) measurements were performed by PhysioFlow™ in ventilated adults ready for weaning. Patients with a SaO₂>90% while breathing with a FiO₂ of 40% or less, a PEEP<5cmH₂O, a hemoglobin level above 8g/dl and without electrolyte disorders were included. Patients with inotropic drugs, altered mental status or pregnant women were excluded. We assessed the cardiac function during mechanical ventilation (MV) and during a T-piece trial of 30 minutes (SV). If a patient had any signs of poor tolerance during the trial the mechanical ventilation was reinstated. Comparison of continuous variables was done with Student's T-test. A p value under 0.05 was considered as significant. Results are expressed as mean +/- standard error.

Results:

7 patients were included and 10 trials were executed. The rate of success was 70%. Three patients failed the trial (two met the criteria of a respiratory distress (respiratory frequency greater than 30/min) and one altered his Glasgow score. For the patients with a respiratory distress the Hr (108 +/- 11 bpm vs 108 +/- 15 bpm), Sv (73 +/- 10 ml vs 89 +/- 16 ml) and Ci (4.5 +/- 1.5 l/min.m² vs 5.6 +/- 2.1 l/min.m²) were unchanged during SV compared with MV. For the other patients Hr increased from 85 +/- 21 bpm to 90 +/- 19 bpm (p<0.05), Sv dropped from 80 +/- 10 ml to 72 +/- 14 ml (p<0.05) and Ci was unchanged with 3.5 +/- 0.7 vs 3.3 +/- 0.6 l/min.m².

Conclusion:

We showed that the hemodynamic consequences of a spontaneous breathing trial was a decrease of Sv for the patients without signs of respiratory distress. Thoracic bioimpedance could be a good tool for the hemodynamic assessment during ventilator weaning.

Non-invasive Haemodynamic Monitoring to Predict Outcome and Guide Therapy in Acute Critical Illness

International Journal of Intensive Care, Spring 2007

Authors:

- William Shoemaker, MD.

Abstract-aim:

To compare invasive pulmonary artery catheter (PAC) data with continuous noninvasive haemodynamic monitoring using a program to predict outcome and guide therapy beginning shortly after emergency department (ED) admission in a university-run inner city public hospital.

Methods:

We compared PAC data with noninvasive monitored: cardiac function by cardiac output (CI), mean arterial blood pressure (MAP), and heart rate (HR); respiratory function by arterial oxygen saturation (SapO₂); tissue perfusion/oxygenation by transcutaneous tensions of CO₂ and O₂ indexed to FIO₂. A search and display program calculated survival probabilities (SP) and a decision support program predicted effects of various therapies

Results:

Survivors' MAP, CI, SapO₂, and PtcO₂/FIO₂, and SP were significantly higher ($p < 0.05$) than nonsurvivors' values in each diagnostic category.

Conclusion:

Compared with the PAC, noninvasive monitoring is safer, simpler, easier, quicker, cheaper, reasonably accurate, and available anywhere in the hospital or prehospital areas. Increased CI and tissue oxygenation determined by the distribution of metarteriolar flow are underlying haemodynamic patterns associated with survival.

Thoracic electrical bioimpedance: a tool to determine cardiac versus non-cardiac causes of acute dyspnoea in the emergency department

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Objectives:

To determine whether cardiohaemodynamic parameters, using non-invasive thoracic electrical bioimpedance (TEB), can differentiate between cardiac and non-cardiac causes of acute breathlessness in adult emergency department (ED) patients.

Methods:

A prospective cohort study of adult patients who presented with acute breathlessness to the ED of a large urban teaching hospital. Study patients had their cardiohaemodynamic parameters measured, using a TEB device. The patient's hospital discharge diagnosis was used as the definitive diagnosis to determine whether the underlying cause of acute dyspnoea was cardiac or non-cardiac related. The definitive diagnosis was compared with the TEB data and the ED physician's diagnosis

Results:

52 patients were recruited into the study, of whom 51 had complete TEB data and were included in the analysis. There were statistically significant differences in cardiac output (6.2 vs 7.9, $p < 0.001$), cardiac index (CI; 3.1 vs 4.4, $p < 0.001$), systemic vascular resistance (1227 vs 933, $p = 0.002$) and systemic vascular resistance index (2403 vs 1681, $p < 0.001$) between the cardiac and non-cardiac cohort. CI was found to be an excellent discriminator (receiver operating characteristics area under the curve 0.906). The optimal diagnostic criterion for CI to distinguish between cardiac and non-cardiac dyspnoea was 3.2 l/min per square metre or less (positive likelihood ratio 7.9; negative likelihood ratio 0.14).

Conclusion:

This study demonstrated that non-invasive TEB cardiohaemodynamic parameters can differentiate between cardiac and non-cardiac-related causes of dyspnoea in ED patients presenting with acute breathlessness. A large-scale trial is required to determine if TEB-derived cardiohaemodynamic information can aid ED clinicians in their early clinical decision-making and improve the care and outcome of patients with dyspnoea.

The utility of impedance cardiography in hemodynamic monitoring of patients with sepsis

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Authors:

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|---|--|

Abstract:

Background:

Commonly used biochemical indicators and hemodynamic and physiologic parameters of sepsis vary with regard to their sensitivity and specificity to the diagnosis. The aim of this preliminary study was to evaluate non-invasive impedance cardiography as a monitoring tool of the hemodynamic status of patients with sepsis throughout their initial volume resuscitation to explore the possibility of identifying additional measurements to be used in the future treatment of sepsis.

Methods:

Methods:

Nine patients who presented to the emergency room and received a surgical consultation during a 3-month period in 2016, meeting the clinical criteria of sepsis defined by systemic inflammatory response syndrome in the 2012 Surviving Sepsis Campaign Guidelines, were included in this study. We applied cardiac impedance monitors to each patient's anterior chest and neck and obtained baseline recordings. Measurements were taken at activation of the sepsis alert and 1 hour after fluid resuscitation with 2 L of intravenous crystalloid solution.

Results:

Nine patients met the inclusion criteria. The mean age was 60±17 years and two were female; eight were febrile, five were hypotensive, four were tachycardic, seven were treated for infection, and six had positive blood cultures. Hemodynamic parameters at presentation and 1 hour after fluid resuscitation were heart rate (beats per minute) (97±13 and 93±18; p=0.23), mean arterial pressure (mm Hg) (81±13 and 85±14; p=0.55), systemic vascular resistance (dyne-s/cm⁻⁵) (861±162 and 1087±272; p=0.04), afterload measured as systemic vascular resistance index (dyne-s/cm⁻⁵/m²) (1813±278 and 2283±497; p=0.04), and left cardiac work index (kg*m/m²) (3.6±1.4 and 3.3±1.3; p=0.69).

Discussion:

Through measuring a patient's systemic vascular resistance and systemic vascular resistance index (afterload), statistical significance is achieved after intervention with a 2 L crystalloid bolus. This suggests that, along with clinical presentation and biochemical markers, impedance cardiography may show utility in providing supporting hemodynamic data to trend resuscitative efforts in patients with sepsis.

2.4 ANESTHESIA

Decreased Cardiovascular Hemodynamics as Possible Mechanisms of Hypotension during Cesarean Delivery under Spinal Anesthesia: Role of Thoracic Impedance Cardiography

Society of Obstetrics Anesthesiology and Perinatology (SOAP), March 2008

Authors:

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Abstract-Background:

Maintaining normal blood pressure in pregnant patients is important for normal placental blood flow and to avoid undesirable symptomatic adverse effects such as nausea and vomiting. Despite our practice to maintain normal baseline blood pressure with phenylephrine, an α 1-agonist, hypotension remains the most common complication during Cesarean delivery under spinal anesthesia. A decrease in cardiac output as a result of decreased preload, and a decrease in systemic vascular resistance from spinal-induced sympathetic blockade are two mechanisms postulated to be responsible for the hypotension in this patient population. Other drugs used intra-operatively, such as oxytocin, may further compromise patient hemodynamics. Normal cardiovascular functions, including cardiac output, stroke volume, heart rate, and systemic vascular resistance, are known to maintain blood pressure. We propose that a continuous monitoring of these cardiovascular functions (ie. hemodynamics) may provide insights into the mechanism(s) of hypotension during a Cesarean delivery under spinal anesthesia.

Objectives:

In the present pilot study, we aim to (1) measure several cardiovascular hemodynamics continuously during elective Cesarean delivery under spinal anesthesia using noninvasive thoracic impedance cardiography, and (2) to determine whether these cardiovascular hemodynamics may be responsible for changes in bloodpressure.

Methods:

With Institutional Research Ethics Board approval, and patients' informed consent, 10 ASA I and II patients undergoing elective Cesarean delivery under spinal anesthesia were observed in a prospective, nonrandomized, non-blinded observational cross-sectional pilot study. The Physioflow Impedance Device (VasoCom Inc, Philadelphia) was used to measure the cardiac index (CI), systemic vascular resistance (SVRI), stroke volume (SV), systolic blood pressure (SBP) and heart rate (HR). Baseline hemodynamics were measured before the spinal anesthesia. All patients were in a left lateral position with a wedge and standard anesthesia monitors were applied. Spinal anesthesia was then performed with 12.5 mg of 0.75%

hyperbaric bupivacaine, 10 mcg fentanyl and 100 mcg morphine via a 27G Whittacre needle. Thereafter, hemodynamics were monitored every minute until completion of the surgical procedure. All patients were preloaded with 1000 ml of Lactated Ringers' solution prior to the insertion of the spinal anesthesia. Phenylephrine at doses of 100-200 mcg bolus was the preferred treatment of hypotension with the aim to preserve systolic blood pressure at 100% of baseline. Repeated measures analysis of variance (ANOVA) was used to compare any differences from baseline controls, with p value < 0.05 to be statistically significant.

Results:

We were successful in measuring continuously several cardiovascular functions in all 10 patients until the completion of the Cesarean delivery. We observed the greatest change of the cardiovascular hemodynamics before and after delivery. Table 1 showed that the SBP before (98.3 • } 7.0) and after (98.3 • } 5.7) were significantly decreased by 25% when compared to baseline control (133 • } 5.6). In addition, all measured cardiovascular functions (CI, HR, SV, SVRI) were also significantly decreased before and after delivery.

Conclusion:

Despite a preventive approach using phenylephrine to maintain baseline blood pressure, significant hypotension still occurs during Cesarean delivery under spinal anesthesia. Our results suggest that significant decrease in several cardiovascular functions (CI, HR, SV, and SVRI) may be responsible for the occurrence of hypotension. In addition, thoracic impedance cardiography with the Physioflow Impedance device provides a reliable noninvasive monitoring of the cardiovascular hemodynamics. Thus, continuous monitoring of cardiovascular functions with noninvasive impedance may provide insights into the mechanisms of hypotension. This may lead to preemptive treatments before significant hypotension occurs and to avoid undesirable symptomatic effects. A larger study is further required to confirm these preliminary findings.

Table 1. Cardiovascular Hemodynamics Before and After Delivery^a

Hemodynamics Parameters ^b	Baseline	Delivery	
	Control	Before ^c	After ^c
SBP	133 ± 5.6	98.3 ± 7.04	98.3 ± 5.7
CI	4.6 ± 0.32	2.9 ± 0.16	3.5 ± 0.31
HR	93.3 ± 3.0	63.1 ± 1.6	72.4 ± 3.6
SV	94.3 ± 5.48	79.7 ± 4.5	83.4 ± 5.7
SVRI	1823.2 ± 206.7	1336.5 ± 165.5	1224.2 ± 171.5

^aAll data are presented as mean ± S.E of n = 10 patients.

^bSBP: systolic blood pressure (mmHg), CI: cardiac index (L/min/m²), HR: heart rate (bpm), SV: stroke volume (ml/beat), SVRI: systemic vascular resistance index (dyne / s/cm⁵/m²).

^cAll results before and after delivery were significant p < 0.05, when compared to control baseline.

References:

Tihtonen, K et al. BJOG 2006; 113, 657

Maternal haemodynamics at elective caesarean section: a randomised comparison of oxytocin 5-unit bolus and placebo infusion with oxytocin 5-unit bolus and 30-unit infusion

International journal of Obstetric Anesthesia, Volume 19, Issue 2, Pages 155-160 (April 2010)

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Background:

Rapid intravenous injection of oxytocin is associated with marked hypotension secondary to decreased venous return. Reductions in dose and rate of bolus administration have reduced the incidence of cardiovascular side effects, but no study has yet investigated cardiovascular stability when oxytocin is infused for several hours after delivery. This study compared maternal haemodynamics during a 4-h 30-unit oxytocin infusion and during a placebo infusion following caesarean section.

Keywords:

- Maternal haemodynamics*
- Caesarean section*
- Oxytocin*
- Bioimpedance*

Methods:

Women booked for elective caesarean section were randomised to receive either oxytocin 5-unit bolus and placebo infusion or oxytocin 5-unit bolus and oxytocin 30-unit infusion. Before, during and for 4 h after surgery electrocardiogram, oxygen saturation, systolic and diastolic pressure and heart rate were monitored non-invasively and cardiac index (CI), left ventricular work index (LVWi) and systemic vascular resistance index (SVRi) by thoracic bioimpedance.

Results:

A total of 74 women agreed to haemodynamic measurements. Heart rate, systolic and diastolic pressure, CI, LCWi and SVRi all fell following the onset of spinal anaesthesia, and, with the exception of SVRi, continued to decrease throughout surgery. After delivery of the baby, slow injection of oxytocin 5 units was associated with a temporary rise in CI, LCWi and heart rate, a decrease in SVRi and no change in systolic or diastolic pressure. Thereafter, haemodynamic measures returned to normal over 60 min with no adverse effects apparent from the additional oxytocin infusion.

Conclusion:

An additional oxytocin infusion at elective caesarean section did not adversely affect maternal haemodynamics either during or after surgery.

IMPEDANCE CONSULTATION PREOPERATOIRE - SFAR 2006

Introduction:

Les évènements cardiovasculaires indésirables péri opératoires (ECVI) sont associés à une morbidité accrue à long terme (Anesthesiology 1996, 84 : 772-81). Le but de cette étude était d'identifier parmi les paramètres de cardio-impédancemétrie mesurés en préopératoire les facteurs prédictifs de survenue d'ECVI.

Matériel & Méthodes :

Après avis d'un comité d'éthique et recueil d'un consentement éclairé, une mesure des paramètres de cardio-impédancemétrie (Physioflow®) a été réalisée en préopératoire chez 67 patients devant subir une anesthésie générale pour chirurgie abdominale ou vasculaire entre octobre et décembre 2005. Pendant l'intervention et pour chaque patient inclus, ont été rapportées par un médecin ne connaissant pas les paramètres d'impédance mesurés en préopératoire, la survenue ou non d'un ECVI (hypotension, hypertension, bradycardie, tachycardie, modification ST). La fréquence des ECVI a été notée et des comparaisons ont ensuite été effectuées entre l'ECVI le plus fréquent et les différents paramètres mesurés en préopératoire. Une ANOVA ou un test de Kruskal-Wallis ont été utilisés selon l'égalité de variance ou non.

Résultats :

Les caractéristiques de l'échantillon étaient : âge moyen 65,3 ans, sex ratio M/F 2,5, score de Goldman 10 points, coronariens : 28 %, ASA ≥ 3 : 13 %. Une hypotension a été notée chez 48 % des patients, une HTA (10 %), une bradycardie (12 %). Une association significative a été notée entre la survenue d'une hypotension et les paramètres suivants : Fc (p=0,02), VES (p<0,05), RPD (indice de remplissage proto diastolique (p=0,014). La survenue d'une hypotension augmentait avec l'âge (p=0,05), et l'ICT (indice de contractilité) (NS : p=0,056). Il n'existait pas d'association significative entre l'hypotension et les paramètres suivants : index cardiaque, PAS, résistances indexées, TEV, IFT (eau intra thoracique).

Discussion:

Bien qu'une conférence internationale propose un algorithme décisionnel sur le risque cardiovasculaire péri opératoire (J Am Coll Cardiol 2002, 39 : 542-53), l'appréciation de ce dernier reste difficile à apprécier, consommateur de temps et parfois de moyens d'investigation agressifs. La cardio-impédancemétrie est une technique de mesure non invasive du débit cardiaque facile à effectuer en préopératoire. Les renseignements fournis et en particulier les indices de remplissage pourraient être une aide à la décision d'investigations complémentaires pour les cas de risque intermédiaire.

Non-Invasive Measurement of Cardiac Contractility, Stroke Volume and Cardiac Output

ASA, October 17-21, 2009, New Orleans, LA

Authors:

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•Hirsh, M.D.,	•Ph.D.	

Introduction:

The Electrical-Mechanical Interval is the time between a specific event on ECG, and its corresponding mechanical event in a peripheral artery. Let E be the instant when the ECG voltage, ECG(t) accelerates maximally upward. E, then, is the time of ECG''(t)max. Let M be the instant when the arterial pressure, ABP(t) accelerates maximally upward. M, then, is the time of ABP''(t)max. ECG''(t) and ABP''(t) are second time derivatives. The time from E to M, (E-M), is the 'Electrical Mechanical Interval.' This interval is related to the ratio of the Stroke Volume SV and Left Ventricular Systolic Ejection Interval EI by

$$- \ln(SV/EI) = A + B * (1/(E-M)) \text{ eq. 1}$$

where A and B are empirical constants.

We have previously shown that $\ln(SV/EI)$ is linearly proportional to $\ln(dP/dt_{max})$ where P is Left Ventricular Pressure. Hence,

$$- \ln(dP/dt_{max}) = C + D * (1/(E-M)) \text{ eq. 2}$$

where C and D are empirical constants. So $1/(E-M)$ is also an index of dP/dt_{max} , or myocardial contractility. The purpose of this study was to demonstrate feasibility of a new method for the non-invasive measurement of myocardial contractility, stroke volume, and cardiac output.

Methods:

After IRB approval a Physioflow® trans-thoracic impedance monitor (Manatec Inc.) was used to measure SV and EI, in 6 human volunteers. Physioflow® provides an ECG lead II output. A T-line® (Tensys Medical Inc.) was applied over the radial artery. This provided non-invasive ABP(t). (E-M) intervals for each heartbeat were calculated using second derivative maxima of ECG and ABP. Subjects were exercised on a stepping machine (Nautilus Inc.) to 80% of maximal heart rate. Data were collected as the heart rate declined from maximum to baseline.

Results:

Corresponding 30-second epochs of $\ln(SV/EI)$ and $1/(E-M)$ data were averaged. We plotted corresponding $\ln(SV/EI)$ against $1/(E-M)$. A calibration curve is shown in fig. 1. The scaling parameters A and B in eq. 1 derived from linear regression of the plotted data were shown to be reproducible with repeated exercise sessions.[figure1]

Conclusion:

Because the T-line and ECG are non-invasive, it is possible, using a device such as Physioflow, to calibrate eq. 1 and determine SV/EI from $1/(E-M)$. Since EI can be measured non-invasively using Doppler, or impedance measurements, we can determine beat-by-beat SV, and Stroke Volume Variability (SVV). SVV can be used to assess preload in patients having positive-pressure ventilation. Cardiac Output is easily obtained from $SV/EI * EI/T$ where T is the period of the cardiac cycle. These results demonstrate feasibility of a novel non-invasive cardiac monitoring technology

Natural Log of Average Left Ventricular Systolic Volume Outflow Rate

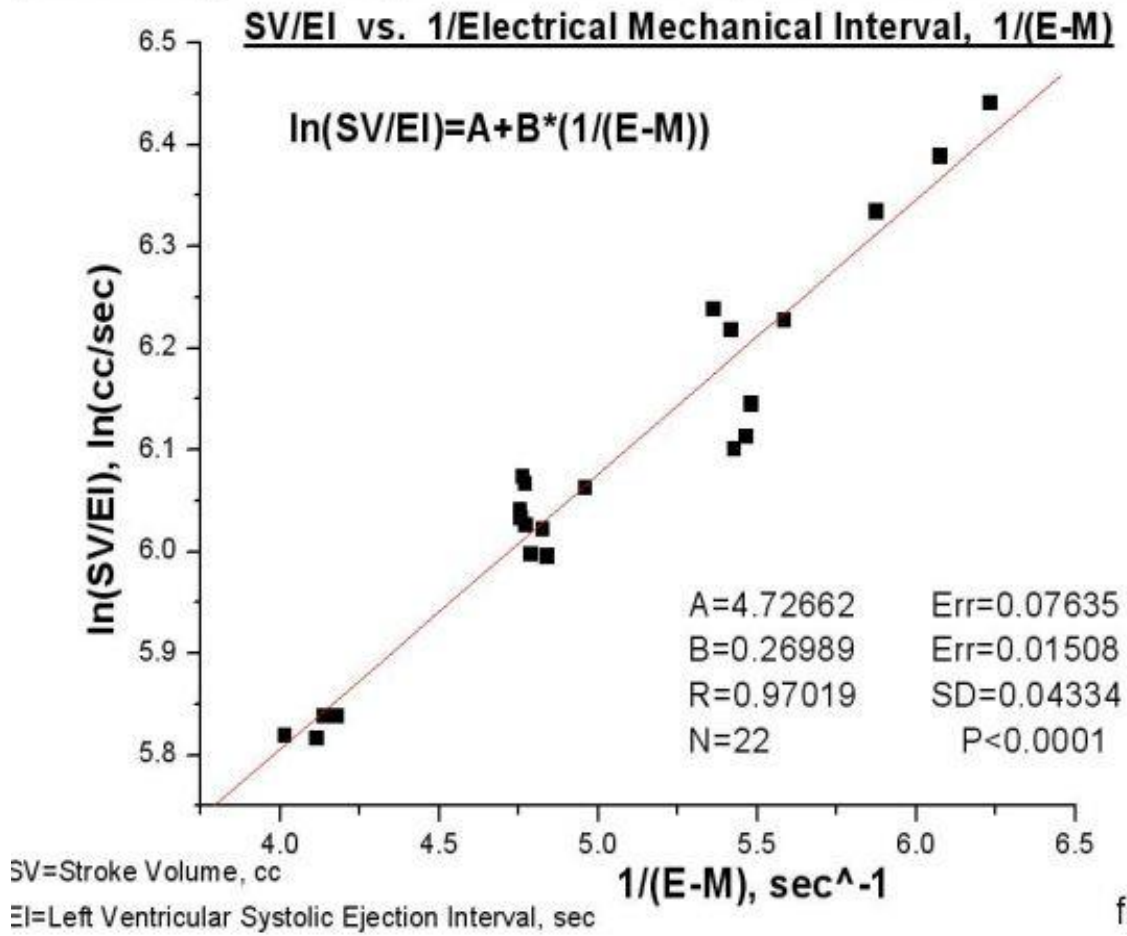


fig. 1

Continuous Cardiac Output Monitoring During Major Intra-Abdominal Surgery: Physioflow Signal-Morphology Impedance Cardiography vs. FloTrac/Vigileo vs. Central Venous Oxygen Saturation

Authors:

• Irwin Gratz, D.O., Edward Deal, D.O., Francis Spitz, M.D., Elaine Allen, Ph.D., Erin Pukenas, M.D.

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Abstract:

Hemodynamic monitoring and optimizing cardiac output during surgery improves patient outcome [1]. The clinical standard for cardiac output (CO) determination has been thermodilution which requires a pulmonary artery catheter, an invasive procedure with the possibility of numerous complications. Central venous oxygen saturation (ScvO₂) has been used as a surrogate for CO monitoring but requires the insertion of a central venous catheter. The risks associated with such catheters have led to advent of the less invasive FloTrac/Vigileo system which estimates CO based on pulse contour analysis from an arterial line. Several new totally non-invasive systems claim ability to accurately display continuous cardiac output values. One such system is the PhysioFlow which determines CO and other parameters based on signal morphology impedance cardiography. The instant changes in thoracic blood volume (a reflection of the stroke volume) cause changes in impedance between the 4 electrodes placed on the neck and thorax. On the basis of these changes in impedance, the computer calculates cardiac output.

The aim of our study was to compare the CO values obtained using Vigileo/FloTrac system with those obtained with the PhysioFlow and correlate both to ScvO₂ measurements during major intra-abdominal surgery.

Methods:

With IRB approval patients scheduled for major intra-abdominal surgery had simultaneous CO measured using pulse contour analysis by the Vigileo system and PhysioFlow. In addition to central BP, ScvO₂ was also monitored during the procedure. Data were combined from the PhysioFlow, Vigileo, ScvO₂ and arterial line on a minute by minute basis. Pearson correlation coefficients were calculated between systolic BP and CO by PhysioFlow and Vigileo as well as ScvO₂. During periods of electro-cautery, data from the PhysioFlow was not analyzed secondary to interference. Patients were managed aggressively with vasopressors and fluid administration.

Results:

CO data from the two devices were plotted over time (see Figure 1). Plots of systolic BP and ScvO₂ were overlaid with the same times in the X-axis (see Figure 1). There was virtually no correlation between the Vigileo and PhysioFlow systems (N=239, r² = -0.002, p=0.981). The Vigileo CO values trended well with systolic BP (N=191, r² = 0.730, p<0.001) compared to the PhysioFlow (N=178, r² = 0.081, p=0.280). The PhysioFlow cardiac output values trended better with ScvO₂ (N=224, r² = 0.726, p<0.001) compared to the Vigileo (N=252, r² = 0.314, p<0.001).

Conclusion:

Cardiac output values obtained with the Vigileo with the 3rd generation software is more variable and appears to mirror changes seen in systolic BP. In contrast, CO values obtained by PhysioFlow are less variable, and trends better with ScvO₂. The 3rd-generation FloTrac/Vigileo device appears unreliable for tracking changes in CO during major abdominal surgery.

3 RESEARCH

3.1 PHYSIOLOGY

Exercise Capacity and Idebenone Intervention in Children and Adolescents with Friedreich Ataxia

Presented in part to the American College of Sports Medicine, Seattle, WA, May 28, 2009.

Authors:

•Bart E. Drinkard, MSPT, Randall E. Keyser, PhD, Scott M. Paul, MD, Ross Arena, PhD, PT, Jonathan F. Plehn, MD, Jack A. Yanovski, MD, PhD, Nicholas A. Di Prospero, MD, PhD

Abstract:

Drinkard BE, Keyser RE, Paul SM, Arena R, Plehn JF, Yanovski JA, Di Prospero NA. Exercise capacity and idebenone intervention in children and adolescents with Friedreich ataxia.

Keywords:

- Exercise,
- Friedreich Ataxia,
- Idebenone [substance name],
- Rehabilitation

Objective:

To determine the exercise capacity of children and adolescents with Friedreich's Ataxia (FA) and to evaluate the effects of 6 months of idebenone treatment on exercise capacity.

Design:

Exploratory endpoint in a randomized double-blind, placebo-controlled, phase II clinical trial designed to investigate the effects of idebenone on a biomarker of oxidative stress.

Setting:

Exercise physiology laboratory in a single clinical research center.

Participants:

Ambulatory subjects (N=48; age range, 9–17y) with genetically confirmed FA.

Intervention:

Idebenone administered orally 3 times a day for a total daily dose of approximately 5, 15, and 45mg/kg or matching placebo for 6 months.

Main Outcome Measures

Peak oxygen consumption per unit time (peak VO₂) and peak work rate (WR) were measured during incremental exercise testing at baseline and after treatment. Echocardiography and neurologic assessments were also completed before and after treatment.

Results

Baseline mean peak VO₂ ± SD was 746±246mL/min (16.2±5.8mL/kg/min), and WR was 40±23W for all subjects. Peak VO₂ and WR were correlated with short guanine-adenine-adenine allele length and neurologic function. Relative left ventricular wall thickness was increased but left ventricular ejection fraction was normal in most subjects; there was no relationship between any exercise and echocardiographic measures. There were no significant changes in mean peak VO₂ or WR after idebenone treatment at any dose level relative to placebo.

Conclusion:

Exercise capacity in children and adolescents with FA was significantly impaired. The basis for the impairment appears to be multifactorial and correlated to the degree of neurologic impairment. Although idebenone has previously been shown potentially to improve features of FA, idebenone treatment did not increase exercise capacity relative to placebo.

Post Immersion Delayed Vasomotor Adjustments to Dehydration?

European Underwater and Baromedical Society News letter, 2000

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Abstract :

While hemodynamic and fluid balance changes have been fairly well studied during immersion, the corresponding changes post-immersion are almost totally ignored. Ten trained divers (33 +/- 5 years) underwent two similar 6 hours hyperbaric hyperoxic exposures with intermittent cycling exercise, one day in dry ambience (DY) and three weeks later immersed up to the neck (IM). They had no food or beverage intake during either session. Whole body weight was assessed and venous blood samples were taken before and 15 min after each exposure session. Venous occlusion of the thighs was performed at 30, 40, 50, 60 mmHg during segmental weighing before and after each session. Segmental weighing performed with our original device allows measuring rapid changes in weight of lower limbs, abdomen-pelvis, and thorax related fluid shifts in the body. The data collected during these manoeuvres provided information about venous tone in the legs through distensibility and compliance assessments, and about arterial flow in the leg and splanchnic vessels. During segmental weighing, stroke volume (SV), cardiac output (CO) and heart rate (HR) were recorded using a Physioflow® impedance cardiography device. As described in a companion paper, on average, the final weight losses were similar in the two ambiances (2.2 kg in DY vs 2.3 kg in IM), whereas plasma contraction was greater in the IM session (-14.7% vs -9.7% in DY; $p < 0.001$) as evidenced by changes in hematocrite, blood haemoglobin and plasma proteins. Plasma levels of noradrenaline (NA), arginine-vasopressin (APV) were increased 20 min after each session versus pre-exposure, a change 3 times higher after IM than DY ($p > 0.01$). Inversely, atrial and brain natriuretic peptides (ANP and BNP) as well as cyclic guanosine monophosphate (cGMP) remained increased 20 min post IM ($p < 0.05$). Heart rate was decreased after DY (-7 min⁻¹; $p < 0.05$) but slightly increased after IM (+3 min⁻¹; $p < 0.05$). Conversely, stroke volume was more reduced after IM than DY (-9 mL vs -4 mL respectively; $p < 0.05$). Venous compliance and distensibility of the legs were reduced after DY ($p < 0.05$) but preserved after IM. Indexes of arterial flow in both the leg and splanchnic vascular bed were reduced following DY. Thus on the other hand, after DY the increase in plasma vasoconstrictive mediators (NA, APV) likely supported the increased venous and arterial vasomotor tone required to preserve cardiac output and blood pressure, in turn slightly lowering heart rate through baroreflex activation. On the other hand, the paradoxical coexistence of markedly increased levels of NA and APV 30 min post IM together with unchanged vasomotor tone 1) was consistent with the decreased SV and CO but slightly increased HR; 2) was likely explained by the persistence of high level of natriuretic peptides within the first hour post-immersion.

Cardiovascular and Oxygen Uptake Kinetics during Sequential Heavy Cycling Exercises

Accepted by Canadian Journal of Applied Physiology, May 27, 2002

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Abstract :

The purpose of the present study was to assess the relationship between the rapidity of increased oxygen uptake (VO₂) and increased cardiac output (CO) during heavy exercise. Six subjects performed repeated bouts on a cycle ergometer above the ventilatory threshold (~80% of peak VO₂) separated by 10-min recovery cycling at 35% peak VO₂. VO₂ was determined breath-by-breath and CO was determined continuously by impedance cardiography (PhysioFlow, Paris, France). CO and VO₂ values were significantly higher during the 2-min period preceding the second bout. The overall responses for VO₂ and CO were significantly related, and were faster during the second bout. Prior heavy exercise resulted in a significant increase in the amplitude of the fast component of VO₂, with no change in the time constant, and a decrease in the slow component. Under these circumstances, the amplitude of the fast component was more sensitive to prior heavy exercise than was the associated time constant.

Effect of Exercise Intensity on Relationship between VO₂max and Cardiac Output

Med. Sci. Sports Exerc., Vol. 36, No. 8, pp. 000–000, 2004.

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Abstract:

Effect of Exercise Intensity on Relationship between VO₂max and Cardiac Output.

Purpose:

The purpose of this study was to determine whether the maximal oxygen uptake (VO_{2max}) is attained with the same central and peripheral factors according to the exercise intensity.

Keywords:

- Stroke volume
- Arterial-venous difference
- Cycling
- Hypoxemia

Methods:

Nine well-trained males performed an incremental exercise test on a cycle ergometer to determine the maximal power associated with VO_{2max} (pVO_{2max}) and maximal cardiac output (Q_{max}). Two days later, they performed two continuous cycling exercises at 100% (tlimΔ100 = 5 min 12 s ± 2 min 25 s) and at an intermediate work rate between the lactate threshold and pVO_{2max} (tlimΔ50 = 12 min 6 s ± 3 min 5 s). Heart rate and stroke volume (SV) were measured (by impedance) continuously during all tests. Cardiac output (Q) and arterial-venous O₂ difference (a-vO₂ diff) were calculated using standard equations.

Results:

Repeated measures ANOVA indicated that: 1) maximal heart rate, VE, blood lactate, and VO₂ (VO_{2max}) were not different between the three exercises but Q was lower in tlimΔ50 than in the incremental test (24.4 ± 3.6 L·min⁻¹ vs 28.4 ± 4.1 L·min⁻¹; *P* < 0.05) due to a lower SV (143 ± 27 mL·beat⁻¹ vs 179 ± 34 mL·beat⁻¹; *P* < 0.05), and 2) maximal values of a-vO₂ diff were not significantly different between all the exercise protocols but reduced later in tlimΔ50 compared with tlim100 (6 min 58 s ± 4 min 29 s vs 3 min 6 s ± 1 min 3 s, *P* = 0.05). This reduction in a-vO₂ diff was correlated with the arterial oxygen desaturation (SaO₂ = -15.3 ± 3.9%) in tlimΔ50 (*r* = -0.74, *P* = 0.05).

Conclusion:

VO_{2max} was not attained with the same central and peripheral factors in exhaustive exercises, and tlimΔ50 did not elicit the maximal Q. This might be taken into account if the training aim is to enhance the central factors of VO_{2max} using exercise intensities eliciting VO_{2max} but not necessarily Q_{max}.

Cardiac Output and Oxygen Release during very High-intensity Exercise Performed until Exhaustion

European Journal of Applied Physiology- Springer – Verlag 2004, DOI10.1007/s00421-004-1149-7

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Abstract:

Our objectives were firstly, to study the patterns of the cardiac output (Q) and the arteriovenous oxygen difference [(a-v)O₂] responses to oxygen uptake (VO₂) during constant workload exercise (CWE) performed above the respiratory compensation point (RCP), and secondly, to establish the relationships between their kinetics and the time to exhaustion. Nine subjects performed two tests: a maximal incremental exercise test (IET) to determine the maximal VO₂ (VO₂peak), and a CWE test to exhaustion, performed at pΔ50 (intermediate power between RCP and VO₂ peak). During CWE, VO₂ was measured breath-by-breath? Q was measured beat-by-beat with an impedance device, and blood lactate (LA) was sampled each minute. To calculate (a-v)O₂, the values of VO₂ and Q were synchronised over 10 intervals. A fitting method was used to describe the VO₂, Q and (a-v)O₂ kinetics. The (a-v) O₂ difference followed a rapid monoexponential function, whereas both VO₂ and Q were best fitted by a single exponential plus linear increase: the time constant (τ) VO₂ [57 (20s)] was similar to τ (a-v) O₂, whereas τ for Q was significantly higher [89(34)s, $P < 0.05$] (values expressed as the mean and standard error). LA started to increase after 2 min CWE then increased rapidly, reaching a similar maximal value as that seen during the IET. During CWE, the rapid component of VO₂ uptake was determined by a rapid and maximal (a-v)O₂ extraction coupled with a two-fold longer Q increase. It is likely that lactic acidosis markedly increased oxygen availability, which when associated with the slow linear increase of Q , may account for the VO₂ slow component. Time to exhaustion was larger in individuals with shorter time delay for (a-v)O₂ and greater τ for Q .

Keywords:

- Oxygen slow component,
- Cardiac Output,
- Arteriovenous oxygen difference,
- Time to exhaustion

Faut-il Mesurer le Débit Cardiaque à L'exercice?

Journées Francophones ALVEOLE, Montpellier, Mars 2004. Dyspnées Cardiologiques Difficiles

Authors:

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Méthodes:

La mesure du Q à l'effort par impédancemétrie revalorisée par les acquisitions de la technologie moderne (PhysioFlow – Manatec) offre de solides perspectives par rapport aux autres méthodes non invasives (CO₂ rebreathing, échocardiographie, doppler...). Nous l'avons validée par comparaison avec la méthode invasive de Fick au cours de mesures simultanées répétées lors d'une épreuve à puissance constante [3] et lors d'un test d'effort maximal [4] et l'utilisons à présent systématiquement dans nos ECRM. La variation d'impédance produite par la systole permet d'obtenir Q cycle par cycle et de là le VES. En parallèle cette mesure associée à la mesure simultanée de la VO₂ aboutit à une détermination quasi continue de la da v O₂ grâce au calcul du rapport VO₂/Q.

Résultats:

1/ **A puissance constante ou lors d'un test maximal** à charges croissantes on obtient une détermination directe et quasi continue des ajustements centraux (VES) et périphériques (da v O₂). Nous avons observé ainsi chez les patients des VES d'emblée maximaux ou au contraire s'ajustant jusqu'aux paliers sous maximaux de l'effort. Aucune cinétique évolutive "standard" du VES de l'effort ne peut plus être actuellement affirmée. De même s'agissant de la da v O₂ les valeurs mesurées sont souvent très différentes chez les malades désadaptés que celles communément admises chez les sujets sains, sédentaires ou sportifs.

2/ **L'épreuve temps limite** : au cours de ce test qui consiste à soutenir à 90% de la VO₂ max du sujet nous pouvons suivre grâce au **PhysioFlow** la cinétique des grandeurs, Q, FC, VES et, VO₂, da v O₂ et déterminer notamment la constante de temps (τ , t_{ôt}) de chaque monoexponentielle qui les décrit. Chez ces sujets sains la contribution de chaque élément de l'équation de Fick pour assurer à chaque moment l'ajustement de la VO₂ peut être représentée graphiquement – en % de leur valeur maximale. Une telle approche dynamique des ajustements s'avère précieuse chez les cardiaques, tant au plan explicatif que prédictif : ainsi KOIKE et al ont montré la relation entre les constantes de temps de VO₂ et de Q mesurées lors d'un **effort** constant et les valeurs des fractions d'éjection ventriculaire gauche mesurées **au repos**.

Conclusion:

L'origine de toute dyspnée d'effort est certes multifactorielle ; mais chez le cardiaque prédominant le dysfonctionnement myocardique et ses conséquences : la sédentarité, et donc le déconditionnement physique. La mesure continue du débit cardiaque par impédancemétrie (**PhysioFlow**), associée aux données de l'épreuve cardiorespiratoire, permet de cerner tous les facteurs d'ajustement de la VO₂ tels qu'exprimés dans l'équation de Fick. La généralisation de cette évaluation « intégrative » grâce à une mesure continue et « non invasive » du débit cardiaque devrait ouvrir vers une meilleure compréhension des « dyspnées ».

Eccentric Cycle Exercise: Training Application of Specific Circulatory Adjustments

Medicine & Science in Sports & Exercise. 36(11):1900-1906, November 2004.MSSE

Authors:

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Abstract-Purpose:

Despite identical oxygen uptake (VO₂), enhanced heart rate (HR) and cardiac output ([Latin capital letter Q with dot above]) responses have been reported in eccentric (ECC) versus concentric (CON) cycle exercise. The aim of this study was to describe the specific circulatory adjustments (HR and stroke volume (SV)) to incremental ECC cycle exercise in order to: 1) determine the HR values leading to identical VO₂ in ECC and CON cycling; and 2) estimate the interindividual variability of this HR correspondence between the two exercise modes, with emphasis upon rehabilitation and training purposes.

Methods:

Eight healthy male subjects (age, 28 +/- 2 yr) participated in this study. They performed CON and ECC cycle incremental exercises (power output increases of 50 W every 3 min). Breath-by-breath gas exchange analysis and beat-by-beat thoracic impedancemetry were used to determine VO₂ and Q_c, respectively.

Results:

At the same metabolic power VO₂ of 1.08 +/- 0.05 L[middle dot]min⁻¹ in CON vs 1.04 +/- 0.06 Lmin⁻¹ in ECC), SV was not different, but HR was 17% higher in ECC (P < 0.01), leading to a 27% enhanced Q_c (P < 0.01). Q_c and HR net adjustments (exercise minus resting values) in ECC versus CON muscle involvement demonstrated important interindividual variability with coefficients of variation amounting to 32% and 30%, respectively

Conclusion:

In practice, if a given level of VO₂ is to be reached, ECC HR has to be set above the CON one. Taking into account the interindividual variability of the circulatory adjustments in ECC versus CON muscle involvement, a precise HR correspondence can be established individually from the VO₂/HR relationship obtained using ECC incremental testing, allowing prescription of accurate target HR for rehabilitation or training purposes.

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Heart Rate Deflection Point as a Strategy to Defend Stroke Volume during Incremental Exercise

J Appl Physiol 98: 1660-1665, 2005. First published December 23, 2004; doi:10.1152/jappphysiol.00837.2004

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Submitted 4 August 2004 ; accepted in final form 29 November 2004

Abstract:

The purpose of this study was to examine whether the heart rate (HR) deflection point (HRDP) in the HR-power relationship is concomitant with the maximal stroke volume (SV_{\max}) value achievement in endurance-trained subjects. Twenty-two international male cyclists (30.3 ± 7.3 yr, 179.7 ± 7.2 cm, 71.3 ± 5.5 kg) undertook a graded cycling exercise (50 W every 3 min) in the upright position. Thoracic impedance was used to measure continuously the HR and stroke volume (SV) values. The HRDP was estimated by the third-order curvilinear regression method. As a result, 72.7% of the subjects (HRDP group, $n = 16$) presented a break point in their HR-work rate curve at $89.9 \pm 2.8\%$ of their maximal HR value. The SV value increased until $78.0 \pm 9.3\%$ of the power associated with maximal O_2 uptake ($\dot{V}O_{2\max}$) in the HRDP group, whereas it increased until $94.4 \pm 8.6\%$ of the power associated with $\dot{V}O_{2\max}$ in six other subjects (no-HRDP group, $P = 0.004$). Neither SV_{\max} (ml/beat or $ml \cdot beat^{-1} \cdot m^{-2}$) nor $\dot{V}O_{2\max}$ (ml/min or $ml \cdot kg^{-1} \cdot min^{-1}$) were different between both groups. However, SV significantly decreased before exhaustion in the HRDP group (153 ± 44 vs. 144 ± 40 ml/beat, $P = 0.005$). In the HRDP group, 62% of the variance in the power associated with the SV_{\max} could also be predicted by the power output at which HRDP appeared. In conclusion, in well-trained subjects, the power associated with the SV_{\max} -HRDP relationship supposed that the HR deflection coincided with the optimal cardiac work for which SV_{\max} was attained.

Keywords:

- Physical work curve break point,
- Left ventricular ejection fraction,
- Cycling graded test

Evolution of Cardiac Output during Resistive Exercise in the Healthy Subject

Presented at the CSEP conference, Quebec, 2005

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Abstract:

Muscular reinforcement is a type of training that is often used in physical rehabilitation. The acute impact of such training on cardiac training is not well known. It seems important to understand this hemodynamic response better in order to apply this technique to numerous different patient populations, including cardiac patients. The aim of this study is to follow the evolution of cardiac parameters (heart rate (HR), blood pressure (SBP and DBP), cardiac output (Qc), stroke volume (SV), and derivative parameters (rate pressure product RPP, and peripheral systemic resistance PSR) in a continuous and non invasive manner during a classical resistive training.

Methods

23 healthy subjects (average age: 24 years) realised 3 series of 10 knee flexion-extensions on a quadriceps chair (Technogym). The imposed load was 75 % of maximal voluntary contraction (MVC). The work rhythm was of 1 second for a complete extension and 1 second to return to the flexed position. The recovery period was fixed at 1 minute between series. The blood pressure was continuously measured with the "Finapres". Qc and SV were continuously measured with a "Physio-flow"®.

Results:

We observe an 8 to 36 % increase of Qc during the exercise. The Qc decreases during the periods of rest but never reaches the starting values within the imposed 1 minute of rest time. This increase of Qc is essentially due to an increase of the HR (+ 45, 19 and 11% during the first, second and third series). The SV practically doesn't vary (+/- 5%). The observed raise of Qc is relatively low compared to what is described in the literature for an equivalent dynamic effort (75% of VO2 max / 75 %CMV). The DP follows an evolution previously described in the literature.

Conclusion:

The Qc increases in a moderate manner during a short but intense resistive effort. The Qc doesn't return to the rest values within 1 minute of recovery. The SV contributes little to the raise of Qc. The raise of Qc is essentially due to the HR increase.

Non-invasive Evaluation of Maximal Arteriovenous Oxygen Difference and Adolescent Boys' Fitness Levels

Science & Sports Volume 22, Issue 2, April 2007, Pages 104-109

Authors:

- N. Ben Brahim Boudhina ^a, •T. Vogel ^b,
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- P.-M. Leprêtre ^c, Yahmed ^a

Objective:

To evaluate non-invasively the patterns of the Fick equation components during an incremental ergocycle test.

Methods:

Simultaneous measurements of gas exchanges and cardiac output (\dot{Q}_c) — thoracic impedance device Physioflow Manatec — supply the Fick equation's variables:

$\dot{V}O_2 = \dot{Q}_c \times d(a - \bar{v})O_2$. Their dynamics are studied at 1st and 2nd ventilatory threshold (SV1, SV2) and at PMT (Max Tolerated Power) in 41 active adolescent boys; 25 of them are highly trained (TP) and 16 occasionally (P). There is no anthropometric difference between the 2 groups

Results:

- 1) Individual slopes "a" of \dot{Q}_c regression against $\dot{V}O_2$ are negative: the higher the "a" value the lower $\dot{V}O_{2max}$, PMT, maximal tissular O_2 extraction $d(a - \bar{v})O_{2max}$, and... the adolescents' performance;
- 2) as early as at SV1, $d(a - \bar{v})O_2$ in TP is always higher than in P; whereas \dot{Q}_c , FC and stroke volume (VES) have similar values in both groups at SV1, SV2 and PMT; 3) in all subjects, TP and P, VES max and $d(a - \bar{v})O_{2max}$ were reached at the level of SV2.

Conclusion:

Non-invasive and simultaneous \dot{Q}_c and $\dot{V}O_2$ measurements during incremental test lead to Fick equation adjustments, $\dot{Q}_c/\dot{V}O_2$ "a" slope and $d(a - \bar{v})O_2$ difference contributing thus to interesting indications of subjects' fitness.

Children Cardiorespiratory Performance Index by Simultaneous and Independent Measure of Oxygen Uptake and Cardiac Output

Science & Sports Volume 22, Issue 2, April 2007, Pages 120-122

Authors:

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Objective:

To demonstrate that the linear coefficient of the $\dot{Q}_c - \dot{V}O_2$ relationship is an indice of the tissular oxygen extraction capacity $(d(a - \bar{v})O_2)$ in children.

Keywords:

- Non-invasive cardiac output
- O_2 arteriovenous difference
- PhysioFlow slope analysis

Synthesis of facts:

Twelve soccers (11.7 ± 0.7 years) performed a maximal progressive test. Our results show that \dot{Q}_c is strongly correlated with $\dot{V}O_2$ ($r = 0.96, p < 0.01$), and the individual values of the linear coefficient of the $\dot{Q}_c - \dot{V}O_2$ relationship are conversely correlated with $d(a - \bar{v})O_{2max}$ values ($r = -0.91, p < 0.05$).

Conclusion:

It thus seems that $d(a - \bar{v})O_{2max}$ is the main predicting factor for $\dot{V}O_{2max}$.

Am J Physiol Regul Integr Comp Physiol, 2008 Apr 16.

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Abstract:

The goal of the study was to determine the effects of continuous (CT) vs. intermittent (IT) training yielding identical mechanical work and training duration on skeletal muscle and cardiorespiratory adaptations in sedentary subjects. Eleven subjects (6 men and 5 women, 45+/-3 years) were randomly assigned to two periods of 24 trainings sessions over 8 weeks in a cross-over design, separated by 12 weeks of detraining. Maximal oxygen uptake (VO₂max) measured during maximal exercise testing increased after both trainings (9% with CT vs. 15% with IT), whereas only IT was associated with faster VO₂ kinetics (tau: 68.0+/-1.6 vs. 54.9+/-0.7 sec, p<0.05) measured during a test to exhaustion (TTE) and with improvements in maximal cardiac output (Q_{max}, from 18.1+/-1.1 to 20.1+/-1.2 L.min(-1), p<0.01). Skeletal muscle mitochondrial oxidative capacities (V_{max}) were only increased after IT (3.3+/-0.4 before and 4.5+/-0.6 micromol O₂.min(-1).gdw(-1) after training, p<0.05) whereas capillary density increased after both trainings, with a 2-fold higher enhancement after CT (+21+/-1% for IT and +40+/-3% after CT, p<0.05). The gain of V_{max} was correlated with the gain of TTE and the gain of VO₂max with IT. The Gain of Q_{max} was also correlated with the gain of VO₂max. These results suggest that fluctuations of workload and oxygen uptake during training sessions, rather than exercise duration or global energy expenditure, are key factor in improving muscle oxidative capacities. In an integrative view, IT seems optimal in maximizing peripheral muscle and central cardiorespiratory adaptations, permitting significant functional improvement. These data support the symmorphosis concept in sedentary subjects. Key words: mitochondria, endurance training, performance.

Shock and Awe: Hemodynamic Changes during ECT Measured with a Non-Invasive Cardiac Output Monitor

Anesthesiology 2006; 105: A613
October 15, 2006
2:00 PM - 4:00 PM
Room Hall E, Area G

Authors:

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Introduction:

Typical cardiovascular effects of ECT include hypertension and tachycardia. Blood pressure tends to transiently increase 30-40% and there is about a 10% increase in heart rate (1). These changes result from an increase in sympathetic nervous system activity following an initial parasympathetic response to a seizure. There is little information about the hemodynamic changes occurring in patients with normal cardiac function during this procedure.

We investigated the changes occurring in normal subjects using a thoracic bioimpedance monitor to assess cardiac function.

Methods:

Patients were enrolled in the study after providing informed consent. Patients with cardiovascular disease were excluded from this study. General anesthesia was induced with glycopyrrolate, 0.1-0.2 mg; propofol, 1-1.5 mg/kg; and succinylcholine, 1 mg/kg. Patients were ventilated by mask with 100% oxygen throughout the treatment. Continuous hemodynamic measurements were made using a PhysioFlow™ thoracic bioimpedance cardiac output monitor. Patients were followed throughout their treatment with measurements recorded at the following intervals: baseline, immediately pre-seizure stimulus, 1 min after end of seizure stimulus and 5 min after end of seizure stimulus. The data was analyzed using the student's t-test for paired samples.

Results:

Nine patients (M:F=2/5), were studied. The average age was 39.7 ± 9.5 yrs (range: 23-52 yr). Eleven treatments in were studied in total. The BSA was 1.91 ± 0.31 (range:1.31-2.02). The CI gradually decrease through to 1 min after the end of seizure stimulus and then increases. The HR and SV were constant through the treatment period. There is a trend of increasing EDV with decreasing EF and systemic vascular resistance during the treatment and into the post-ictal phase.

Conclusion:

The CI is maintained during ECT and increases in the post-ictal period. The EDV gradually increases while the EF decreases, resulting in a rather constant SV throughout the treatment. Because there is a trend toward decreasing SVR and since no intravenous fluids were administered during these treatments, the increase in EDV probably reflects transient cardiovascular depression from propofol. These observations reflect how younger patients without cardiovascular disease respond to propofol anesthesia and the stress of ECT. The changes are consistent with other reports in the literature suggesting that non-invasive hemodynamic monitoring is reliable in clinical situations.

Evaluation of the hemodynamic response in older patients (>65 yr) without cardiovascular disease is in progress.

1.Ding Z, White PF. Anesthesia for electroconvulsive therapy. *Anesth Analg* 2002; 94:1351-1364.

Relationships between hemodynamic, hemorheological and metabolic responses during exercise

Biorheology 00 (2009) 1–11 1
DOI 10.3233/BIR-2009-0529
IOS Press 1

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Abstract:

Aerobic performance is dependent on both cardio-respiratory and peripheral factors with hemodynamic parameters playing a major role. However, whether blood rheology might affect aerobic performance through an effect on hemodynamic factors is not known. The aim of the present study was to assess the relationships between hemodynamic, hemorheological and metabolic parameters in response to a sub-maximal cycling exercise protocol consisting of three successive levels of nine min duration (50, 100 and 150 W). Ten young sportsmen participated in the present study. Mean arterial pressure (MAP) was measured manually, with thoracic impedance used to monitor cardiac output (Q_c): systemic vascular resistance (SVR) was then calculated. Whole blood viscosity (η_b) was measured and used to calculate systemic vascular hindrance. Hematocrit (Hct) was determined by microcentrifugation and red blood cell (RBC) deformability (EI) was determined by ektacytometry. A breath-by-breath gas analyzer was used to measure oxygen uptake (VO_2); the Fick equation was used to calculate arteriovenous oxygen difference $[(a-v)O_2]$ from VO_2 and Q_c . All measurements were performed at rest, during exercise and during recovery. Compared to baseline, Q_c , MAP, Hct, EI, VO_2 , and $(a-v)O_2$ increased during exercise. η_b increased above baseline only at 150 W and remained elevated during recovery; the increase in η_b during the last level of exercise was associated with a decrease of SVR and systemic vascular hindrance. There was a significant negative correlation between EI and SVR ($r = -0.35, p < 0.01$) and a significant positive relationship between EI and $(a-v)O_2$ ($r = 0.35, p < 0.01$) and between EI and VO_2 ($r = 0.37, p < 0.01$) across all exercise workloads, thus suggesting a potential role for RBC deformability as a factor affecting aerobic performance via oxygen delivery to tissues. These data lend support to the concept that hemorheological parameters may contribute to hemodynamic and cardio-respiratory adaptations in response to exercise in moderately trained sportsmen.

Keywords:

- Blood rheology,
- Exercise physiology,
- Hemodynamics,
- Oxygen uptake

⊙ Oxygen uptake efficiency slope' in trained and untrained subjects exposed to hypoxia

Respiratory Physiology & Neurobiology 161 (2008) 167–173

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Accepted 26 January 2008

Abstract:

We assessed the ability of the oxygen uptake efficiency slope, whether calculated on 100 and 80% of maximal exercise test duration (OUES100 and OUES80), to identify the change in cardiorespiratory capacities in response to hypoxia in subjects with a broad range of VO₂ peak. Four maximal exercise tests were performed in trained (T) and untrained subjects (UT) in normoxia and at 1000, 2500 and 4500 m. The mean reductions in maximal exercise capacities at 4500m were the same in T subjects for VO₂ peak (-30%), OUES80 (-26%) and OUES100 (-26%) whereas in UT subjects only OUES100 (-14%), but not OUES80 (-20%), was lower compared with 'VO₂ peak (-21%, p < 0.05). OUES100 and OUES80 were correlated with VO₂ peak and the ventilatory anaerobic threshold in both groups. Multiple regression analyses showed that VO₂ peak, OUES100 and OUES80 were significantly linked to O₂ arterial-venous difference. The OUES80 could be considered as an interesting sub-maximal index of cardiorespiratory fitness in normal or hypoxemic subjects unable to reach VO₂ peak.

Keywords:

- Hypoxia;
- Exercise;
- Ventilatory response;
- Testing;
- OUES;
- O₂ utilisation;
- Fitness;
- Training

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Determinant factors of the decrease in aerobic performance in moderate acute hypoxia in women endurance athletes

Respiratory Physiology & Neurobiology 159 (2007) 178–186

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Accepted 23 June 2007

Abstract:

The purpose of this study was to evaluate the limiting factors of maximal aerobic performance in endurance trained (TW) and sedentary (UW) women. Subjects performed four incremental tests on a cycle ergometer at sea level and in normobaric hypoxia corresponding to 1000, 2500 and 4500 m. Maximal oxygen uptake decrement ($\Delta V_{O_2 \max}$) was larger in TW at each altitude. Maximal heart rate and ventilation decreased at 4500m in TW. Maximal cardiac output remained unchanged. In both groups, arterialized oxygen saturation ($Sa_{O_2 \max}$) decreased at and above 2500m and maximal O_2 transport ($Q_{aO_2 \max}$) decreased from 1000m. At 4500m, there was no more difference in $Q_{aO_2 \max}$ between TW and UW. Mixed venous O_2 pressure ($P_{vO_2 \max}$) was lower and O_2 extraction (O_2ER_{\max}) greater in TW at each altitude. The primary determinant factor of $VO_2 \max$ decrement in moderate acute hypoxia in trained and untrained women is a reduced maximal O_2 transport that cannot be compensated by tissue O_2 extraction.

Keywords:

- Cardiac output;
- Arterial O_2 saturation;
- Venous O_2 saturation;
- Tissue O_2 extraction

Determinants of maximal oxygen uptake in moderate acute hypoxia in endurance athletes

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- Jean-Paul Richalet.

Abstract:

The factors determining maximal oxygen consumption were explored in eight endurance trained subjects (TS) and eight untrained subjects (US) exposed to moderate acute normobaric hypoxia. Subjects performed maximal incremental tests at sea level and simulated altitudes (1,000, 2,500, 4,500 m). Heart rate (HR), stroke volume (SV), cardiac output (Q) arterialized oxygen saturation (Sa'O₂), oxygen uptake (V O_{2max}); ventilation (VE; expressed in normobaric conditions) were measured. At maximal exercise, ventilatory equivalent (VE/VO_{2max}); O₂ transport (QaO_{2max}) and O₂ extraction (O₂ER_{max}) were calculated. In TS, Q_{max} remained unchanged despite a significant reduction in HR_{max} at 4,500 m. SV_{max} remained unchanged. VE_{max} decreased in TS at 4,500 m, VE/VO_{2max} was lower in TS and greater at 4,500 m vs. sea level in both groups. Sa'O_{2max} decreased at and above 1,000 m in TS and 2,500 m in US, O₂ER_{max} increased at 4,500 m in both groups. QaO_{2max} decreased with altitude and was greater in TS than US up to 2,500 m but not at 4,500 m. VO_{2max} decreased with altitude but the decrement (Δ VO_{2max}) was larger in TS at 4,500 m. In both groups Δ VO_{2max} in moderate hypoxia was correlated with Δ QaO_{2max}. Several differences between the two groups are probably responsible for the greater Δ VO_{2max} in TS at 4,500 m : (1) the relative hypoventilation in TS as shown by the decrement in V_Emax at 4,500 m (2) the greater QaO_{2max} decrement in TS due to a lower Sa'O_{2max} and unchanged Q_{max} 3) the smaller increase in O₂ER_{max} in TS, insufficient to compensate the decrease in Q_aO_{2max}.

Keywords:

- Aerobic performance;
- Cardiac output;
- Arterial O₂ saturation;
- Venous O₂ saturation;
- Tissue O₂ extraction

Improvement of VO₂ max by cardiac output and oxygen extraction adaptation during intermittent versus continuous endurance training

Eur J Appl Physiol DOI 10.1007/s00421-007-0499-3

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Abstract:

Improvement of exercise capacity by continuous (CT) versus interval training (IT) remains debated. We tested the hypothesis that CT and IT might improve peripheral and/or central adaptations, respectively, by randomly assigning 10 healthy subjects to two periods of 24 trainings sessions over 8 weeks in a cross-over design, separated by 12 weeks of detraining. Maximal oxygen uptake ($\dot{V}O_{2\max}$); cardiac output (Q_{\max}) and maximal arteriovenous oxygen difference ($D_{a-v}O_{2\max}$) were obtained during an exhaustive incremental test before and after each training period. $\dot{V}O_{2\max}$ and Q_{\max} increased only after IT (from 26.3 ± 1.6 to 35.2 ± 3.8 ml min^{-1} kg^{-1} and from 17.5 ± 1.3 to 19.5 ± 1.8 l min^{-1} , respectively; $P < 0.01$). $D_{a-v}O_{2\max}$ increased after both protocols (from 11.0 ± 0.8 to 12.7 ± 1.0 ; $P < 0.01$ and from 11.0 ± 0.8 to 12.1 ± 1.0 ml 100 ml^{-1} , $P < 0.05$ in CT and IT, respectively). At submaximal intensity a significant rightward shift of the $\dot{V}O_2/D_{a-v}O_2$ relationship appeared only after CT. These results suggest that in isoenergetic training, central and peripheral adaptations in oxygen transport and utilization are training-modality dependant. IT improves both central and peripheral components of $\dot{V}O_{2\max}$ whereas CT is mainly associated with greater oxygen extraction.

Keywords:

- Training modality
- Cardiac output,
- Arteriovenous difference,
- Maximal oxygen consumption,
- Sedentary subjects

Vasoconstrictive Response in the Vascular Beds of the Non-Exercising Forearm During Leg Exercise in Patients With Mild Chronic Heart Failure

Circ J 2007; 71: 922 –928

(Received July 25, 2006; revised manuscript received February 15, 2007; accepted March 2, 2007)

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Background:

Reduced exercise capacity may be related to decreased redistribution of blood flow from the nonexercising tissues to the exercising skeletal muscle in patients with mild chronic heart failure (CHF).

Keywords:

- Blood flow;
- Exercise;
- Forearm;
- Heart failure;
- Oxygen consumption

Methods & Results:

In the present study 14 patients with mild CHF and 10 healthy subjects (N) underwent symptom-limited multistage-ergometer exercise, during which forearm vascular resistance (FVR), cardiac index(CI), systemic vascular resistance index (SVRI), and oxygen uptake (VO₂) were measured non-invasively using the plethysmograph, impedance, and respiratory gas analysis methods, respectively. The VO₂ and CI at peak exercise were lower ($p < 0.01$ each), and SVRI and FVR at both rest and peak exercise were higher in the CHF group than in N. However, both the percent increase in FVR and percent decrease in SVRI from the resting state to peak exercise were lower in CHF than N, and both of them correlated with not only peak VO₂, but also the corresponding resting value of FVR and SVRI ($p < 0.01$ each).

Conclusion:

Redistribution of blood flow from the non-exercising tissues to the working skeletal muscles, which may participate in exercise capacity, can be blunted in CHF. The decreased vasoconstrictive response in the non-exercising tissues is intimately related to the increased resting vascular tone in CHF. (*Circ J* 2007; 71: 922 – 928)

Expiratory muscle loading increases intercostal muscle blood flow during leg exercise in healthy humans

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Abstract:

We investigated whether expiratory muscle loading induced by the application of expiratory flow limitation (EFL) during exercise in healthy subjects causes a reduction in quadriceps muscle blood flow in favour of the blood flow to the intercostal muscles. We hypothesized that during exercise with EFL quadriceps muscle blood flow would be reduced, whereas intercostal muscle blood flow would be increased compared to exercise without EFL. We initially performed an incremental exercise test on eight healthy male subjects with a Starling resistor in the expiratory line limiting expiratory flow to ~ 1 L/sec⁻¹ to determine peak EFL exercise workload (WR_{peakEFL}). On a different day, two constant-load exercise trials were performed in a balanced ordering sequence during which subjects exercised with or without EFL at WR_{peakEFL} for 6 minutes. Intercostal (probe over the 7th intercostal space) and vastus lateralis muscle blood flow index (BFI) was calculated by near-infrared spectroscopy using indocyanine green, whereas cardiac output (CO) was measured by an impedance cardiography technique. At exercise termination CO and stroke volume (SV) were not significantly different during exercise with or without EFL (CO: 16.5 vs 15.2 l/min⁻¹, SV: 104 vs 107 ml/beat⁻¹, respectively). Quadriceps muscle BFI during exercise with EFL (5.4 nM/s) was significantly ($p = 0.043$) lower compared to exercise without EFL (7.6 nM/s), whereas intercostal muscle BFI during exercise with EFL (3.5 nM/s) was significantly ($p = 0.021$) greater compared to that recorded during control exercise (0.4 nM/s). In conclusion, increased respiratory muscle loading during exercise in healthy humans causes an increase in blood flow to the intercostal muscles and a concomitant decrease in quadriceps muscle blood flow.

Keywords:

- Exercise;
- Expiratory flow limitation;
- Intercostal muscle blood flow;
- Quadriceps muscle blood flow.

Cardiac function and arteriovenous oxygen difference during exercise in obese adults

EUROPEAN JOURNAL OF APPLIED PHYSIOLOGY

DOI: 10.1007/s00421-010-1554-

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Abstract:

The purpose of this study was to assess cardiac function and arteriovenous oxygen difference (a-vO₂ difference) at rest and during exercise in young, normal-weight (n = 20), and obese (n = 12) men and women who were matched for age and fitness level. Participants were assessed for body composition, peak oxygen consumption (VO₂peak), and cardiac variables (thoracic bioimpedance)—cardiac index (CI), cardiac output (Q), stroke volume (SV), heart rate (HR), and ejection fraction (EF)—at rest and during cycling exercise at 65% of VO₂peak. Differences between groups were assessed with multivariate ANOVA and mixed-model ANOVA with repeated measures controlling for sex. Absolute VO₂peak and VO₂peak relative to fat-free mass (FFM) were similar between normal-weight and obese groups (Mean ± SEE 2.7 ± 0.2 vs. 3.3 ± 0.3 l min⁻¹, p = 0.084 and 52.4 ± 1.5 vs. 50.9 ± 2.3 ml kg FFM⁻¹ min⁻¹, p = 0.583, respectively). In the obese group, resting Q and SV were higher (6.7 ± 0.4 vs. 4.9 ± 0.1 l min⁻¹, p < 0.001 and 86.8 ± 4.3 vs. 65.8 ± 1.9 ml min⁻¹, p < 0.001, respectively) and EF lower (56.4 ± 2.2 vs. 65.5 ± 2.2%, p = 0.003, respectively) when compared with the normal-weight group. During submaximal exercise, the obese group demonstrated higher mean CI (8.8 ± 0.3 vs. 7.7 ± 0.2 l min⁻¹ m⁻², p = 0.007, respectively), Q (19.2 ± 0.9 vs. 13.1 ± 0.3 l min⁻¹, p < 0.001, respectively), and SV (123.0 ± 5.6 vs. 88.9 ± 4.1 ml min⁻¹, p < 0.001, respectively) and a lower a-vO₂ difference (10.4 ± 1.0 vs. 14.0 ± 0.7 ml l00 ml⁻¹, p = 0.002, respectively) compared with controls. Our study suggests that the ability to extract oxygen during exercise may be impaired in obese individuals.

Keywords:

- Cardiac function
- Exercise
- Obese
- Stroke volume

Effects of Acute Hypoxia at Moderate Altitude on Stroke Volume and Cardiac Output During Exercise

International Heart Journal
Vol. 51 (2010), No. 3 pp.170-175

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Abstract:

It has been unclear how acute hypoxia at moderate altitude affects stroke volume (SV), an index of cardiac function, during exercise. The present study was conducted to reveal whether acute normobaric hypoxia might alter SV during exercise.

Nine healthy male subjects performed maximal exercise testing under normobaric normoxic, and normobaric hypoxic conditions (O₂: 14.4%) in a randomized order. A novel thoracic impedance method was used to continuously measure SV and cardiac output (CO) during exercise.

Acute hypoxia decreased maximal work rate (hypoxia; 247 ± 6 [SE] versus normoxia; 267 ± 8 W, (P < 0.005) and VO₂ max (hypoxia; 2761 ± 99 versus normoxia; 3039 ± 133 mL/min, P < 0.005). Under hypoxic conditions, SV and CO at maximal exercise decreased (SV: hypoxia; 145 ± 11 versus normoxia; 163 ± 11 mL, P < 0.05, CO: hypoxia; 26.7 ± 2.1 versus normoxia; 30.2 ± 1.8 L/min, P < 0.05). In acute hypoxia, SV during submaximal exercise at identical work rate decreased. Furthermore, in hypoxia, 4 of 9 subjects attained their highest SV at maximal exercise, while in normoxia, 8 of 9 subjects did.

Acute normobaric hypoxia attenuated the increment of SV and CO during exercise, and SV reached a plateau earlier under hypoxia than in normoxia. Cardiac function during exercise at this level of acute normobaric hypoxia might be attenuated. (Int heart J 2010 : 170-175)

Keywords:

- [Normobaric hypoxia](#),
- [Cardiac output](#),
- [Oxygen uptake](#),
- [Exercise testing](#)

Maximal exercise limitation in functionally overreached triathletes: role of cardiac adrenergic stimulation.

Journal of Applied Physiology (1985). 2014 Jun 12. pii: jap.00191.2014.

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Background:

Functional overreaching (F-OR) induced by heavy load endurance training programs has been associated with reduced heart rate values both at rest and during exercise. Because this phenomenon may reflect an impairment of cardiac response, this research was conducted to test this hypothesis.

Keywords:

- *Cardiac response*
- *Endurance training*
- *Fatigue*
- *Overreaching*
- *Overtraining*

Methods & Results:

Thirty-five experienced male triathletes were tested (11 control and 24 overload subjects) before overloading (Pre), immediately after overloading (Mid) and after a 2-week taper period (Post). Physiological responses were assessed during an incremental cycling protocol to volitional exhaustion, including catecholamine release, oxygen uptake (VO₂), arteriovenous O₂ difference, cardiac output (Q), systolic (SBP) and diastolic blood pressure (DBP). Twelve subjects of the overload group developed signs of F-OR at Mid (decreased performance with concomitant high perceived fatigue), while 12 others did not (acute fatigue group, AF). VO₂max was reduced only in F-OR subjects at Mid. Lower Q and SBP values with greater arteriovenous O₂ difference were reported in F-OR subjects at all exercising intensities, while no significant change was observed in the control and AF groups. A concomitant decrease in epinephrine excretion was reported only in the F-OR group. All values returned to baseline at Post.

Conclusion:

Following an overload endurance training program leading to F-OR, the cardiac response to exhaustive exercise is transiently impaired, possibly due to reduced epinephrine excretion. This finding is likely to explain the complex process of underperformance syndrome experienced by F-OR endurance athletes during heavy load programs.

Cardiovascular and hemodynamic responses on dryland vs. immersed cycling

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Article history: Received 9 June 2014 Received in revised form 29 July 2014 Accepted 13 August 2014

Objectives:

To investigate the effect of water immersion on oxygen uptake ($\dot{V}O_2$) and central hemodynamic responses during incremental maximal exercise at the same external power output (P_{ext}) and recovery on an immersible ergocycle vs. a dryland ergocycle.

Keywords:

- Oxygen uptake
- Central hemodynamic
- External power output
- Pedalling rate
- Immersed ergocycle

Methods:

Twenty healthy participants (32 ± 7 years; 173 ± 6 cm; 71.7 ± 9.7 kg) performed maximal incremental exercise tests while pedalling either immersed on immersible ergocycle (Hydroider®) or on dryland ergocycle (Ergoline 800S; Bitz, Germany). Initial P_{ext} of dryland ergocycle protocol was set at 25 W and increased by 25 W every minute until exhaustion. P_{ext} on immersible ergocycle was controlled by pedalling rate (rpm). Initial rpm was set at 40 rpm and was increased by 10 rpm until 70 rpm and thereafter by 5 rpm until exhaustion. Gas exchange and central hemodynamic parameters were measured continuously during exercise and a 5-min recovery period. Reported $\dot{V}O_2$, stroke volume, cardiac output (\dot{Q}) and arteriovenous difference ($C(a-v)O_2$) were compared.

Conclusion:

During exercise and recovery in immersion, $\dot{V}O_2$ and $C(a-v)O_2$ were reduced in healthy young participants. We may believe that the reduced muscle O_2 extraction during immersion could occur due to increased blood flow and hyper perfusion of lower limb skeletal muscle, reducing red cell transit time and thereby decreasing muscle oxygen diffusion. In parallel, during immersed cycling exercise, stroke volume and cardiac output were improved for the same P_{ext} . This may be due to a combination of decreased afterload and/or increased contractility. During recovery, immersion increased stroke volume, ejection fraction and contractility presumably via an increased sensitivity of cardiac contractile proteins to calcium. Further studies are needed to understand by which mechanisms $\dot{V}O_2$ is decreased during water exercise on IE at the same external power output (P_{ext}) relative to exercise on DE.

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Objectives:

To assess the effect of a 4-month high-intensity interval training programme on cognitive functioning, cerebral oxygenation, central haemodynamic and cardiometabolic parameters and aerobic capacity in obese patients. *Methods:* Cognitive functioning, cerebral oxygenation, central haemodynamic, cardiometabolic and exercise parameters were measured before and after a 4-month highintensity interval training programme in 6 obese patients (mean age 49 years (standard deviation 8), fat mass percentage 31 ± 7%).

Keywords:

- high-intensity interval training;
- obesity;
- cognition;
- cerebral oxygenation.

Results:

Body composition (body mass, total and trunk fat mass, waist circumference) and fasting insulin were improved after the programme ($p < 0.05$). $\dot{V}O_2$ and power output at ventilatory threshold and peak power output were improved after the programme ($p < 0.05$). Cognitive functioning, including short-term and verbal memory, attention and processing speed, was significantly improved after training ($p < 0.05$). Cerebral oxygen extraction was also improved after training ($p < 0.05$).

Conclusion:

These preliminary results indicate that a 4-month high-intensity interval training programme in obese patients improved both cognitive functioning and cerebral oxygen extraction, in association with improved exercise capacity and body composition.

IMPORTANT NOTE FROM THE MANUFACTURER:

It is likely that the use of stroke volume index and cardiac index in lieu of stroke volume and cardiac output would have shown bigger changes thanks to the training-related weight loss. Normalizing SV et CO with the lean body mass could have been an interesting avenue as well.

Reproducibility of cardiac output derived by impedance cardiography during postural changes and exercise

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Background:

Evaluation of cardiac output (CO) and other haemodynamic parameters may aid in understanding factors involved in arterial blood pressure (BP) changes with exercise and postural stress. Impedance cardiography offers a rapid, non-invasive means to acquire this information, however there is limited data assessing the reproducibility of this technique during haemodynamic perturbation. This study aimed to assess reproducibility of CO and other haemodynamic parameters derived from impedance cardiography during exercise and in different postures.

Keywords:

- Haemodynamics;
- Cardiac output;
- Impedance
- cardiography;
- Blood pressure;
- Reproducibility

Methods:

51 participants (mean age 57 ± 9 years, 57% male) had CO and other haemodynamic variables (including end diastolic volume, left ventricular work, ejection fraction and systemic vascular resistance) measured via impedance cardiography (Physio Flow) at two visits separated by 12 ± 7 days. Measures were recorded at rest in three postures (supine, seated and standing), during upright cycle ergometry at a fixed workload (40 W), and also during steady state exercise at an intensity of 60% and 70% of age-predicted maximum heart rate (HR_{max}).

Results

CO reproducibility was assessed over a wide range (5.27 ± 1.00e12.09 ± 2.02 l/min). There was good agreement between CO measured at each visit in all postures and exercise conditions (intra-class correlation coefficient [ICC] range 0.729e0.888, P < 0.05 for all) with a small difference between visits (mean difference 0.06 ± 1.10 l/min). All other haemodynamic variables showed good agreement between visits (ICC range 0.714e0.970, P < 0.05 for all).

Conclusion:

Non-invasive impedance cardiography provides an acceptably reproducible means to evaluate CO and other haemodynamic variables relevant to arterial BP regulation during different postures and light-to-moderate intensity exercise.

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Increased cardiac output elicits higher VO_{2max} in response to self-paced exercise

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Abstract:

Recently, a self-paced protocol demonstrated higher energy (maximal oxygen uptake) versus the traditional ramp protocol. The primary aim of the current study was to further explore potential differences in maximal oxygen uptake between the ramp and self-paced protocols using simultaneous measurement of cardiac output. Active men and women of various fitness levels (N = 30, mean age = 26.0 ± 5.0 years) completed 3 graded exercise tests separated by a minimum of 48 h. Participants initially completed progressive ramp exercise to exhaustion to determine maximal oxygen uptake followed by a verification test to confirm maximal oxygen uptake attainment. Over the next 2 sessions, they performed a self-paced and an additional ramp protocol. During exercise, gas exchange data were obtained using indirect calorimetry, and thoracic impedance was utilized to estimate hemodynamic function (stroke volume and cardiac output). One-way ANOVA with repeated measures was used to determine differences in maximal oxygen uptake and cardiac output between ramp and self-paced testing. Results demonstrated lower ($p < 0.001$) maximal oxygen uptake via the ramp ($47.2 \pm 10.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) versus the self-paced ($50.2 \pm 9.6 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) protocol, with no interaction ($p = 0.06$) seen for fitness level. Maximal heart rate and cardiac output ($p = 0.02$) were higher in the self-paced protocol versus ramp exercise. In conclusion, data show that the traditional ramp protocol may underestimate maximal oxygen uptake compared with a newly developed self-paced protocol, with a greater cardiac output potentially responsible for this outcome.

Keywords:

- maximal oxygen uptake,
- stroke volume,
- cycle ergometer,
- RPE,
- VO_{2max} limitations

Results:

With the exception of 1 male in HIGH who did not complete his final RAMP test because of an acute injury, all participants completed all trials during the study. Data were combined for men and women across groups, as no significant sex interaction ($p > 0.05$) was revealed.

Conclusion:

In 30 men and women differing in fitness levels, a self-paced cycling protocol demonstrated higher VO_{2max} than the traditional RAMP, which was consequent with significantly higher values for maximal HR and CO. Whether these findings can be replicated in older individuals and/or those with chronic disease remains to be determined, as evoking a higher VO_{2max} in response to this newly developed protocol has great implications for the determination of VO_{2max} to quantify responses to training and establish training intensities.

Estimating Hemodynamic Responses to the Wingate Test Using Thoracic Impedance

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Abstract:

Techniques including direct Fick and Doppler echocardiography are frequently used to assess hemodynamic responses to exercise. Thoracic impedance has been shown to be a noninvasive alternative to these methods for assessing these responses during graded exercise to exhaustion, yet its feasibility during supra-maximal bouts of exercise is relatively unknown. We used thoracic impedance to estimate stroke volume (SV) and cardiac output (CO) during the Wingate test (WAnT) and compared these values to those from graded exercise testing (GXT). Active men ($n = 9$) and women ($n = 7$) (mean age = 24.8 ± 5.9 yr) completed two Wingate tests and two graded exercise tests on a cycle ergometer. During exercise, heart rate (HR), SV, and CO were continuously estimated using thoracic impedance. Repeated measures analysis of variance was used to identify potential differences in hemodynamic responses across protocols. Results: Maximal SV (138.6 ± 37.4 mL vs. 135.6 ± 26.9 mL) and CO (24.5 ± 6.1 L·min⁻¹ vs. 23.7 ± 5.1 L·min⁻¹) were similar ($p > 0.05$) between repeated Wingate tests. Mean maximal HR was higher ($p < 0.01$) for GXT (185 ± 7 b·min⁻¹) versus WAnT (177 ± 11 b·min⁻¹), and mean SV was higher in response to WAnT (137.1 ± 32.1 mL) versus GXT (123.0 ± 32.0 mL), leading to similar maximal cardiac output between WAnT and GXT (23.9 ± 5.6 L·min⁻¹ vs. 22.5 ± 6.0 L·min⁻¹). Our data show no difference in hemodynamic responses in response to repeated administrations of the Wingate test. In addition, the Wingate test elicits similar cardiac output compared to progressive cycling to VO₂ max.

Keywords:

- Stroke volume
- Cardiac output
- Cycle ergometer
- Maximal oxygen uptake
- Supramaximal exercise

Conclusion:

Data show no differences in repeated estimates of SV and CO obtained during the Wingate test from thoracic impedance. In addition, CO was similar although HR and SV varied between WAnT and GXT despite these bouts dramatically differing in intensity and duration, which opposes some existing data (Sagiv et al., 2000). This lack of agreement in SV and CO responses to intense exercise merits further studies investigating hemodynamic changes to acute exercise using different techniques as well as in response to chronic aerobic and interval training regimens in various populations.

Hemodynamic adjustments during breath-holding in trained divers

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DOI 10.1007/s00421-013-2690-z

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Abstract:

Purpose Voluntary breath-holding (BH) elicits several hemodynamic changes, but little is known about maximal static immersed-body BH. We hypothesized that the diving reflex would be strengthened with body immersion and would spare more oxygen than maximal dry static BH, resulting in a longer BH duration.

Methods Eleven trained breath-hold divers (BHDs) performed a maximal dry-body BH and a maximal immersedbody BH. Cardiac output (CO), stroke volume (SV), heart rate (HR), left ventricular end-diastolic volume (LVEDV), contractility index (CTI), and ventricular ejection time (VET) were continuously recorded by bio-impedancemetry (PhysioFlow PF-05). Arterial oxygen saturation (SaO₂) was assessed with a finger probe oximeter.

Keywords:

- Diving reflex
- Water immersion
- Kinetics Hemodynamic
- Breath-holding In

Results:

In both conditions, BHDs presented a bi-phasic kinetic for CO and a tri-phasic kinetic for SV and HR. In the first phase of immersed-body BH and dry-body BH, results (mean ± SD) expressed as percentage changes from starting values showed decreased CO (55.9 ± 10.4 vs. 39.3 ± 16.8 %, respectively; $p < 0.01$ between conditions), due to drops in both SV (24.9 ± 16.2 vs. 9.0 ± 8.5 %, respectively; $p < 0.05$ between conditions) and HR (39.7 ± 16.7 vs. 33.6 ± 17.0 %, respectively; $p < 0.01$ between conditions). The second phase was marked by an overall stabilization of hemodynamic variables. In the third one, CO kept stabilizing due to increased SV (17.0 ± 20.2 vs. 10.9 ± 13.8 %, respectively; $p < 0.05$ between conditions) associated with a second HR drop (14.0 ± 10.0 vs. 12.7 ± 8.9 %, respectively; $p < 0.01$ between conditions). **Conclusion** This study highlights similar time-course patterns for cardiodynamic variables during dry-body and immersed-body BH, although the phenomenon was more pronounced in the latter condition

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Mixed venous oxygen saturation is impaired during maximal exercise in patients with cystic fibrosis

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Introduction:

We have recently described that patients with cystic fibrosis (CF) exhibit a reduced skeletal muscle oxidative metabolism at rest which may contribute to exercise intolerance in this population. Alterations in muscle oxidative metabolism may reduce the extraction of oxygen (O₂) by the muscle during exercise, resulting in a higher mixed venous O₂ saturation. However, whether or not this impairment is present in CF during exercise has yet to be elucidated.

Purpose:

This study sought to test the hypothesis that mixed venous O₂ saturation is higher in patients with CF compared to controls both at rest and during maximal exercise.

Methods:

Seventeen patients with CF (CF: 8 males and 9 females; 22 ± 9 years) and fifteen controls (C: 7 males and 8 females; 27 ± 8 years) volunteered for this study. An exhaustive incremental exercise test was performed on a cycle ergometer using the Godfrey protocol to determine exercise capacity (VO₂peak). Cardiac output (CO) was monitored non-invasively by Signal-Morphology Impedance Cardiology (PhysioFlow) both at rest and during maximal exercise. Mixed venous oxygen saturation (SvO₂) was determined using a derivation of the Fick equation.

Results:

VO₂ peak normalized for fat-free mass was significantly lower (p<0.001) in CF (42.2 ± 1.4 ml·kg FFM⁻¹·min⁻¹) compared with C (51.6 ± 1.6 ml·kg FFM⁻¹·min⁻¹). CO was similar at both rest (5.0 ± 0.2 vs. 5.4 ± 0.2 l/min, p=0.165) and at maximal exercise (13.3 ± 0.8 vs. 15.6 ± 1.1 l/min, p=0.117) in patients with CF and C, respectively. No differences in SvO₂ were observed between groups at rest (CF: 73 ± 1 vs. C: 74 ± 2 %, p=0.651); however, SvO₂ was significantly higher (p=0.020) at maximal exercise in CF (38 ± 2%) compared with C (28 ± 4%). Additionally, a significant negative correlation was identified between SvO₂ at maximal exercise and VO₂ peak (r = -0.508, p=0.005).

Conclusion:

For the first time, we have documented a higher mixed venous O₂ saturation during maximal exercise in patients with CF that is inversely related to exercise capacity. These findings indicate that the mismatch between O₂ delivery and muscle extraction during exercise may contribute to exercise intolerance in this population. Supported in part by Vertex Pharmaceuticals IIS and NIH/NIDDK R21DK100783 (RAH).

Periodic breathing in healthy humans at exercise in hypoxia

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Abstract:

Periodic breathing is frequent in heart failure or ventilatory disorders during sleep, and common during sleep at high altitude, but has been rarely studied in wakefulness and during exercise. A retrospective analysis of ventilation from hypoxia exercise tests was realized in 82 healthy subjects separated into two groups with either high or low ventilatory response to hypoxia at exercise (HVRe). A fast Fourier transform spectral analysis of the breath-by-breath ventilation (V_E) signal, O_2 saturation, and end-tidal PCO_2 evidenced a periodic pattern with a period of 11.1 to 12.0 s. The peak power of the V_E spectrum was higher in the high HVRe group ($P < 0.001$). A prospective study (25 subjects) was performed to evaluate the influence of cardiorespiratory factors on the amplitude and period of oscillations in various conditions of exercise (20 to 40% maximal aerobic power) and hypoxia (0 to 4,000 m altitude). The period of V_E was shorter at exercise (vs. rest, $P < 0.001$) and hypoxia (vs. normoxia, $P < 0.001$), and inversely related with cardiac output and V_E ($P < 0.001$). V_E peak power was higher at exercise ($P < 0.001$) and hypoxia ($P < 0.001$), and was positively related with cardiac output and V_E ($P < 0.001$). V_E peak power in hypoxia was positively related with the ventilatory response to CO_2 (HCVR). This novel observation suggests that healthy subjects demonstrate a spontaneous periodic breathing, not clearly observable at rest and in normoxia, but triggered by hypoxic exercise. The periodic pattern is enhanced in subjects with high HVRe and high HCVR, suggesting that oxygen and CO_2 play synergistic roles in the modulation of these oscillations.

Keywords:

- Hypoxia
- Control of ventilation
- Periodic breathing
- Hypoxic ventilator response
- Hypercapnic ventilator response
- Exercise

Ventilatory oscillations at exercise: effects of hyperoxia, hypercapnia, and acetazolamide

Physiological Reports ISSN 2051-817X

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Abstract:

Periodic breathing has been found in patients with heart failure and sleep apneas, and in healthy subjects in hypoxia, during sleep and wakefulness, at rest and, recently, at exercise. To unravel the cardiorespiratory parameters liable to modulate the amplitude and period of ventilatory oscillations, 26 healthy subjects were tested under physiological (exercise) and environmental (hypoxia, hyperoxia, hyperoxic hypercapnia) stresses, and under acetazolamide (ACZ) treatment. A fast Fourier transform spectral analysis of breath-by-breath ventilation (VE) evidenced an increase in VE peak power under hypercapnia (vs. normoxia and hyperoxia, $P < 0.001$) and a decrease under ACZ (vs. placebo, $P < 0.001$), whereas it was not modified in hyperoxia. VE period was shortened by exercise in all conditions (vs. rest, $P < 0.01$) and by hypercapnia (vs. normoxia, $P < 0.05$) but remained unchanged under ACZ (vs. placebo). VE peak power was positively related to cardiac output (Q_c) and VE in hyperoxia ($P < 0.01$), in hypercapnia ($P < 0.001$) and under ACZ ($P < 0.001$). VE period was negatively related to Q_c and VE in hyperoxia ($P < 0.01$ and $P < 0.001$, respectively), in hypercapnia ($P < 0.05$ and $P < 0.01$, respectively) and under ACZ ($P < 0.05$ and $P < 0.01$, respectively). Total respiratory cycle time was the main factor responsible for changes in VE period. In conclusion, exercise, hypoxia, and hypercapnia increase ventilator oscillations by increasing Q_c and VE, whereas ACZ decreases ventilatory instability in part by a contrasting action on O_2 and CO_2 sensing. An intrinsic oscillator might modulate ventilation through a complex system where peripheral chemoreflex would play a key role.

Keywords:

- Acetazolamide, • Exercise,
- Hypercapnia,
- Hyperoxia,
- Hypoxia,
- Periodic breathing,
- Ventilatory oscillations.

Cardiovascular Hemodynamic Response to the Normal and Pathologic Human Diving Reflex

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Purpose:

This study followed our award winning clinical abstract from ACSM 2015. Human diving reflex is well known reaction of the cold water immersion. However only limited data are available for those cases, when clinically significant case appears. The aim of the study was to monitor hemodynamic response for two groups of individuals - one with physiologically appropriate reaction, and second with pathological reaction manifested by clinically relevant symptoms

Methods:

Two groups of individuals were monitored during cold water face immersion. Each individual placed the face into the cold water (7°C) immersion until exhaustion. The test has been repeated three times for each individual. The cardiovascular hemodynamic parameters were monitored via 12 lead ECG and noninvasive bio-impedance system PhysioFlow. The following parameters were recorded: heart rate (HR), stroke volume (SV), cardiac output (CO), and systemic vascular resistance (SVR)

Results:

2 individuals with symptomatic pathology (presyncope, dizziness or dyscoordination during swimming) and 5 normal individuals were included. All together 21 measurements were recorded. The detailed information are included in the following table:

		HR (BPM)		SV (ml)		CO (L/min)		SVR (dyn.s/cm ⁵)	
		Pre	Test	Pre	Test	Pre	Test	Pre	Test
Pathologic response	Mean	88	23	83	51	7.3	1.2	944	5141
	1σ	5.8	1.5	5.1	5.6	0.4	0.2	134	667
Normal response	Mean	86	45	95	74	8.2	3.3	890	3240
	1σ	6.6	3.2	4.9	4.5	0.4	0.23	120	580

Conclusion:

Our study demonstrated for the first time, that pathological (overshoot) response to the face water immersion is not only manifested by severe bradycardia. This is rather a whole body circulatory collapse with clinically relevant drop in heart rate and stroke volume resulting in insufficient cardiac output, compensated by global systemic vasoconstriction. Results might help us to understand better possible causes of the sudden death of swimmers and triathlon racers

Histamine H₂ receptor blockade augments blood pressure responses to acute submaximal exercise in males

Appl. Physiol. Nutr. Metab. 41: 605–610 (2016) dx.doi.org/10.1139/apnm-2015-0450
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Abstract:

Histamine is a potent vasodilator that has been found to increase during exercise. We tested the hypothesis that histamine would attenuate blood pressure (BP), cardiac output (CO), and vascular resistance responses to short-term, submaximal dynamic exercise during H₂ receptor blockade. Fourteen healthy men (20–29 years of age) were studied. Systolic (SBP), diastolic (DBP), and mean arterial (MAP) BP and heart rate (HR) were assessed at rest and during the last minute of 10 min of submaximal cycling exercise (60% of peak oxygen consumption) in the absence and presence of histamine H₂ receptor blockade (ranitidine, 300 mg). Stroke volume (SV) (impedance cardiography) and plasma norepinephrine (NE) were measured, and CO, rate × pressure product (RPP), and total peripheral resistance (TPR) were calculated. Plasma levels of histamine were also measured. H₂ blockade had no effects on any variables at rest. During exercise, SBP (184±3mmHg vs. 166±2mmHg), MAP (121 ± 2mmHg vs. 112±5mmHg), and RPP (25.9 ± 0.8 × 103mmHg·beats/min vs. 23.5 ± 0.8 × 103mmHg/beats·min) were greater during blocked conditions (P < 0.05), and an interaction was observed for TPR. SV, DBP, HR, and NE levels were unaffected by blockade. Plasma histamine increased from 1.83 ± 0.14 ng/mL at rest to 2.33 ± 0.23 ng/mL during exercise (P < 0.05) and was not affected by H₂ blockade (1.56 ± 0.23 ng/mL vs. 1.70 ± 0.24 ng/mL). These findings suggest that, during submaximal exercise, histamine attenuates BP, vascular resistance, and the work of the heart via activation of H₂ receptors and that these effects occurred primarily in the vasculature and not in the myocardium.

Key Words:

- cycling,
- norepinephrine,
- rate × pressure product,
- stroke volume,
- ranitidine.

Conclusion:

The results of this study demonstrate that histamine can act on H₂ receptors to attenuate BP, TPR, and RPP in male subjects during short-term submaximal exercise that is capable of causing increases in plasma histamine. Because these effects occur in the absence of changes in HR, SV, and CO, it appears that there is also a redistribution of CO whereby increases in blood flow in some regional circulations are offset by decreases in others. Consequently, we suggest that, during short-term submaximal exercise, histamine mediates peripheral vasodilation, which limits increases in BP and afterload and lowers cardiac workload, effects that lessen stress on the heart.

Effects of chronic dietary nitrate supplementation on the hemodynamic response to dynamic exercise

Am J Physiol Regul Integr Comp Physiol 309: R459–R466, 2015.

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Abstract:

Effects of chronic dietary nitrate supplementation on the hemodynamic response to dynamic exercise. *Am J Physiol Regul Integr Comp Physiol* 309: R459–R466, 2015. First published June 17, 2015; doi:10.1152/ajpregu.00099.2015.—While acute treatment with beetroot juice (BRJ) containing nitrate (NO₃) can lower systolic blood pressure (SBP), afterload, and myocardial O₂ demand during submaximal exercise, effects of chronic supplementation with BRJ (containing a relatively low dose of NO₃, 400 mg) on cardiac output (CO), SBP, total peripheral resistance (TPR), and the work of the heart in response to dynamic exercise are not known. Thus, in 14 healthy males (22 ± 1 yr), we compared effects of 15 days of both BRJ and nitrate-depleted beetroot juice (NDBRJ) supplementation on plasma concentrations of NO_x (NO₃/NO₂), SBP, diastolic blood pressure (DBP), mean arterial pressure (MAP), CO, TPR, and rate pressure product (RPP) at rest and during progressive cycling exercise. Endothelial function was also assessed via flow-mediated dilation (FMD). BRJ supplementation increased plasma NO_x from 83.8 ± 13.8 to 167.6 ± 13.2 μ M. Compared with NDBRJ, BRJ reduced SBP, DBP, MAP, and TPR at rest and during exercise (*P* < 0.05). In addition, RPP was decreased during exercise, while CO was increased, but only at rest and the 30% workload (*P* < 0.05). BRJ enhanced FMD induced increases in brachial artery diameter (pre: 12.3 ± 1.6%; post: 17.8 ± 1.9%). We conclude that 1) chronic supplementation with BRJ lowers blood pressure and vascular resistance at rest and during exercise and attenuates RPP during exercise and 2) these effects may be due, in part, to enhanced endothelium-induced vasodilation in contracting skeletal muscle. Findings suggest that BRJ can act as a dietary nutraceutical capable of enhancing O₂ delivery and reducing work of the heart, such that exercise can be performed at a given workload for a longer period of time before the onset of fatigue.

Results:

Physical characteristics of the subjects are shown in Table 1. Table 2 presents effects of BRJ supplementation on plasma NO_x and brachial artery FMD. BRJ supplementation caused significant increases in resting plasma NO_x concentrations and in FMD. NDBRJ supplementation had no effect on NO_x concentrations or FMD. FMD was positively correlated to NO_x concentrations (*r* = 0.4; *P* < 0.05).

Absolute values of all hemodynamic variables at rest and during the 30%, 60%, and 80% of VO_{2 peak} workloads were not altered by NDBRJ supplementation. Compared with pretreatment conditions, BRJ supplementation reduced SAP, DBP, MAP, and TPR at rest and during all workloads, while RPP was attenuated at every workload (*P* < 0.05) (Figs. 1 and 2). No effects of BRJ on HR were seen (Fig. 1). SV was higher at rest and at the 30% and 60% of VO_{2 peak} workloads after BRJ supplementation, while CO was elevated at rest and during exercise at the 30% of VO_{2 peak} workload (*P* < 0.05) (Fig. 2). Absolute values of all hemodynamic variables at rest and during all workloads were similar when compared between pre-NDBRJ and pre-BRJ supplementation conditions. When compared with NDBRJ supplementation, BRJ attenuated SBP, DBP, MAP, and RPP responses at rest and during exercise (*P* < 0.05) (Figs. 3 and 4). In addition, BRJ augmented SV and attenuated TPR at rest and during the 30% and 60% VO_{2 peak} workloads and augmented CO at the workloads of 30% and 60% of VO_{2 peak} (*P* < 0.05) (Fig. 4). No differences in HR were found between the two conditions at rest or across any workload (Fig. 3).

Single session of sprint interval training elicits similar cardiac output but lower oxygen uptake versus ramp exercise to exhaustion in men and women

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Abstract:

Sprint interval training (SIT) elicits comparable long-term adaptations versus continuous exercise training (CEX) including increased maximal oxygen uptake (VO_2max) and fat utilization. However, there is limited research examining acute hemodynamic responses to SIT. The aim of this study was to examine hemodynamic responses to low-volume SIT. Active men ($n=6$, $\text{VO}_2\text{max} = 39.8 \pm 1.7$ mL/kg/min) and women ($n=7$, $\text{VO}_2\text{max} = 37.3 \pm 5.7$ mL/kg/min) performed a ramp-based VO_2max test (RAMP) to determine workload for the SIT session. Subjects returned within 1 wk and completed a session of SIT consisting of six 30-s bouts of “all-out” cycling at 130% maximal workload (W_{max}) interspersed with 120 s of active recovery. Continuously during RAMP and exercise and recovery in SIT, VO_2 was obtained and thoracic impedance was used to estimate heart rate (HR), stroke volume (SV), and cardiac output (CO). Results revealed no significant differences in CO_{max} ($p = 0.12$, 19.7 ± 2.4 L/min vs. 20.3 ± 1.8 L/min) but lower SV_{max} ($p = 0.004$, 110.4 ± 15.7 mL vs. 119.4 ± 15.5 mL) in RAMP versus SIT. HR_{max} from SIT (179.0 ± 11.8 b/min) was lower ($p = 0.008$) versus RAMP (184.4 ± 7.9 b/min). Peak VO_2 (L/min) was lower ($p < 0.001$) in response to SIT (2.43 ± 0.82 L/min) compared to RAMP (2.84 ± 0.82 L/min). Hemodynamic variables increased linearly across SIT bouts and remained significantly elevated in recovery. Sprint interval training consisting of 3 min of supramaximal exercise elicits similar CO yet lower VO_2 compared to RAMP.

Keywords:

- VO_2max ,
- cycle ergometer,
- cardiac output,
- stroke volume,
- interval training

High-Intensity Interval Training Increases Cardiac Output and VO_{2max}

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Purpose:

This study examined changes in VO_{2max} and cardiac output (CO) in response to periodized HIIT.

Methods:

Thirty-nine active men and women (mean age and $VO_{2max} = 22.9 \pm 5.4$ yr and 39.6 ± 5.6 mL kg⁻¹min⁻¹) performed HIIT and 32 men and women (age and $VO_{2max} = 25.7 \pm 4.5$ yr and 40.7 ± 5.2 mL kg⁻¹min⁻¹) were nonexercising controls (CON). The first 10 sessions of HIIT required eight to ten 60 s bouts of cycling at 90%–110% percent peak power output interspersed with 75 s recovery, followed by randomization to one of three regimes (sprint interval training (SIT), high-volume interval training (HIITHI), or periodized interval training (PER) for the subsequent 10 sessions. Before, midway, and at the end of training, progressive cycling to exhaustion was completed during which VO_{2max} and maximal CO were estimated.

Results:

Compared with CON, significant ($P < 0.001$) increases in VO_{2max} in HIIT + SIT (39.8 ± 7.3 mL kg⁻¹min⁻¹ to 43.6 ± 6.1 mL kg⁻¹min⁻¹), HIIT + HIITHI (41.1 ± 4.9 mL kg⁻¹min⁻¹ to 44.6 ± 7.0 mL kg⁻¹min⁻¹), and HIIT + PER (39.5 ± 5.6 mL kg⁻¹min⁻¹ to 44.1 ± 5.4 mL kg⁻¹min⁻¹) occurred which were mediated by significant increases in maximal CO (20.0 ± 3.1 L min⁻¹ to 21.7 ± 3.2 L min⁻¹, $P = 0.04$). Maximal stroke volume was increased with HIIT ($P = 0.04$), although there was no change in maximal HR ($P = 0.88$) or arteriovenous O₂ difference ($P = 0.36$).

Keywords:

- Interval Exercise,
- Maximal Oxygen Uptake,
- Stroke Volume,
- Thoracic Impedance,
- Fick Equation,
- Cycle Ergometry

Conclusion:

Increases in VO_{2max} exhibited in response to different HIIT regimes are due to improvements in oxygen delivery.

Influence of Active Recovery on Cardiovascular Function During Ice Hockey

Burr et al. Sports Medicine - Open (2015) 1:27
DOI 10.1186/s40798-015-0026-8

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Abstract:

Background: Ice hockey is a popular sport comprised of high-intensity repeated bouts of activity. Light activity, as opposed to passive rest, has been shown to improve power output in repeated sprinting and could potentially help to offset venous pooling, poor perfusion, and the risk of an ischemic event. The objective of our study was, thus, to examine the efficacy of low-intensity lower body activity following a simulated hockey shift for altering hemodynamic function.

Methods: In a cross-over design, 15 healthy hockey players (23 ± 1 years, 54 ± 3 mL/kg/min) performed two simulated hockey shifts. In both conditions, players skated up to 85 % of age-predicted heart rate maximum, followed by either passive recovery or active recovery while hemodynamic measures were tracked for up to 180 s of rest.

Results: Light active recovery within the confines of an ice hockey bench, while wearing skates and protective gear, was effective for augmenting cardiac output (an average of 2.5 ± 0.2 L/min, $p = 0.03$) at 45, 50, and 120 s. These alterations were driven by a sustained elevation in heart rate (12 bpm, $p = 0.05$) combined with a physiological relevant but non-significant (11.6 mL, $p = 0.06$) increase in stroke volume.

Keywords:

- Impedance cardiography;
- Performance; Cardiac risk;
- Venous return;
- Sprint

Key Points:

- Evidence that light activity in the form of standing/pacing is effective for maintaining cardiac output, and thus venous return

- Increased cardiac output and venous return may help reduce the chances of poor perfusion (ischemia) and could also promote recovery for performance

- This is a simple, low-risk, intervention demonstrated for the first time to work within the confines of a player's bench while wearing hockey gear

Conclusion:

Standing and pacing between shifts offers a realistic in-game solution to help slow the precipitous drop in cardiac output (heart rate and stroke volume) that typically occurs with passive rest. Prolonging the duration of an elevated cardiac output further into recovery may be beneficial for promoting recovery of the working skeletal muscles and also avoiding venous pooling and reduced myocardial perfusion.

Physiological Comparison of Concentric and Eccentric Arm Cycling In Males and Females

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Abstract:

Lower body eccentric exercise is well known to elicit high levels of muscular force with relatively low cardiovascular and metabolic strain. As a result, eccentric exercise has been successfully utilised as an adaptive stressor to improve lower body muscle function in populations ranging from the frail and debilitated, to highly-trained individuals. Here we investigate the metabolic, cardiorespiratory, and energy costs of upper body eccentric exercise in a healthy population. Seven men and seven women performed 4-min efforts of eccentric (ECC) or concentric (CON) arm cycling on a novel arm ergometer at workloads corresponding to 40, 60, and 80% of their peak workload as assessed in an incremental concentric trial. The heart rate, ventilation, cardiac output, respiratory exchange ratio, and blood lactate concentrations were all clearly greater in CON condition at all of the relative workloads (all $p < 0.003$). Effect size calculations demonstrated that the magnitude of the differences in VO_2 and work economy between the ECC and CON exercise ranged from very large to extremely large; however, in no case did mechanical efficiency (η_{MECH}) differ between the conditions (all $p > 0.05$). In contrast, delta efficiency (η_{Δ}), as previously defined by Coyle and colleagues in 1992, demonstrated a sex difference (men > women; $p < 0.05$). Sex differences were also apparent in arteriovenous oxygen difference and heart rate during CON. Here, we reinforce the high-force, low cost attributes of eccentric exercise which can be generalised to the muscles of the upper body. Upper body eccentric exercise is likely to form a useful adjunct in debilitating, rehabilitative, and adaptive clinical exercise programs; however, reports of a shift towards an oxidative phenotype should be taken into consideration by power athletes. We suggest delta efficiency as a sensitive measure of efficiency that allowed the identification of sex differences.

Central and peripheral adjustments during high-intensity exercise following cold water immersion

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Abstract:

Purpose We investigated the acute effects of cold water immersion (CWI) or passive recovery (PAS) on physiological responses during high-intensity interval training (HIIT).

Methods In a crossover design, 14 cyclists completed 2 HIIT sessions (HIIT1 and HIIT2) separated by 30 min. Between HIIT sessions, they stood in cold water (10 °C) up to their umbilicus, or at room temperature (27 °C) for 5 min. The natural logarithm of square-root of mean squared differences of successive R–R intervals (ln rMSSD) was assessed pre- and post-HIIT1 and HIIT2. Stroke volume (SV), cardiac output (\dot{Q}), O₂ uptake ($\dot{V}O_2$), total muscle hemoglobin (tHb) and oxygenation of the vastus lateralis were recorded (using near infrared spectroscopy); heart rate, \dot{Q} , and $\dot{V}O_2$ on-kinetics (i.e., mean response time, MRT), muscle de-oxygenation rate, and anaerobic contribution to exercise were calculated for HIIT1 and HIIT2.

Results ln rMSSD was likely higher [between-trial difference (90 % confidence interval) [13.2 % (3.3; 24.0)] after CWI compared with PAS. CWI also likely increased SV [5.9 % (-0.1; 12.1)], possibly increased \dot{Q} [4.4 % (-1.0; 10.3)], possibly slowed \dot{Q} MRT [18.3 % (-4.1; 46.0)], very likely slowed $\dot{V}O_2$ MRT [16.5 % (5.8; 28.4)], and likely increased the anaerobic contribution to exercise [9.7 % (-1.7; 22.5)].

Conclusion:

CWI between HIIT slowed $\dot{V}O_2$ on-kinetics, leading to increased anaerobic contribution during HIIT2. This detrimental effect of CWI was likely related to peripheral adjustments, because the slowing of $\dot{V}O_2$ onkinetics was twofold greater than that of central delivery of O₂ (i.e., \dot{Q}). CWI has detrimental effects on high-intensity aerobic exercise performance that persist for 45 min

Keywords:

- Autonomic nervous system
- $\dot{V}O_2$ on kinetics
- Muscle oxygenation
- High-intensity cycling
- Post-exercise recovery
- Hydrotherapy

Effects of cold water immersion and active recovery on hemodynamics and recovery of muscle strength following resistance exercise

Submitted 14 April 2015; accepted in final form 8 June 2015

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Abstract:

Effects of cold water immersion and active recovery on hemodynamics and recovery of muscle strength following resistance exercise. *Am J Physiol Regul Integr Comp Physiol* 309: R389–R398, 2015. First published June 15, 2015; doi:10.1152/ajpregu.00151.2015.—Cold water immersion (CWI) and active recovery (ACT) are frequently used as postexercise recovery strategies. However, the physiological effects of CWI and ACT after resistance exercise are not well characterized. We examined the effects of CWI and ACT on cardiac output (\dot{Q}), muscle oxygenation (SmO_2), blood volume (tHb), muscle temperature (T_{muscle}), and isometric strength after resistance exercise. On separate days, 10 men performed resistance exercise, followed by 10 min CWI at 10°C or 10 min ACT (low-intensity cycling). \dot{Q} (7.9 ± 2.7 l) and T_{muscle} ($2.2 \pm 0.8^\circ\text{C}$) increased, whereas SmO_2 ($-21.5 \pm 8.8\%$) and tHb ($-10.1 \pm 7.7 \mu\text{M}$) decreased after exercise ($P < 0.05$). During CWI, \dot{Q} (-1.1 ± 0.7 l) and T_{muscle} ($-6.6 \pm 5.3^\circ\text{C}$) decreased, while tHb ($121 \pm 77 \mu\text{M}$) increased ($P < 0.05$). In the hour after CWI, \dot{Q} and T_{muscle} remained low, while tHb also decreased ($P < 0.05$). By contrast, during ACT, \dot{Q} (3.9 ± 2.3 l), T_{muscle} ($2.2 \pm 0.5^\circ\text{C}$), SmO_2 ($17.1 \pm 5.7\%$), and tHb ($91 \pm 66 \mu\text{M}$) all increased ($P < 0.05$). In the hour after ACT, T_{muscle} and tHb remained high ($P < 0.05$). Peak isometric strength during 10-s maximum voluntary contractions (MVCs) did not change significantly after CWI, whereas it decreased after ACT (-30 to -45 Nm; $P < 0.05$). Muscle deoxygenation time during MVCs increased after ACT ($P < 0.05$), but not after CWI. Muscle reoxygenation time after MVCs tended to increase after CWI ($P = 0.052$). These findings suggest first that hemodynamics and muscle temperature after resistance exercise are dependent on ambient temperature and metabolic demands with skeletal muscle, and second, that recovery of strength after resistance exercise is independent of changes in hemodynamics and muscle temperature.

Keywords:

- cryotherapy*;
- muscle*
- oxygenation*;
- blood flow*;
- recovery*

Associations between G tolerance and changes of stroke volume, heart rate, and cardiac output in operating anti-G straining maneuver

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Introduction:

The purpose of performing anti-G straining maneuver (AGSM) is to increase cardiac output (CO) and ultimately, blood supply to the brain, to avoid black out and G-induced loss of consciousness (G-LOC) during high G air combat maneuvers. Until now, the effectiveness of AGSM performed by trainees in Taiwan is evaluated subjectively.

Aims:

To investigate the association between G tolerance and cardiac performance parameters while performing AGSM on the ground and during high G endurance training.

Methods:

This is a longitudinal study design. Young male volunteers were randomly recruited from 2015 flights surgeons/aviation physiologist training program. Cardiac performance parameters (cardiac output, CO ; stroke volume, SV and heart rate, HR) were evaluated using non-invasive instrumentation (PhysioFlow® Enduro™ Manatec Biomedical, Paris, France) on the ground at 1G and during high G endurance training in a human centrifuge (Latécoère, France).

Results and Conclusion:

Five young male (age, 27.8 ± 2.8 years; body mass index, 23.8 ± 3.3) participated in the study. Their mean relaxed and straining G tolerance were 4.7 and 8.6 G, respectively. The effectiveness of AGSM (G increment or gain) was 3.9 G. Ratios of SV, HR, CO between high G training and ground training while performing AGSM were 1.09, 0.94 and 0.95, respectively. During training, three subjects non G-LOC group (n=3) were 1.2, 0.92 and 0.98, respectively while those in the G-LOC group (n=2) were 0.93, 0.97 and 0.89, respectively. When comparing AGSM effectiveness, ratios of SV, HR, CO in G increment $\geq 4G$ group (n=3) were 1.19, 0.98 and 1.08, respectively while those in G increment $< 4G$ group (n=2) were, 0.94, 0.88 and 0.75, respectively. We were able to measure cardiac performance during centrifuge training with non-invasive methodology. In the future, we will recruit air force cadets into our study to pursue our final aim.

Aerospace medicine and human performance, vol.87, N°1 March 2016, P.315

Low haemoglobin concentration in Tibetan males is associated with greater high-altitude exercise capacity

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Abstract:

Tibetans living at high altitude have adapted genetically such that many display a low erythropoietic response, resulting in near sea-level haemoglobin (Hb) concentration. We hypothesized that absence of the erythropoietic response would be associated with greater exercise capacity compared to those with high [Hb] as a result of beneficial changes in oxygen transport. We measured, in 21 Tibetan males with [Hb] ranging from 15.2 g dl⁻¹ to 22.9 g dl⁻¹ (9.4 mmol l⁻¹ to 14.2 mmol l⁻¹), [Hb], ventilation, volumes of O₂ and CO₂ utilized at peak exercise (\dot{V}_{O_2} and \dot{V}_{CO_2}), heart rate, cardiac output and arterial blood gas variables at peak exercise on a cycle ergometer at ~4200 m. Lung and muscle O₂ diffusional conductances were computed from these measurements. [Hb] was related (negatively) to \dot{V}_{O_2} kg⁻¹ ($r = -0.45$, $P < 0.05$), cardiac output kg⁻¹ (QT kg⁻¹, $r = -0.54$, $P < 0.02$), and O₂ diffusion capacity in muscle (DM kg⁻¹, $r = -0.44$, $P < 0.05$), but was unrelated to ventilation, arterial partial pressure of O₂ (P_{aO_2}) or pulmonary diffusing capacity. Using multiple linear regression, variance in peak \dot{V}_{O_2} kg⁻¹ was primarily attributed to QT, DM, and P_{CO_2} ($R^2 = 0.88$). However, variance in pulmonary gas exchange played essentially no role in determining peak \dot{V}_{O_2} . These results (1) show higher exercise capacity in Tibetans without the erythropoietic response, supported mostly by cardiac and muscle O₂ transport capacity and ventilation rather than pulmonary adaptations, and (2) support the emerging hypothesis that the polycythaemia of altitude, normally a beneficial response to low cellular P_{O_2} , may become maladaptive if excessively elevated under chronic hypoxia. The cause and effect relationships among [Hb], QT, DM, and P_{CO_2} remain to be elucidated.

Conclusion:

At altitude >4000 m, Tibetan males with sea-level [Hb], compared to those with elevated [Hb], exhibit greater exercise capacity, higher cardiac output, and greater O₂ diffusional conductance in muscle but not lung. These components as well as PaCO₂ are further associated with exercise capacity. The physiological and genetic relationships among [Hb], cardiac function and muscle O₂ diffusional conductance remain to be elucidated. Supplemental (100%) O₂ given during exercise increases peak work rate in Tibetans by only a third of that reported in Caucasian lowlanders acclimatized to altitude (with no difference between high and low [Hb] groups). Acclimatized Han Chinese males performed similarly in terms of exercise capacity and components of O₂ transport to the high [Hb] Tibetan group, suggesting a lack of adaptive changes in these groups. As indicated in many reports, the fact that healthy Andeans are polycythaemic at altitude, while many Amhara Ethiopians and Tibetans are not, suggests distinct evolutionary paths between these native highland groups.

Impact of Polyphenol Antioxidants on Cycling Performance and Cardiovascular Function

Nutrients. 2014 Mar; 6(3): 1273–1292.

Published online 2014 Mar 24. doi: 10.3390/nu6031273

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Abstract:

This investigation sought to determine if supplementation with polyphenol antioxidant (PA) improves exercise performance in the heat (31.5 °C, 55% RH) by altering the cardiovascular and thermoregulatory responses to exercise. Twelve endurance trained athletes ingested PA or placebo (PLAC) for 7 days. Consecutive days of exercise testing were performed at the end of the supplementation periods. Cardiovascular and thermoregulatory measures were made during exercise. Performance, as measured by a 10 min time trial (TT) following 50 min of moderate intensity cycling, was not different between treatments (PLAC: 292 ± 33 W and PA: 279 ± 38 W, $p = 0.12$). Gross efficiency, blood lactate, maximal neuromuscular power, and ratings of perceived exertion were also not different between treatments. Similarly, performance on the second day of testing, as assessed by time to fatigue at maximal oxygen consumption, was not different between treatments (PLAC; 377 ± 117 s vs. PA; 364 ± 128 s, $p = 0.61$). Cardiovascular and thermoregulatory responses to exercise were not different between treatments on either day of exercise testing. Polyphenol antioxidant supplementation had no impact on exercise performance and did not alter the cardiovascular or thermoregulatory responses to exercise in the heat.

Keywords:

- *thermoregulation*,
- *exercise*,
- *antioxidant*

Conclusion:

Based on the findings of this study, polyphenol antioxidant supplementation had no beneficial effect on performance during both prolonged and short duration exhaustive exercise in the heat in endurance-trained cyclists. Accordingly, polyphenol antioxidant supplementation had no effect on gross cycling efficiency, rating of perceived exertion, or the cardiovascular and thermoregulatory responses to exercise. Overall, these findings question the use of polyphenol antioxidant supplementation as an ergogenic aid aimed at improving endurance exercise performance.

Acute hypoxia in a simulated high-altitude airdrop scenario due to oxygen system failure

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Submitted 22 February 2017; accepted in final form 15 August 2017

Abstract:

High-Altitude High Opening (HAHO) is a military operational procedure in which parachute jumps are performed at high altitude requiring supplemental oxygen, putting personnel at risk of acute hypoxia in the event of oxygen equipment failure. This study was initiated by the Norwegian Army to evaluate potential outcomes during failure of oxygen supply, and to explore physiology during acute severe hypobaric hypoxia. A simulated HAHO without supplemental oxygen was carried out in a hypobaric chamber with decompression to 30,000 ft (9,144 m) and then recompression to ground level with a descent rate of 1,000 ft/min (305 m/min). Nine subjects were studied. Repeated arterial blood gas samples were drawn throughout the entire hypoxic exposure. Additionally, pulse oximetry, cerebral oximetry, and hemodynamic variables were monitored. Desaturation evolved rapidly and the arterial oxygen tensions are among the lowest ever reported in volunteers during acute hypoxia. PaO₂ decreased from baseline 18.4 (17.3–19.1) kPa, 138.0 (133.5–143.3) mmHg, to a minimum value of 3.3 (2.9–3.7) kPa, 24.8 (21.6–27.8) mmHg, after 180 (60–210) s, [median (range)], N 9. Hyperventilation with ensuing hypocapnia was associated with both increased arterial oxygen saturation and cerebral oximetry values, and potentially improved tolerance to severe hypoxia. One subject had a sharp drop in heart rate and cardiac index and lost consciousness 4 min into the hypoxic exposure. A simulated high-altitude airdrop scenario without supplemental oxygen results in extreme hypoxemia and may result in loss of consciousness in some individuals.

Keywords:

- Acute hypoxia
- Altitude
- Blood gas
- HAHO
- Hypoxic syncope

Conclusion:

Failure in oxygen delivery systems during high-altitude airdrops at 30,000 ft (9,144 m) will lead to rapid desaturation and severe hypoxemia. Hypoxic syncope occurred within 4 min in one of our subjects and illustrates the marginal window of opportunity to solve problems in-flight during oxygen supply failure. However, when heart rate and cardiac output are maintained, healthy, fit subjects will transiently tolerate extremely low oxygen tensions. Loss of consciousness occurred in 1 of 9 exposures. We urge personnel engaged in HAHO training to carefully consider the risk-benefit of training at altitudes above 25,000 ft, due to the risk of hypoxic syncope in the event of equipment failure. Proper training in emergency procedures related to problems with oxygen equipment should be implemented in HAHO training.

Cardiac function and exercise adaptation in 8 children with LPIN1 mutations**

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Abstract:

Introduction: Lipin-1 deficiency is a major cause of rhabdomyolysis that are precipitated by febrile illness. The prognosis is poor, with one-third of patients dying from cardiac arrest during a crisis episode. Apart from acute rhabdomyolysis, most patients are healthy, showing normal clinical and cardiac ultrasound parameters. **Patients and methods:** We report cardiac and exercise examinations of 8 children carrying two LPIN1 mutations. The examinations were performed outside of a myolysis episode, but one patient presented with fever during one examination.

Results: All but one patient displayed normal resting cardiac function, as determined by echocardiography. One patient exhibited slight left ventricular dysfunction at rest and a lack of increased stroke volume during cycle ramp exercise. During exercise, peripheral muscle adaptation was impaired in 2 patients compared to healthy controls: they presented an abnormal increase in cardiac output relative to oxygen uptake: $dQ/dVO_2 = 8.2$ and $9.5 (> 2DS$ of controls population). One patient underwent 2 exercise tests; during one test, the patient was febrile, leading to acute rhabdomyolysis in the following hours. He exhibited changes in recovery muscle reoxygenation parameters and an increased dQ/dVO_2 during exercise compared with that under normothermia (7.9 vs 6), which did not lead to acute rhabdomyolysis. The four patients assessed by cardiac 1H-magnetic resonance spectroscopy exhibited signs of intracardiac steatosis.

Conclusion:

We observed abnormal haemodynamic profiles during exercise in 3/8 patients with lipin-1 deficiency, suggesting impaired muscle oxidative phosphorylation during exercise. Fever appeared to be an aggravating factor. One patient exhibited moderate cardiac dysfunction, which was possibly related to intracardiac stored lipid toxicity.

Keywords:

- *Lipin-1*
- *Cardiopulmonary exercise test*
- *Cardiac function*
- *Peripheral muscle adaptation*

**The authors declare that they have no potential, perceived, or real conflicts of interest. The authors declare that there is no study sponsor.
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Hemodynamic adjustments during breath-holding in trained divers.

[Eur J Appl Physiol](#). 2013 Oct;113(10):2523-9. doi: 10.1007/s00421-013-2690-z. Epub 2013 Jul 3.

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Abstract:

PURPOSE:

Voluntary breath-holding (BH) elicits several hemodynamic changes, but little is known about maximal static immersed-body BH. We hypothesized that the diving reflex would be strengthened with body immersion and would spare more oxygen than maximal dry static BH, resulting in a longer BH duration.

METHODS:

Eleven trained breath-hold divers (BHDs) performed a maximal dry-body BH and a maximal immersed-body BH. Cardiac output (CO), stroke volume (SV), heart rate (HR), left ventricular end-diastolic volume (LVEDV), contractility index (CTI), and ventricular ejection time (VET) were continuously recorded by bio-impedancemetry (PhysioFlow PF-05). Arterial oxygen saturation (SaO₂) was assessed with a finger probe oximeter.

RESULTS:

In both conditions, BHDs presented a bi-phasic kinetic for CO and a tri-phasic kinetic for SV and HR. In the first phase of immersed-body BH and dry-body BH, results (mean ± SD) expressed as percentage changes from starting values showed decreased CO (55.9 ± 10.4 vs. 39.3 ± 16.8 %, respectively; $p < 0.01$ between conditions), due to drops in both SV (24.9 ± 16.2 vs. 9.0 ± 8.5 %, respectively; $p < 0.05$ between conditions) and HR (39.7 ± 16.7 vs. 33.6 ± 17.0 %, respectively; $p < 0.01$ between conditions). The second phase was marked by an overall stabilization of hemodynamic variables. In the third one, CO kept stabilizing due to increased SV (17.0 ± 20.2 vs. 10.9 ± 13.8 %, respectively; $p < 0.05$ between conditions) associated with a second HR drop (14.0 ± 10.0 vs. 12.7 ± 8.9 %, respectively; $p < 0.01$ between conditions).

Conclusion:

This study highlights similar time-course patterns for cardiodynamic variables during dry-body and immersed-body BH, although the phenomenon was more pronounced in the latter condition.

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The oxygen-conserving potential of the diving response: A kinetic-based analysis.

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Abstract:

We investigated the oxygen-conserving potential of the human diving response by comparing trained breath-hold divers (BHDs) to non-divers (NDs) during simulated dynamic breath-holding (BH). Changes in haemodynamics [heart rate (HR), stroke volume (SV), cardiac output (CO)] and peripheral muscle oxygenation [oxyhaemoglobin ([HbO₂]), deoxyhaemoglobin ([HHb]), total haemoglobin ([tHb]), tissue saturation index (TSI)] and peripheral oxygen saturation (SpO₂) were continuously recorded during simulated dynamic BH. BHDs showed a breaking point in HR kinetics at mid-BH immediately preceding a more pronounced drop in HR (-0.86 bpm.%-1) while HR kinetics in NDs steadily decreased throughout BH (-0.47 bpm.%-1). By contrast, SV remained unchanged during BH in both groups (all $P > 0.05$). Near-infrared spectroscopy (NIRS) results (mean \pm SD) expressed as percentage changes from the initial values showed a lower [HHb] increase for BHDs than for NDs at the cessation of BH ($+24.0 \pm 10.1$ vs. $+39.2 \pm 9.6\%$, respectively; $P < 0.05$). As a result, BHDs showed a [tHb] drop that NDs did not at the end of BH (-7.3 ± 3.2 vs. $-3.0 \pm 4.7\%$, respectively; $P < 0.05$). The most striking finding of the present study was that BHDs presented an increase in oxygen-conserving efficiency due to substantial shifts in both cardiac and peripheral haemodynamics during simulated BH. In addition, the kinetic-based approach we used provides further credence to the concept of an "oxygen-conserving breaking point" in the human diving response.

Keywords:

- *Diving reflex;*
- *NIRS;*
- *breath-holding;*
- *haemodynamics;*
- *kinetics;*
- *oxygen-conserving effect*

PMID: 27167834 DOI: 10.1080/02640414.2016.1183809

Hemodynamic and cardiorespiratory responses to various arm cycling regimens in men with spinal cord injury

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Abstract:

Study design

Repeated measures within-subjects crossover study.

Objectives

High intensity interval exercise (HIIE) elicits higher oxygen consumption (VO₂) and heart rate (HR) versus moderate intensity continuous exercise (MICE) in men with spinal cord injury (SCI). No study has compared hemodynamic responses to HIIE versus MICE in SCI. In this study, we determined hemodynamic and cardiorespiratory responses to different bouts of arm cycling in men with SCI.

Setting

Human Performance Laboratory, San Diego, CA.

Methods

Five men (age and injury duration = 42.6 ± 16.1 yr and 9.9 ± 7.6 yr) with SCI participated in the study. VO_{2peak} and peak power output were initially assessed. Subsequent visits included MICE, HIIE, sprint interval exercise (SIE), and a no-exercise control (CON). Energy expenditure was matched across modes and equal to 100 ± 10 kcal. During the bouts, cardiac output (CO), stroke volume (SV), HR, and VO₂ were measured.

Results:

Heart rate, SV, and CO increased in response to all exercise bouts and were higher during exercise versus CON. During HIIE and SIE, heart rate approached 90% of maximum, and stroke volume increased by 40% which was higher ($p < 0.05$) versus MICE and CON. In addition, exercise led to a two (MICE) to threefold increase in CO (HIIE and SIE) although it was not different from CON. VO₂ during SIE and HIIE was higher ($p < 0.05$) versus MICE.

Conclusion:

Similar to results in non-disabled populations, HIIE and SIE elicit near-maximal values of SV and CO.

Effect of New Zealand Blackcurrant Extract on Physiological Responses at Rest and during Brisk Walking in Southeast Asian Men: A Randomized, Double-Blind, Placebo-Controlled, Crossover Study.

Nutrients. 2018 Nov 12;10(11). pii: E1732. doi: 10.3390/nu10111732.

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Abstract:

New Zealand blackcurrant (NZBC) extract affects cardiovascular and metabolic responses during rest and exercise in Caucasian men. Ethnicity and nutritional habits may affect responses to nutritional ergogenic aids. We examined the effects of NZBC extract on cardiovascular, metabolic, and physiological responses during seated rest and moderate-intensity exercise in Southeast Asian men. Seventeen healthy Thai men (age: 22 ± 3 years; body mass index (BMI): 21.8 ± 1.1 kg·m⁻²) participated. Resting metabolic equivalent (1-MET) was measured (Oxycon™ mobile, Germany), and an incremental walking protocol was completed to establish the relationship between walking speed and MET. In a double-blind, randomized, placebo-controlled, crossover design, cardiovascular (Physioflow, $n = 12$) and physiological responses (Oxycon, $n = 17$) were measured during both seated rest and a 30-min treadmill walk at five metabolic equivalent (5-MET), with either a seven-day intake of placebo (PL) or two capsules of NZBC extract (each 300 mg capsule contains 35% blackcurrant extract) with a 14-day washout. Paired *t*-tests were used with significance accepted at $p < 0.05$ and a trend for $0.05 > p \leq 0.10$. During 30 min of treadmill walking at 5-MET, no differences were observed for heart rate and substrate oxidation. With intake of NZBC during treadmill walking, there was a trend for increased stroke volume by 12% (PL: 83.2 ± 25.1 ; NZBC: 93.0 ± 24.3 mL; $p = 0.072$) and cardiac output increased by 12% (PL: 9.2 ± 2.6 ; NZBC: 10.3 ± 2.8 L·min⁻¹; $p = 0.057$). Systemic vascular resistance decreased by 10% (PL: 779 ± 267 ; NZBC: 697 ± 245 dyn·s·cm⁻⁵; $p = 0.048$). NZBC extract had no effect on metabolic, physiological, and cardiovascular parameters during seated rest and exercise-induced fat oxidation in Thai men, in contrast to observations in Caucasian men. During treadmill walking, Thai men showed cardiovascular response, indicating vasodilatory effects during moderate-intensity exercise with the intake of NZBC extract. Our findings suggest that the ergogenic responses to anthocyanin intake from New Zealand blackcurrant may be ethnicity-dependent.

Keywords:

- anthocyanins;
- cardiovascular function;
- ethnicity;
- health promotion;
- indirect calorimetry;
- sports nutrition;
- substrate oxidation

Accuracy of Impedance Cardio graphy for Hemodynamic Assessment During Rest and Exercise in Wheelchair Rugby Players

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| • Natalia Morgulec-Adamowicz | • a Józef Pilsudski University of Physical Education in Warsaw. |

Abstract:

Purpose:

The aim of the study was to analyze the accuracy of impedance cardiography (ICG) for hemodynamic assessment in wheelchair rugby players during rest and exercise.

Methods

The study included 21 players (mean age 33.0 ± 5.4 , 86% male) with posttraumatic tetraplegia. ECG, echocardiography, and gas exchange analysis during rest and exercise were used to obtain heart rate (HR), stroke volume (SV), and cardiac output (CO) for comparison with PhysioFlow®.

Results

There was a good correlation between reference methods and ICG for HR, SV, CO at rest and CO at peak exercise ($r = 0.69-0.77$, $p < .001$) and a very good correlation for peak HR ($r = 0.91$, $p < .0001$). ICG overestimated SV at rest, CO at rest, and peak CO, which resulted in low intraclass correlation coefficients (ICC = 0.250 and 0.570).

Conclusion:

ICG can serve as a good estimate of basic hemodynamic parameters during rest and exercise in wheelchair rugby players but overestimates stroke volume and cardiac output.

🌀 **Évaluation de la réponse cardiaque lors d'une apnée statique chez les apnéistes expérimentés par rapport aux sujets témoins et analyse du débit cardiaque en temps réel par méthode non invasive: le PhysioFlow®**

Médecine humaine et pathologie. 2018 (Version française)

Authors:

• Justine Michon • Université de Bordeaux

Résumé :

Introduction :

L'apnée induit des modifications physiologiques qui comprennent une bradycardie et la redistribution du flux sanguin périphérique. Le PhysioFlow® est un outil récent qui utilise les variations de l'impédance thoracique pour mesurer le débit cardiaque (QC) de manière non invasive. Objectif : analyser à l'aide du PhysioFlow® les adaptations cardiaques [QC, fréquence cardiaque (FC) et volume d'éjection systolique (VES)] et leur cinétique lors d'une apnée statique sèche chez un groupe d'apnéistes expérimentés (AE) en comparaison à un groupe témoin non apnéistes (NA). Méthodes : étude de cohorte prospective, conduite entre mai 2017 et octobre 2018 au CHU de Bordeaux. Nous avons inclus un groupe d'AE (n = 10) et un groupe de sujets NA (n = 10). Les critères d'inclusions des sujets AE étaient : avoir participé à des compétitions de niveau régional et avoir un record d'apnée sèche supérieur à quatre minutes. Les sujets ont réalisé une apnée statique sèche maximale après un entraînement d'une douzaine de minutes. Nous avons analysé les données obtenues par le PhysioFlow® sous forme de variations relatives par rapport aux valeurs de départ. Le test U de Mann-Whitney a été utilisé pour comparer les moyennes des deux populations. Critère de jugement principal : Analyse des adaptations cardiaques et leur cinétique au cours de l'apnée. Résultats : les deux échantillons étaient comparables, sauf pour la FC de repos qui était supérieure chez les AE [70 (± 9) vs 59 (± 11) p = 0.025]. La durée de l'apnée était significativement supérieure chez les AE par rapport aux NA [292 ± 51 sec vs 128 ± 44sec, p = 0,0002]. Les AE ont présenté une bradycardie significativement plus importante [FC nadir relative = 55.4 % vs 77.6 %, p = 0.001] et plus durable au cours de l'apnée [FC finale relative = 64.8 % vs 94.8 %, p = 0.001]. Ils atteignaient la FC nadir significativement plus tard au cours de l'apnée [203 sec vs 51 sec, p = 0.003]. Les AE baissaient aussi plus leur QC [QC nadir relatif = 51.2 % vs 65.4 % p = 0.079 ; QC final relatif = 64.6 % vs 88.3 % p = 0.016]. Conclusion : nous avons mis en évidence une majoration significative des adaptations cardiaques chez les AE par rapport aux NA au cours d'une apnée statique sèche en accord avec les études comparables.

Acute cardiopulmonary responses to strength training, high-intensity interval training and moderate-intensity continuous training

2019 Jul;119(7):1513-1523 s00421-019-04138-1. Epub 2019 Apr 8.

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Abstract:

Purpose :

Long-term effects of exercise training are well studied. Acute hemodynamic responses to various training modalities, in particularly strength training (ST), have only been described in a few studies. This study examines the acute responses to ST, high-intensity interval training (HIIT) and moderate-intensity continuous training (MCT).

Methods:

Twelve young male subjects (age 23.4 ± 2.6 years; BMI 23.7 ± 1.5 kg/m²) performed an incremental exertion test and were randomized into HIIT (4 × 4-min intervals), MCT (continuous cycling) and ST (five body-weight exercises) which were matched for training duration. The cardiopulmonary (impedance cardiography, ergo-spirometry) and metabolic response were monitored.

Results:

Similar peak blood lactate responses were observed after HIIT and ST (8.5 ± 2.6 and 8.1 ± 1.2 mmol/l, respectively; $p = 0.83$). The training impact time was $90.7 \pm 8.5\%$ for HIIT and $68.2 \pm 8.5\%$ for MCT ($p < 0.0001$). The mean cardiac output was significantly higher for HIIT compared to that of MCT and ST (23.2 ± 4.1 vs. 20.9 ± 2.9 vs. 12.9 ± 2.9 l/min, respectively; $p < 0.0001$). VO_{2max} was twofold higher during HIIT compared to that observed during ST (2529 ± 310 vs. 1290 ± 156 ml; $p = 0.0004$). Among the components of ST, squats compared with push-ups resulted in different heart rate (111 ± 13.5 vs. 125 ± 15.7 bpm, respectively; $p < 0.05$) and stroke volume (125 ± 23.3 vs. 104 ± 19.8 ml, respectively; $p < 0.05$).

Conclusion:

Despite an equal training duration and a similar acute metabolic response, large differences with regard to the training impact time and the cardiopulmonary response give evident. HIIT and MCT, but less ST, induced a sufficient cardiopulmonary response, which is important for the preventive effects of training; however, large differences in intensity were apparent for ST.

Single-leg cycling increases limb-specific blood flow without concurrent increases in normalised power output when compared with double-leg cycling in healthy middle-aged adults

2020 Mar;20(2):202-210 17461391.2019.1617789. Epub 2019 May 23.

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Abstract:

This study examined the acute performance, cardiovascular and local muscular responses to perceived exertion-based high-intensity interval exercise using either double- or single-leg cycling. Fifteen healthy middle-aged adults completed, on separate occasions, ten 30-s double-leg intervals interspersed with 60 s passive recovery and twenty (ten with each leg) 30-s single-leg intervals interspersed with 60 s passive recovery. Impedance cardiography, blood pressure, muscle oxygenation and total haemoglobin content (near-infrared spectroscopy), oxygen consumption and power output were measured throughout each session. Normalised to the lean mass used during each trial, single-leg cycling resulted in lower power output (single-leg: 8.92 ± 1.74 W kg⁻¹ and double-leg: 10.41 ± 3.22 W kg⁻¹; $p < 0.05$) but greater oxygen consumption (single-leg: 103 ± 11 mL kg⁻¹ min⁻¹ and double-leg: 84 ± 21 mL kg⁻¹ min⁻¹; $p < 0.01$) and cardiac output (single-leg: 1407 ± 334 mL kg⁻¹ min⁻¹ and double-leg: 850 ± 222 mL kg⁻¹ min⁻¹; $p < 0.01$), compared with double-leg cycling. Mean arterial pressure (double-leg: 108 ± 11 mmHg and single-leg: 102 ± 10 mmHg), change in total haemoglobin content (double-leg: 8.76 ± 10.65 μM cm s⁻¹ and single-leg: 13.42 ± 4.10 μM cm s⁻¹) and change in tissue oxygenation index (double-leg: $-4.51 \pm 3.56\%$ and single-leg: $-3.97 \pm 3.91\%$) were not different between double-leg and single-leg cycling. When compared to double-leg cycling, single-leg cycling elicited a higher cardiac output relative to the lean mass, but this did not result in greater power output. The dissociation between blood availability and power output is consistent with an ageing model characterised by a decrease in local oxygen delivery and distribution capability.

Performance evaluation of a portable bioimpedance cardiac output monitor for measuring hemodynamic changes in athletes during a head-up tilt test

2020 May 1;128(5):1146-1152 *jappphysiol.00822.2019. Epub 2020 Mar 26.*

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Abstract:

Cardiac output (CO) monitoring is useful for sports performance training, but most methods are unsuitable as they are invasive or hinder performance. The performance of PhysioFlow (PF), a portable noninvasive transthoracic bioimpedance CO monitor, was evaluated and compared with a reference Doppler CO monitor, USCOM, using a head-up tilt (HUT) test. With ethics committee approval, 20 healthy well-trained athletes were subjected to HUT in a fixed order of 0°, 70°, 30°, and 0° for 3 min each. Simultaneous hemodynamic measurements using PF and USCOM were made 30 s after a change in HUT and analyzed using *t* tests, ANOVA, and mountain plots. Heart rate (HR) and stroke volume (SV) from both monitors changed according to physiological expectation of tilt, but PF measurements of SV were higher with a positive bias (PF vs. USCOM, 0°: 87.3 vs. 54.0 mL, $P < 0.001$; 70°: 76.5 vs. 39.5 mL, $P < 0.001$; 30°: 81.4 vs. 50.1 mL, $P < 0.001$; 0°: 88.3 vs. 57.1 mL, $P < 0.001$). Relative changes in SV (Δ SV) after each tilt measured using PF were lower with a negative bias (PF vs. USCOM, 0° to 70°: -12.3% vs. -26.3%, $P = 0.002$; 70° to 30°: +6.4% vs. +31.2%, $P < 0.001$; 30° to 0°: +9.2% vs. +15.8%, $P = 0.280$). CO measurements using PF at 70° were erroneous. Compared with USCOM, PF overestimated SV measurements but underestimated the Δ SV between HUT. Accuracy of the PF deteriorated at 70°, implying a gravitational influence on its performance. These findings suggested that the suitability of PF for sports use is questionable. **NEW & NOTEWORTHY** The use of impedance cardiography to monitor physiological changes in sports is rarely reported. Using head-up tilt test, we evaluated a portable noninvasive impedance cardiography device (PhysioFlow) by comparing it with a reference Doppler monitor (USCOM). Accuracy in tracking hemodynamic changes deteriorated with higher tilt, implying a gravitational influence on its performance. Stroke volume measurements were overestimated, but the changes were underestimated. Despite its convenient physical features, the suitability of PhysioFlow for sports use is questionable.

IMPORTANT NOTE FROM THE MANUFACTURER:

Letter to the editor by Pr. Jonathan Myers and Pr. Pierre-Marie Leprêtre

We wish to draw the readers' attention to a number of significant weaknesses of this study. First, Head Up Tilt test (HUT) was used as a surrogate for actual exercise testing in order to evaluate the agreement between two cardiac output (CO) measurement modalities. However, HUT and exercise are physiologically quite different: HUT is passive, with a purely gravitational effect on hemodynamics. Exercise is active with various kinds of stimuli on hemodynamic function. “Validating” exercise measurements with HUT measurements is therefore limited. Second, The authors use the USCOM technology as a “gold standard” for evaluating CO during HUT (and by extension, exercise). However, the USCOM system has not been formally validated under these circumstances, whereas PhysioFlow was validated against invasive and non-invasive references during exercise, including on healthy trained subjects. Third, the average BSA of the study group is 1.73 m² following the Dubois formula. Therefore, the average USCOM Cardiac Index (CI) is 1.96 l.min⁻¹.m⁻² in supine position, 1.67 at 70°, 1.91 at 30°, and 2.20 at 0°. For PhysioFlow, the matching readings are 3.35, 3.58, 3.29, 3.58. It is universally accepted in cardiology and critical care that the normal range for CI starts at approximately 2.6 l.min⁻¹.m⁻², and that a CI below 2.0 is an indicator of cardiac shock and a strong predictor of increased mortality. These USCOM readings therefore appear physiologically impossible, keeping in mind that the subjects are young, healthy non bradycardic athletes. Fourth, the authors base their analysis of the effect of postural changes on the fact that the aortic root diameter is fixed (as determined by a nomogram with the USCOM system). However, there is some evidence that this might not be the case. A study performed on healthy young adults with echo reported an increase in the aortic root diameter of from 3% to 6% on average from the standing compared to the supine position. Stroke volume (SV), as measured with ultrasound, uses the aortic diameter at the power of two to estimate the aortic cross-sectional area. Therefore, the real increase in cross sectional area could be fairly significant during postural change, leading to an underestimation of SV by a technology like USCOM, when the head is up, and therefore an overestimation of the decrease in SV. PhysioFlow shows more limited, and probably more physiological, drops in SV for these young trained subjects. Fifth, Table 2 shows the changes in SV at different stages of the tilt test, expressed as a percentage change from the previous stage. Contrary to PhysioFlow, the USCOM results show considerable inter-subject variability, which could potentially lead to paradoxical results in terms of average measurements in a small group of 20 subjects. Such errors limit both the interpretation of the data and the conclusions of the study (PhysioFlow does not work during HUT and exercise). The correct conclusion is that the USCOM system should be used with caution because of its potential for error.

Metabolic and Cardiovascular Responses on a Novel, Whole Body Exercise Device Compared to a Cycle Ergometer

2019 Nov 1;12(2):1206-1215 eCollection 2019.

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Abstract:

The purpose of this study was to compare the metabolic effects during a similar bout of exercise on a novel, whole body exercise device (Fish and Kangaroo Machine; FKM) and a cycle ergometer. Recreationally active men and women ($n = 13$) completed two exercise sessions. The exercise protocol included intervals alternating between exercise (3-min) and rest (3-min) for a total duration of 39-min. The exercise intensity between the two modes was matched based on heart rate response. Heart rate, cardiac output, and stroke volume were measured using a wireless telemetry technique (Physioflow Enduro). Oxygen consumption (VO_2) was measured via breath-by-breath automated analysis of expired respiratory gas (MGC Diagnostics Ultima). Capillary blood lactate was measured using a handheld meter (LactatePlus). While maintaining the heartrate response, stroke volume presented at a higher-level during rest periods, although not significant. There was also higher cardiac output at the end of the exercise bout with the FKM. VO_2 was lower at the same heart rate and peak lactate was higher during FKM exercise. Cardiovascular recovery was improved following FKM exercise compared to cycling. The observed responses demonstrated that for a similar heart rate response, the FKM has an enhanced anaerobic metabolic component compared to cycling. These findings demonstrate the FKM may represent a novel exercise device comparable to cycling with unique anaerobic training potential.

Effects of surgical and FFP2/N95 face masks on cardiopulmonary exercise capacity

2020 Jul 6;1-9 s00392-020-01704-y. Online ahead of print.

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Abstract:

Background:

Due to the SARS-CoV2 pandemic, medical face masks are widely recommended for a large number of individuals and long durations. The effect of wearing a surgical and a FFP2/N95 face mask on cardiopulmonary exercise capacity has not been systematically reported.

Methods:

This prospective cross-over study quantitated the effects of wearing no mask (nm), a surgical mask (sm) and a FFP2/N95 mask (ffpm) in 12 healthy males (age 38.1 ± 6.2 years, BMI 24.5 ± 2.0 kg/m²). The 36 tests were performed in randomized order. The cardiopulmonary and metabolic responses were monitored by ergo-spirometry and impedance cardiography. Ten domains of comfort/discomfort of wearing a mask were assessed by questionnaire.

Results:

The pulmonary function parameters were significantly lower with mask (forced expiratory volume: 5.6 ± 1.0 vs 5.3 ± 0.8 vs 6.1 ± 1.0 l/s with sm, ffpm and nm, respectively; $p = 0.001$; peak expiratory flow: 8.7 ± 1.4 vs 7.5 ± 1.1 vs 9.7 ± 1.6 l/s; $p < 0.001$). The maximum power was 269 ± 45 , 263 ± 42 and 277 ± 46 W with sm, ffpm and nm, respectively; $p = 0.002$; the ventilation was significantly reduced with both face masks (131 ± 28 vs 114 ± 23 vs 99 ± 19 l/m; $p < 0.001$). Peak blood lactate response was reduced with mask. Cardiac output was similar with and without mask. Participants reported consistent and marked discomfort wearing the masks, especially ffpm.

Conclusion:

Ventilation, cardiopulmonary exercise capacity and comfort are reduced by surgical masks and highly impaired by FFP2/N95 face masks in healthy individuals. These data are important for recommendations on wearing face masks at work or during physical exercise.

Quantifying the effects of four weeks of low-volume high-intensity sprint interval training on $\dot{V}O_2\text{max}$ through assessment of hemodynamics

2020 Jan;60(1):53-61 S0022-4707.19.09912-2.

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- Marie Gernigon • Laboratory of Complexity, Innovation, Physical Activity, and Sports, University Paris Saclay, Paris, France.
- Henry Chung • Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, UK.

Abstract:

Background:

Sprint interval training is a popular workout modality. Studies have eluded to a positive effect on maximal oxygen uptake, however little is known about the mechanistic basis of this adaptation. Therefore, the purpose of this study was to determine the effects of a short-term high-intensity sprint interval training (SIT) intervention on $\dot{V}O_2\text{max}$ through quantification of both the respiratory and hemodynamic responses.

Methods:


Thirty-six physically active participants undertook 4 weeks of either cycling-based SIT (8×20 s at 170% P- $\dot{V}O_2\text{max}$ with 10 s recovery) or continuous exercise training (CET) (30 min at 70% P- $\dot{V}O_2\text{max}$) 3 times per week. $\dot{V}O_2\text{max}$, blood-based markers and hemodynamic responses were assessed pre and post the intervention period. $\dot{V}O_2\text{max}$ was assessed using breath-by-breath open circuit spirometry, while hemodynamic responses were monitored using thoracic impedance cardiography.

Results:

$\dot{V}O_2\text{max}$ exhibited a non-significant 4.1% increase (ES=0.24) for SIT with 7.0% P=0.007 (ES=0.40) increase for CET. Hemodynamic responses (maximal cardiac output, maximal stroke volume) displayed non-significant responses for CET and SIT while a- $\dot{v}O_2\text{dif-max}$ increased from 15.8±4.8 to 18.3±2.9 mL/100 mL (P=0.02) (ES=0.63) in SIT.

Conclusion:

$\dot{V}O_2\text{max}$ is a function of maximal cardiac output and a- $\dot{v}O_2\text{dif-max}$, so for a meaningful change to occur in cardiorespiratory fitness, there must be a concomitant increase in O₂ delivery. This study demonstrates that a low volume SIT intervention evokes peripherally mediated responses (a- $\dot{v}O_2\text{dif}$) and anaerobic substrate utilization rather than O₂ delivery components. Future works should address the time course of the responses and when assessing $\dot{V}O_2\text{max}$ -based responses that due attention be given to the hemodynamic responses as means of quantification of the response.

 **Evaluation of the cardiac response during static apnea in experienced apneists compared to control subjects and real-time cardiac output analysis using a non-invasive method: the PhysioFlow®.**

Human medicine and pathology 2018 (English version)


Authors:

- Justine Michon
- Université de Bordeaux

Summary:

Introduction:

Apnea induces physiological changes that include bradycardia and redistribution of peripheral blood flow. The PhysioFlow® is a recent tool that uses changes in thoracic impedance to measure cardiac output (QC) non-invasively. Objective: to analyze with PhysioFlow® the cardiac adaptations [QC, heart rate (HR) and systolic ejection volume (SEV)] and their kinetics during dry static apnea in a group of experienced apneists (AE) compared to a non-apneist control group (NA). Methods: Prospective cohort study, conducted between May 2017 and October 2018 at the Bordeaux University Hospital. We included an AE group (n = 10) and a group of NA subjects (n = 10). The criteria for inclusion of AE subjects were: to have participated in regional level competitions and to have a dry apnea record of more than four minutes. Subjects achieved maximum dry static apnea after training for 12 minutes. We analyzed the data obtained by PhysioFlow® as relative variations from baseline values. The Mann-Whitney U-test was used to compare the means of the two populations. Primary endpoint : Analysis of cardiac adaptations and their kinetics during apnea. Results: The two samples were comparable, except for resting HR, which was higher in AEs [70 (± 9) vs. 59 (± 11) p = 0.025]. The duration of apnea was significantly longer in AEs than in NA [292 ± 51 sec vs. 128 ± 44 sec, p = 0.0002]. AEs had significantly greater bradycardia [relative nadir HR = 55.4% vs 77.6%, p = 0.001] and longer duration of apnea [relative final HR = 64.8% vs 94.8%, p = 0.001]. They reached nadir HR significantly later in apnea [203 sec vs. 51 sec, p = 0.003]. AEs also lowered their QC more [relative QC nadir = 51.2% vs. 65.4% p = 0.079; relative final QC = 64.6% vs. 88.3% p = 0.016]. Conclusion: We found a significant increase in cardiac adaptations in AEs compared to NA during dry static apnea in agreement with comparable studies.

 **Priming the cardiodynamic phase of pulmonary oxygen uptake through voluntary modulations of the respiratory pump at the onset of exercise.**

2021 Feb;106(2):555-566. doi: 10.1113/EP089180. Epub 2021 Jan 6

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Abstract:

New findings:

What is the central question of this study? The initial increase in oxygen uptake ($\dot{V}O_2$) at exercise onset results from pulmonary perfusion changes secondary to an increased venous return. Breathing mechanics contribute to venous return through abdominal and intrathoracic pressures variation. Can voluntary breathing techniques (abdominal or rib cage breathing) increase venous return and improve $\dot{V}O_2$ at exercise onset? What is the main finding and its importance? Abdominal and rib cage breathing increase venous return and $\dot{V}O_2$ at exercise onset. This mechanism could be clinically relevant in patients with impaired cardiac function limiting oxygen transport.

Abstract:

What is the central question of this study? The initial increase in oxygen uptake ($\dot{V}O_2$) at exercise onset results from pulmonary perfusion changes secondary to an increased venous return. Breathing mechanics contribute to venous return through abdominal and intrathoracic pressures variation. Can voluntary breathing techniques (abdominal or rib cage breathing) increase venous return and improve $\dot{V}O_2$ at exercise onset? What is the main finding and its importance? Abdominal and rib cage breathing increase venous return and $\dot{V}O_2$ at exercise onset. This mechanism could be clinically relevant in patients with impaired cardiac function limiting oxygen transport.

Quantifying the effects of four weeks of low-volume high-intensity sprint interval training on $\dot{V}O_{2max}$ through assessment of hemodynamics.

2020 Jan;60(1):53-61. doi: 10.23736/S0022-4707.19.09912-2.

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| • Henry Chung | • Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, UK. |

Abstract:

Background:

Sprint interval training is a popular workout modality. Studies have eluded to a positive effect on maximal oxygen uptake, however little is known about the mechanistic basis of this adaptation. Therefore, the purpose of this study was to determine the effects of a short-term high-intensity sprint interval training (SIT) intervention on $\dot{V}O_{2max}$ through quantification of both the respiratory and hemodynamic responses.

Methods:

Thirty-six physically active participants undertook 4 weeks of either cycling-based SIT (8×20 s at 170% P- $\dot{V}O_{2max}$ with 10 s recovery) or continuous exercise training (CET) (30 min at 70% P- $\dot{V}O_{2max}$) 3 times per week. $\dot{V}O_{2max}$, blood-based markers and hemodynamic responses were assessed pre and post the intervention period. $\dot{V}O_{2max}$ was assessed using breath-by-breath open circuit spirometry, while hemodynamic responses were monitored using thoracic impedance cardiography.

Results:

$\dot{V}O_{2max}$ exhibited a non-significant 4.1% increase (ES=0.24) for SIT with 7.0% P=0.007 (ES=0.40) increase for CET. Hemodynamic responses (maximal cardiac output, maximal stroke volume) displayed non-significant responses for CET and SIT while a- $vO_{2dif-max}$ increased from 15.8±4.8 to 18.3±2.9 mL/100 mL (P=0.02) (ES=0.63) in SIT.

Conclusion:

$\dot{V}O_{2max}$ is a function of maximal cardiac output and a- $vO_{2dif-max}$, so for a meaningful change to occur in cardiorespiratory fitness, there must be a concomitant increase in O₂ delivery. This study demonstrates that a low volume SIT intervention evokes peripherally mediated responses (a- vO_{2dif}) and anaerobic substrate utilization rather than O₂ delivery components. Future works should address the time course of the responses and when assessing $\dot{V}O_{2max}$ -based responses that due attention be given to the hemodynamic responses as means of quantification of the response.

 **Changes in VO₂max and cardiac output in response to short-term high-intensity interval training in Caucasian and Hispanic young women: A pilot study.**

2021 Jan 22;16(1):e0244850. doi: 10.1371/journal.pone.0244850. eCollection 2021.

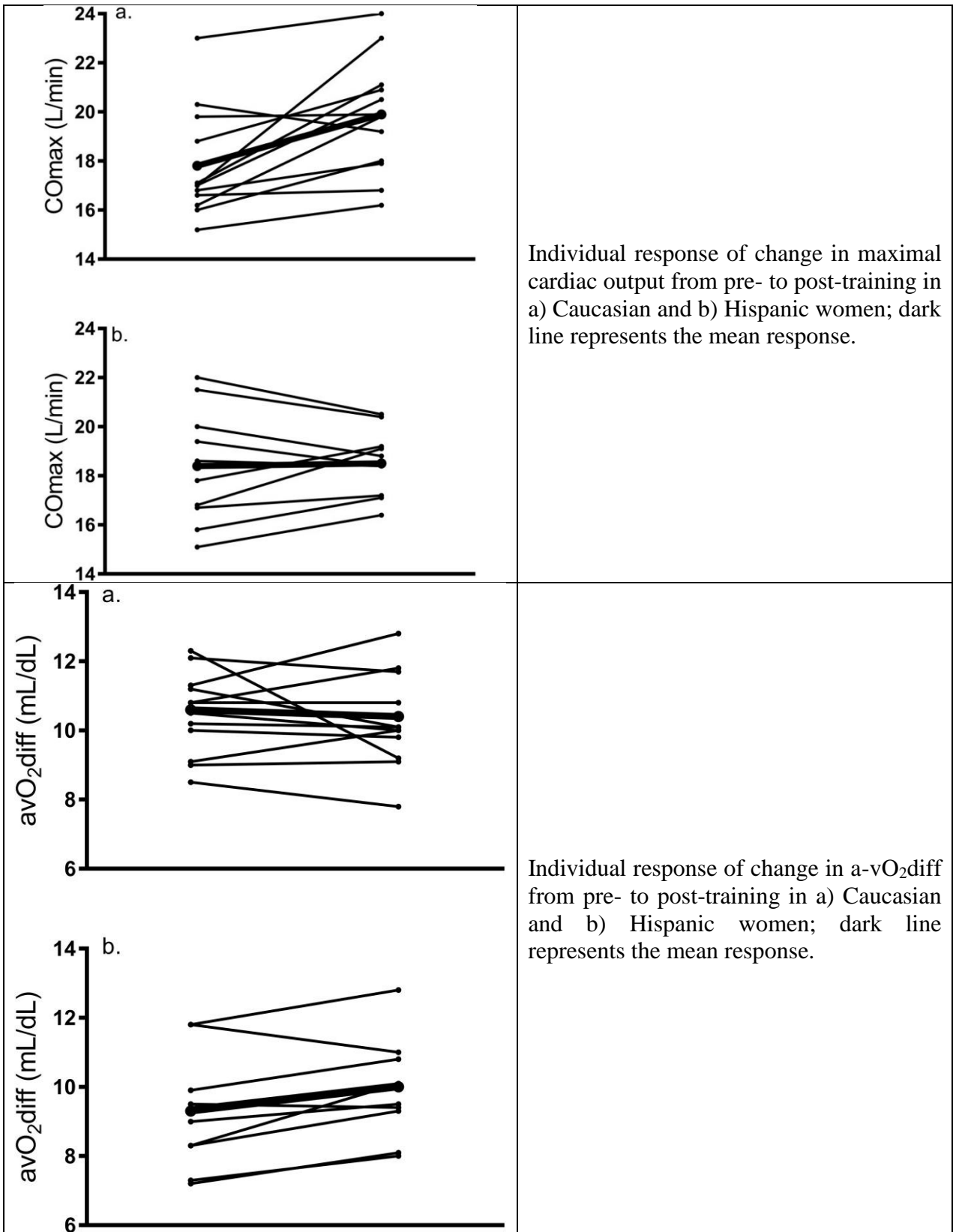
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Abstract:

Data obtained in primarily Caucasian (C) and African American adults show that ethnicity does not mediate responsiveness to exercise training. It is unknown if Hispanics (H), who face elevated health risks and are less active than C, exhibit a similar response to exercise training. This study compared cardiorespiratory and hemodynamic responses to high intensity interval training (HIIT) between C and H women. Twelve C and ten H women ages 19-35 yr who were non-obese and inactive completed nine sessions of HIIT over a 3 wk period. Maximal oxygen uptake (VO₂max) was assessed twice at baseline during which thoracic impedance was used to evaluate heart rate (HR), stroke volume (SV) and cardiac output (CO). Habitual physical activity was assessed using accelerometry. Results showed a significant main effect of training for VO₂max in C and H ($F = 13.97$, $p = 0.001$) and no group by training interaction ($p = 0.65$). There was a main effect of training for CO and SV in C and H ($F = 7.57$, $p = 0.01$; $F = 7.16$, $p = 0.02$), yet post hoc analyses revealed significant increases were only exhibited in C. There was a tendency for a group by training interaction for a-VO₂diff ($F = 1.32$, $p = 0.054$), and a large effect size was seen in H ($d = 1.02$). Overall, data show no effect of ethnicity on changes in VO₂max with low-volume HIIT, yet C and H may achieve this outcome differently. Longer studies in similar populations are needed to verify this result.

<pre> graph TD A[Assessed for eligibility (n=142)] --> B[Pre-Training (n=28)] A --> C[Excluded (n=114) • Declined to participate (n=78) • Did not meet inclusion criteria (n=36)] B --> D[Post-Training (n=22)] B --> E[Did not complete training period due to dropout (n=6)] </pre>	<p>Participant flow through the study.</p>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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<tr><td>62</td><td>7.4</td><td>7.6</td></tr> <tr><td>63</td><td>7.5</td><td>7.7</td></tr> <tr><td>64</td><td>7.6</td><td>7.8</td></tr> <tr><td>65</td><td>7.7</td><td>7.9</td></tr> <tr><td>66</td><td>7.8</td><td>8.0</td></tr> <tr><td>67</td><td>7.9</td><td>8.1</td></tr> <tr><td>68</td><td>8.0</td><td>8.2</td></tr> <tr><td>69</td><td>8.1</td><td>8.3</td></tr> <tr><td>70</td><td>8.2</td><td>8.4</td></tr> <tr><td>71</td><td>8.3</td><td>8.5</td></tr> <tr><td>72</td><td>8.4</td><td>8.6</td></tr> <tr><td>73</td><td>8.5</td><td>8.7</td></tr> <tr><td>74</td><td>8.6</td><td>8.8</td></tr> <tr><td>75</td><td>8.7</td><td>8.9</td></tr> <tr><td>76</td><td>8.8</td><td>9.0</td></tr> <tr><td>77</td><td>8.9</td><td>9.1</td></tr> <tr><td>78</td><td>9.0</td><td>9.2</td></tr> <tr><td>79</td><td>9.1</td><td>9.3</td></tr> <tr><td>80</td><td>9.2</td><td>9.4</td></tr> <tr><td>81</td><td>9.3</td><td>9.5</td></tr> <tr><td>82</td><td>9.4</td><td>9.6</td></tr> <tr><td>83</td><td>9.5</td><td>9.7</td></tr> <tr><td>84</td><td>9.6</td><td>9.8</td></tr> <tr><td>85</td><td>9.7</td><td>9.9</td></tr> <tr><td>86</td><td>9.8</td><td>10.0</td></tr> <tr><td>87</td><td>9.9</td><td>10.1</td></tr> <tr><td>88</td><td>10.0</td><td>10.2</td></tr> <tr><td>89</td><td>10.1</td><td>10.3</td></tr> <tr><td>90</td><td>10.2</td><td>10.4</td></tr> <tr><td>91</td><td>10.3</td><td>10.5</td></tr> <tr><td>92</td><td>10.4</td><td>10.6</td></tr> <tr><td>93</td><td>10.5</td><td>10.7</td></tr> <tr><td>94</td><td>10.6</td><td>10.8</td></tr> <tr><td>95</td><td>10.7</td><td>10.9</td></tr> <tr><td>96</td><td>10.8</td><td>11.0</td></tr> <tr><td>97</td><td>10.9</td><td>11.1</td></tr> <tr><td>98</td><td>11.0</td><td>11.2</td></tr> <tr><td>99</td><td>11.1</td><td>11.3</td></tr> <tr><td>100</td><td>11.2</td><td>11.4</td></tr> <tr><td>101</td><td>11.3</td><td>11.5</td></tr> <tr><td>102</td><td>11.4</td><td>11.6</td></tr> <tr><td>103</td><td>11.5</td><td>11.7</td></tr> <tr><td>104</td><td>11.6</td><td>11.8</td></tr> <tr><td>105</td><td>11.7</td><td>11.9</td></tr> <tr><td>106</td><td>11.8</td><td>12.0</td></tr> <tr><td>107</td><td>11.9</td><td>12.1</td></tr> <tr><td>108</td><td>12.0</td><td>12.2</td></tr> <tr><td>109</td><td>12.1</td><td>12.3</td></tr> <tr><td>110</td><td>12.2</td><td>12.4</td></tr> <tr><td>111</td><td>12.3</td><td>12.5</td></tr> <tr><td>112</td><td>12.4</td><td>12.6</td></tr> <tr><td>113</td><td>12.5</td><td>12.7</td></tr> <tr><td>114</td><td>12.6</td><td>12.8</td></tr> <tr><td>115</td><td>12.7</td><td>12.9</td></tr> <tr><td>116</td><td>12.8</td><td>13.0</td></tr> <tr><td>117</td><td>12.9</td><td>13.1</td></tr> <tr><td>118</td><td>13.0</td><td>13.2</td></tr> <tr><td>119</td><td>13.1</td><td>13.3</td></tr> <tr><td>120</td><td>13.2</td><td>13.4</td></tr> <tr><td>121</td><td>13.3</td><td>13.5</td></tr> <tr><td>122</td><td>13.4</td><td>13.6</td></tr> <tr><td>123</td><td>13.5</td><td>13.7</td></tr> <tr><td>124</td><td>13.6</td><td>13.8</td></tr> <tr><td>125</td><td>13.7</td><td>13.9</td></tr> <tr><td>126</td><td>13.8</td><td>14.0</td></tr> <tr><td>127</td><td>13.9</td><td>14.1</td></tr> <tr><td>128</td><td>14.0</td><td>14.2</td></tr> <tr><td>129</td><td>14.1</td><td>14.3</td></tr> <tr><td>130</td><td>14.2</td><td>14.4</td></tr> <tr><td>131</td><td>14.3</td><td>14.5</td></tr> <tr><td>132</td><td>14.4</td><td>14.6</td></tr> <tr><td>133</td><td>14.5</td><td>14.7</td></tr> <tr><td>134</td><td>14.6</td><td>14.8</td></tr> <tr><td>135</td><td>14.7</td><td>14.9</td></tr> <tr><td>136</td><td>14.8</td><td>15.0</td></tr> <tr><td>137</td><td>14.9</td><td>15.1</td></tr> <tr><td>138</td><td>15.0</td><td>15.2</td></tr> <tr><td>139</td><td>15.1</td><td>15.3</td></tr> <tr><td>140</td><td>15.2</td><td>15.4</td></tr> <tr><td>141</td><td>15.3</td><td>15.5</td></tr> <tr><td>142</td><td>15.4</td><td>15.6</td></tr> </tbody> </table>	Participant	Pre-Training (L/min)	Post-Training (L/min)	1	1.4	1.6	2	1.7	1.9	3	1.8	2.0	4	1.8	2.0	5	1.9	2.0	6	1.9	2.0	7	1.9	2.0	8	2.0	2.1	9	2.0	2.1	10	2.0	2.1	11	2.0	2.1	12	2.0	2.1	13	2.0	2.1	14	2.0	2.1	15	2.0	2.1	16	2.0	2.1	17	2.0	2.1	18	2.0	2.1	19	2.0	2.1	20	2.0	2.1	21	2.0	2.1	22	2.0	2.1	23	2.0	2.1	24	2.0	2.1	25	2.0	2.1	26	2.0	2.1	27	2.0	2.1	28	2.0	2.1	29	2.0	2.1	30	2.0	2.1	31	2.0	2.1	32	2.0	2.1	33	2.0	2.1	34	2.0	2.1	35	2.0	2.1	36	2.0	2.1	37	2.0	2.1	38	2.0	2.1	39	2.0	2.1	40	2.0	2.1	41	2.0	2.1	42	2.0	2.1	43	2.0	2.1	44	2.0	2.1	45	2.0	2.1	46	2.0	2.1	47	2.0	2.1	48	2.0	2.1	49	2.0	2.1	50	2.0	2.1	51	2.0	2.1	52	2.0	2.1	53	2.0	2.1	54	2.0	2.1	55	2.0	2.1	56	2.0	2.1	57	2.0	2.1	58	2.0	2.1	59	2.0	2.1	60	2.0	2.1	61	2.0	2.1	62	2.0	2.1	63	2.0	2.1	64	2.0	2.1	65	2.0	2.1	66	2.0	2.1	67	2.0	2.1	68	2.0	2.1	69	2.0	2.1	70	2.0	2.1	71	2.0	2.1	72	2.0	2.1	73	2.0	2.1	74	2.0	2.1	75	2.0	2.1	76	2.0	2.1	77	2.0	2.1	78	2.0	2.1	79	2.0	2.1	80	2.0	2.1	81	2.0	2.1	82	2.0	2.1	83	2.0	2.1	84	2.0	2.1	85	2.0	2.1	86	2.0	2.1	87	2.0	2.1	88	2.0	2.1	89	2.0	2.1	90	2.0	2.1	91	2.0	2.1	92	2.0	2.1	93	2.0	2.1	94	2.0	2.1	95	2.0	2.1	96	2.0	2.1	97	2.0	2.1	98	2.0	2.1	99	2.0	2.1	100	2.0	2.1	101	2.0	2.1	102	2.0	2.1	103	2.0	2.1	104	2.0	2.1	105	2.0	2.1	106	2.0	2.1	107	2.0	2.1	108	2.0	2.1	109	2.0	2.1	110	2.0	2.1	111	2.0	2.1	112	2.0	2.1	113	2.0	2.1	114	2.0	2.1	115	2.0	2.1	116	2.0	2.1	117	2.0	2.1	118	2.0	2.1	119	2.0	2.1	120	2.0	2.1	121	2.0	2.1	122	2.0	2.1	123	2.0	2.1	124	2.0	2.1	125	2.0	2.1	126	2.0	2.1	127	2.0	2.1	128	2.0	2.1	129	2.0	2.1	130	2.0	2.1	131	2.0	2.1	132	2.0	2.1	133	2.0	2.1	134	2.0	2.1	135	2.0	2.1	136	2.0	2.1	137	2.0	2.1	138	2.0	2.1	139	2.0	2.1	140	2.0	2.1	141	2.0	2.1	142	2.0	2.1	Participant	Pre-Training (L/min)	Post-Training (L/min)	1	1.3	1.5	2	1.4	1.6	3	1.5	1.7	4	1.6	1.8	5	1.7	1.9	6	1.8	2.0	7	1.9	2.1	8	2.0	2.2	9	2.1	2.3	10	2.2	2.4	11	2.3	2.5	12	2.4	2.6	13	2.5	2.7	14	2.6	2.8	15	2.7	2.9	16	2.8	3.0	17	2.9	3.1	18	3.0	3.2	19	3.1	3.3	20	3.2	3.4	21	3.3	3.5	22	3.4	3.6	23	3.5	3.7	24	3.6	3.8	25	3.7	3.9	26	3.8	4.0	27	3.9	4.1	28	4.0	4.2	29	4.1	4.3	30	4.2	4.4	31	4.3	4.5	32	4.4	4.6	33	4.5	4.7	34	4.6	4.8	35	4.7	4.9	36	4.8	5.0	37	4.9	5.1	38	5.0	5.2	39	5.1	5.3	40	5.2	5.4	41	5.3	5.5	42	5.4	5.6	43	5.5	5.7	44	5.6	5.8	45	5.7	5.9	46	5.8	6.0	47	5.9	6.1	48	6.0	6.2	49	6.1	6.3	50	6.2	6.4	51	6.3	6.5	52	6.4	6.6	53	6.5	6.7	54	6.6	6.8	55	6.7	6.9	56	6.8	7.0	57	6.9	7.1	58	7.0	7.2	59	7.1	7.3	60	7.2	7.4	61	7.3	7.5	62	7.4	7.6	63	7.5	7.7	64	7.6	7.8	65	7.7	7.9	66	7.8	8.0	67	7.9	8.1	68	8.0	8.2	69	8.1	8.3	70	8.2	8.4	71	8.3	8.5	72	8.4	8.6	73	8.5	8.7	74	8.6	8.8	75	8.7	8.9	76	8.8	9.0	77	8.9	9.1	78	9.0	9.2	79	9.1	9.3	80	9.2	9.4	81	9.3	9.5	82	9.4	9.6	83	9.5	9.7	84	9.6	9.8	85	9.7	9.9	86	9.8	10.0	87	9.9	10.1	88	10.0	10.2	89	10.1	10.3	90	10.2	10.4	91	10.3	10.5	92	10.4	10.6	93	10.5	10.7	94	10.6	10.8	95	10.7	10.9	96	10.8	11.0	97	10.9	11.1	98	11.0	11.2	99	11.1	11.3	100	11.2	11.4	101	11.3	11.5	102	11.4	11.6	103	11.5	11.7	104	11.6	11.8	105	11.7	11.9	106	11.8	12.0	107	11.9	12.1	108	12.0	12.2	109	12.1	12.3	110	12.2	12.4	111	12.3	12.5	112	12.4	12.6	113	12.5	12.7	114	12.6	12.8	115	12.7	12.9	116	12.8	13.0	117	12.9	13.1	118	13.0	13.2	119	13.1	13.3	120	13.2	13.4	121	13.3	13.5	122	13.4	13.6	123	13.5	13.7	124	13.6	13.8	125	13.7	13.9	126	13.8	14.0	127	13.9	14.1	128	14.0	14.2	129	14.1	14.3	130	14.2	14.4	131	14.3	14.5	132	14.4	14.6	133	14.5	14.7	134	14.6	14.8	135	14.7	14.9	136	14.8	15.0	137	14.9	15.1	138	15.0	15.2	139	15.1	15.3	140	15.2	15.4	141	15.3	15.5	142	15.4	15.6	<p>Individual response of change in absolute VO₂max from pre- to post-training in a) Caucasian and b) Hispanic women; dark line represents the mean response.</p>
Participant	Pre-Training (L/min)	Post-Training (L/min)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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Acute Moderate Hypoxia Reduces One-Legged Cycling Performance Despite Compensatory Increase in Peak Cardiac Output: A Pilot Study.

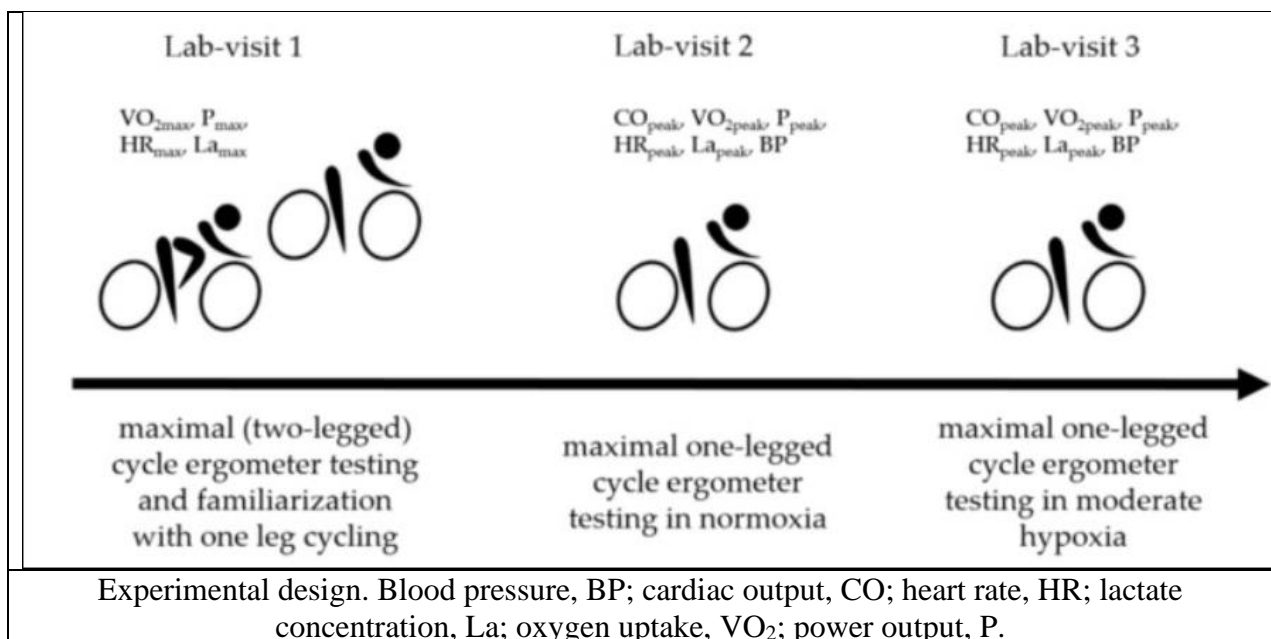
2021 Apr 2;18(7):3732. doi: 10.3390/ijerph18073732

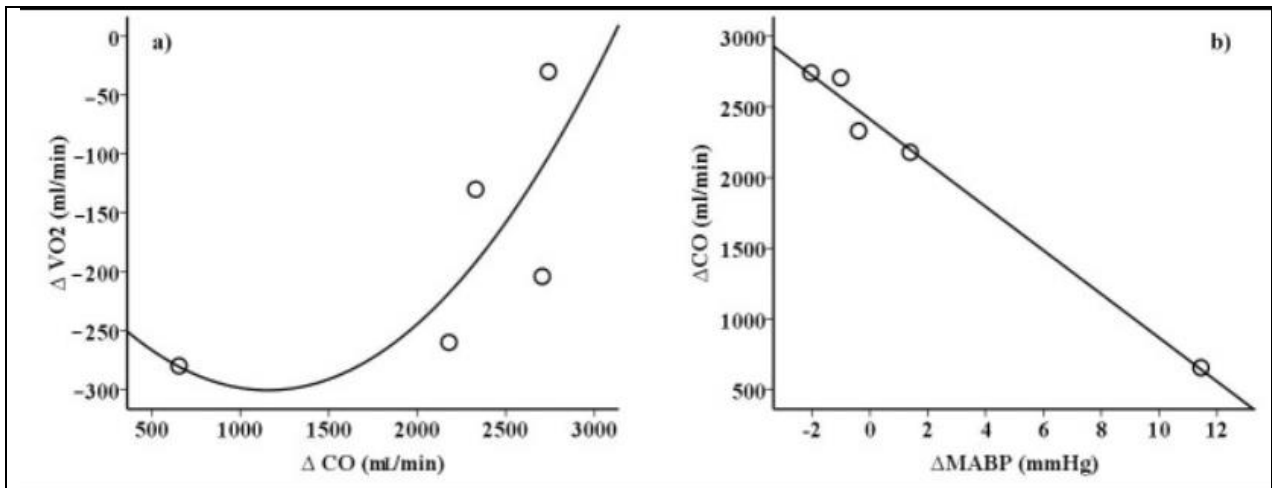
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Abstract:

In severe hypoxia, single-leg peak oxygen uptake (VO_{2peak}) is reduced mainly due to the inability to increase cardiac output (CO). Whether moderate altitude allows CO to increase during single-leg cycling, thereby restoring VO_{2peak} , has not been extensively investigated. Five healthy subjects performed an incremental, maximal, two-legged cycle ergometer test, and on separate days a maximal incremental one-leg cycling test in normoxia and in moderate hypoxia (fraction of inspired oxygen (FiO_2) = 15%). Oxygen uptake, heart rate, blood pressure responses, power output, and CO (PhysioFlow) were measured during all tests. Moderate hypoxia lowered single-leg peak power output (154 ± 31 vs. 128 ± 26 watts, $p = 0.03$) and oxygen uptake (VO_2) (36.8 ± 6.6 vs. 33.9 ± 6.9 mL/min/kg, $p = 0.04$), despite higher peak CO (16.83 ± 3.10 vs. 18.96 ± 3.59 L/min, $p = 0.04$) and systemic oxygen (O_2) delivery (3.37 ± 0.84 vs. 3.47 ± 0.89 L/min, $p = 0.04$) in hypoxia compared to normoxia. Arterial-venous O_2 difference (a-v DO_2) was lower in hypoxia (137 ± 21 vs. 112 ± 19 mL/L, $p = 0.03$). The increases in peak CO from normoxia to hypoxia were negatively correlated with changes in mean arterial pressure (MABP) ($p < 0.05$). These preliminary data indicate that the rise in CO was not sufficient to prevent single-leg performance loss at moderate altitude and that enhanced baroreceptor activity might limit CO increases in acute hypoxia, likely by reducing sympathetic activation. Since the systemic O_2 delivery was enhanced and the calculated a-v DO_2 reduced in moderate hypoxia, a potential diffusion limitation cannot be excluded.





Relationship between changes from normoxia to hypoxia of **(a)** peak oxygen consumption (VO_2) and cardiac output (CO) ($r^2 = 0.91$, Spearman) and **(b)** CO and mean arterial blood pressure (MABP) ($r^2 = 1.0$, Spearman).

Continuous cardiac autonomic and haemodynamic responses to isometric exercise in females.

2021 Jan;121(1):319-329. doi: 10.1007/s00421-020-04525-z. Epub 2020 Oct 18.

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Abstract:

Purpose:

Hypertension is associated with impaired haemodynamic control mechanisms and autonomic dysfunction. Isometric exercise (IE) interventions have been shown to improve autonomic modulation and reduce blood pressure (BP) predominantly in male participants. The physiological responses to IE are unexplored in female populations; therefore, this study investigated the continuous cardiac autonomic and haemodynamic response to a single bout of IE in a large female population.

Methods:

Forty physically inactive females performed a single, individually prescribed isometric wall squat training session. Total power spectral density of heart rate variability (HRV) and associated low-frequency (LF) and high-frequency (HF) power spectral components were recorded in absolute (ms^2) and normalised units (nu) pre, during and post an IE session. Heart rate (HR) was recorded via electrocardiography and baroreceptor reflex sensitivity (BRS) via the sequence method. Continuous blood pressure was recorded via the vascular unloading technique and stroke volume via impedance cardiography. Total peripheral resistance (TPR) was calculated according to Ohm's law.

Results:

During IE, there were significant reductions in HRV ($p < 0.001$) and BRS ($p < 0.001$), and significant increases in heart rate ($p < 0.001$), systolic, mean and diastolic BP ($p < 0.001$ for all). In recovery following the IE session, cardiac autonomic parameters returned to baseline ($p = 0.974$); however, total peripheral vascular resistance significantly reduced below baseline ($p < 0.001$). This peripheral vascular response was associated with significant reductions in systolic (-17.3 ± 16.5 mmHg, $p < 0.001$), mean (-18.8 ± 17.4 mmHg, $p < 0.001$) and diastolic BP (-17.3 ± 16.2 mmHg, $p < 0.001$), below baseline.

Conclusion:

A single IE session is associated with improved haemodynamic cardiovascular responses in females. Cardiac autonomic responses return to baseline values, which suggests that alternative mechanisms are responsible for the post-exercise haemodynamic improvements in females. Future mechanistic research is required to investigate the acute and chronic effects of IE in female populations with different resting BP profiles.

Relationship between oxygen pulse and arteriovenous oxygen difference in healthy subjects: Effect of exercise intensity.

doi.org/10.1016/j.scispo.2019.04.005

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Abstract:

Aims:

Aims were to assess: the relationships between oxygen pulse and arteriovenous oxygen difference; and (2) the reproducibility of cardiac output and stroke volume values during submaximal and maximal exercises.

Methods:

Twelve healthy male participated in the study. They were tested on five occasions, separated by periods of 3 days. After tests familiarization, they performed a duplicate progressive maximal exercise on a cycle ergometer to measure maximal oxygen uptake, maximal aerobic power, maximal cardiac output, maximal Stroke Volume and maximal Heart rate. At the fourth and fifth visits, subjects performed two graded submaximal physical exercises. Values collected during duplicated submaximal and maximal exercises were used for the assessment of the reliability of cardiovascular measurements.

Results:

We found no significant differences between cardiac output and stroke volume values in both first and second trial. All coefficients of variation were under 10% and intra class correlation coefficients values were high than 0.90 during submaximal and maximal exercises. The linear regression analyses indicated high r-squared between oxygen pulse and arteriovenous oxygen difference until 50% of maximal aerobic power. However, at 60% and 100% of maximal aerobic power, this relationship was not found. We found significant increases of stroke volume ($P < 0.05$) between each two successive bouts from rest until 40% of maximal aerobic power, after that, stroke volume values were stabilized. In contrast, we found a progressive increase of oxygen pulse ($P < 0.05$) and arteriovenous oxygen difference ($P < 0.05$) from rest until maximal exercise.

Conclusion:

Using the impedance device, cardiac output and stroke volume values were reproducible during submaximal and maximal exercises. Oxygen pulse could be a predictor of arteriovenous oxygen difference during submaximal exercise (until 50% of the maximal aerobic power) in healthy subjects.

Neonatal Impedance Cardiography in Asphyxiated Piglets—A Feasibility Study

2022 Feb 25. doi: 10.3389/fped.2022.804353

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Abstract:

Objectives

Impedance cardiography (ICG) is a non-invasive method for continuous cardiac output measurement and has the potential to improve monitoring and treatment of sick neonates. PhysioFlow® is a signal-morphology ICG-system showing promising results in adults with low and high cardiac output, but no data from neonates or neonatal models exist. The aim of this study was to investigate PhysioFlow® feasibility in asphyxiated newborn piglets.

Methods

Fifteen piglets, under continuous arterial heart rate (HR) and blood pressure (BP) monitoring, were asphyxiated until asystole. Cardiopulmonary resuscitation was performed and the piglets monitored after return of spontaneous circulation (ROSC). Arterial lactate was measured at baseline, every 5 min throughout asphyxiation, at asystole, and at 10 min and later every 30 min after ROSC. PhysioFlow® measured cardiac stroke volume (SV) and HR, and calculated cardiac index (CI) (L/m²/min). Registrations with a signal quality < 75% were excluded, and registrations recorded for 30 min from start of asphyxia analyzed. Pearson correlations were calculated for CI; and HR, mean BP and blood lactate.

Results

The piglets were asphyxiated for median (interquartile range) 30 (20–35) min and had a lactate at asystole of 15.0 (9.1–17.0) mmol/L. Out of a total of 20.991 registrations in all animals combined, there were 10.148 (48.3%) registrations with a signal quality ≥ 75%. Signal quality ≥ 75% varied in individual piglets from 7 to 82% of registrations. We analyzed 1.254 registrations recorded 30 min from initiation of asphyxia, i.e., in piglets with brief asphyxia times, this included cardiopulmonary resuscitation and post-ROSC observation. There was a positive correlation between CI and SVI ($r = 0.90$, $p < 0.001$), and between CI and HR ($r = 0.446$, $p < 0.001$). There was no correlation between CI, or mean BP or lactate ($p = 0.98$ and 0.51 , respectively).

Conclusion:

About half of ICG-registrations in asphyxiated piglets were of good quality. However, signal quality was highly variable between piglets. In total, there was a higher proportion of reliable ICG-registrations than reported from clinical delivery room studies using electrical velocimetry. Our data are physiologically plausible and supports further research evaluating PhysioFlow® for cardiac output monitoring in perinatal asphyxia. In particular, factors influencing inter-individual variations in signal quality should be explored.

Physiological differences in cardiovascular hemodynamics across treadmill and cycle exercise as assessed through impedance cardiography

2022 May;46(4):280-287. doi: 10.1080/03091902.2022.2040626. Epub 2022 Feb 25

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Abstract:

Impedance cardiography (IC) is a non-invasive method for assessing cardiovascular hemodynamics, and has been utilised during exercise, exclusively on a cycle ergometer. Mode-specific differences in cardiovascular hemodynamics during exercise have previously been identified, but the ability of IC to identify these differences has not been explored. Therefore, we examined the repeatability of cardiovascular hemodynamics within and between exercise modes on the treadmill (TM) and cycle (CY) ergometer. Twenty-one men (age = 21.4 ± 0.5 yr) performed four maximal exercise, two TM and two CY. Within each test, two, five-minute stages were completed corresponding to moderate and vigorous exercise intensities, respectively. Oxygen consumption (VO_2) was measured continuously during each test. Hemodynamic measures were obtained *via* IC, and included cardiac output (CO), heart rate (HR), stroke volume (SV), end diastolic volume (EDV), ejection fraction (EF), and systemic vascular resistance (SVR). Repeated measures ANOVA revealed that within TM exercise, there was a main effect for trial with HR only. There were no main effects for trial within CY exercise. Across exercise modes, there were significant main effects for mode with HR, EDV, and SVR. CY exercise resulted in a higher HR, lower SV and EDV, consistent with previous findings, utilising more criterion and invasive methods. Results suggest that hemodynamics, as assessed by IC, are repeatable within TM and CY exercise. In addition, it appears as though IC is capable of detecting mode-specific differences in hemodynamics, suggesting IC to be a useful assessment tool during exercise.

Central and Peripheral Oxygen Distribution in Two Different Modes of Interval Training

2021 Nov 18;11(11):790. doi: 10.3390/metabo11110790

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Abstract:

In high-intensity interval training the interval duration can be adjusted to optimize training results in oxygen uptake, cardiac output, and local oxygen supply. This study aimed to compare these variables in two interval trainings (long intervals HIIT3m: 3 min work, 3 min active rest vs. short intervals HIIT30s: 30 s work, 30 s active rest) at the same overall work rate and training duration. 24 participants accomplished both protocols, (work: 80% power output at $\text{VO}_{2\text{peak}}$, relief: 85% power output at gas exchange threshold) in randomized order. Spirometry, impedance cardiography, and near-infrared spectroscopy were used to analyze the physiological stress of the cardiopulmonary system and muscle tissue. Although times above gas exchange threshold were shorter in HIIT3m (HIIT3m 1669.9 ± 310.9 s vs. HIIT30s 1769.5 ± 189.0 s, $p = 0.034$), both protocols evoked similar average fractional utilization of $\text{VO}_{2\text{peak}}$ (HIIT3m $65.23 \pm 4.68\%$ $\text{VO}_{2\text{peak}}$ vs. HIIT30s $64.39 \pm 6.78\%$ $\text{VO}_{2\text{peak}}$, $p = 0.261$). However, HIIT3m resulted in higher cardiovascular responses during the loaded phases ($\text{VO}_2p < 0.001$, cardiac output $p < 0.001$). Local hemodynamics were not different between both protocols. Average physiological responses were not different in both protocols owing to incomplete rests in HIIT30s and large response amplitudes in HIIT3m. Despite lower acute cardiovascular stress in HIIT30s, short submaximal intervals may also trigger microvascular and metabolic adaptations similar to HIIT3m. Therefore, the adaptation of interval duration is an important tool to adjust the goals of interval training to the needs of the athlete or patient.

Exercise Training Combined with Calanus Oil Supplementation Improves the Central Cardiodynamic Function in Older Women

2021 Dec 29;14(1):149. doi: 10.3390/nu14010149

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Abstract:

The aim of this study was to investigate the possible beneficial effects of exercise training (ET) with omega-3/Calanus oil supplementation on cardiorespiratory and adiposity parameters in elderly women. Fifty-five women (BMI: 19-37 kg/m², 62-80 years old) were recruited and randomly assigned to the 4 month intervention with ET and omega-3 supplementation (Calanus oil, ET-Calanus) or ET and the placebo (sunflower oil; ET-Placebo). The body composition was determined by dual-energy X-ray absorptiometry (DXA), and cardiorespiratory parameters were measured using spiroergometry and PhysioFlow hemodynamic testing. Both interventions resulted in an increased lean mass whereas the fat mass was reduced in the leg and trunk as well as the android and gynoid regions. The content of trunk fat (in percent of the total fat) was lower

and the content of the leg fat was higher in the ET-Calanus group compared with the ET-Placebo. Although both interventions resulted in similar improvements in cardiorespiratory fitness (VO_{2max}), it was explained by an increased peripheral oxygen extraction ($a-vO_{2diff}$) alone in the ET-Placebo group whereas increased values of both $a-vO_{2diff}$ and maximal cardiac output (CO_{max}) were observed in the ET-Calanus group. Changes in CO_{max} were associated with changes in systemic vascular resistance, circulating free fatty acids, and the omega-3 index. In conclusion, Calanus oil supplementation during a 4 month ET intervention in elderly women improved the cardiorespiratory function, which was due to combined central and peripheral cardiodynamic mechanisms.

Physiological Responses to Exercise in Hypoxia in Preterm Adults: Convective and Diffusive Limitations in the O₂ Transport

2022 Oct 26. doi: 10.1249/MSS.0000000000003077.

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Abstract:

Purpose

Premature birth induces long-term sequelae on the cardiopulmonary system, leading to reduced exercise capacity. However, the mechanisms of this functional impairment during incremental exercise remain unclear. Also, a blunted hypoxic ventilatory response was found in preterm adults, suggesting an increased risk for adverse effects of hypoxia in this population. This study aimed to investigate the oxygen cascade during incremental exercise to exhaustion in both normoxia and hypobaric hypoxia in prematurely born adults with normal lung function and their term born counterparts.

Methods

Non-invasive measures of gas exchange, cardiac hemodynamics, and both muscle and cerebral oxygenation were continuously performed using metabolic cart, transthoracic impedance, and near-infrared spectroscopy, respectively, during an incremental exercise test to exhaustion performed at sea level and after three days of high-altitude exposure in healthy preterm (n = 17, gestational age, 29 ± 1 weeks; normal lung function) and term born (n = 17) adults.

Results

At peak, power output, oxygen uptake, stroke volume indexed for body surface area and cardiac output were lower in preterm compared to term born in normoxia (P = 0.042, P = 0.027, P = 0.030, and P = 0.018, respectively) but not in hypoxia, while pulmonary ventilation, peripheral oxygen saturation, muscle and cerebral oxygenation were similar between groups. These later parameters were modified by hypoxia (P < 0.001). Hypoxia increased muscle oxygen extraction at submaximal and maximal intensity in term born (P < 0.05) but not in preterm participants. Hypoxia decreased cerebral oxygen saturation in term born but not in preterm adults at rest and during exercise (P < 0.05). Convective oxygen delivery was decreased by hypoxia in term born (P < 0.001), but not preterm adults, while diffusive oxygen transport decreased similarly in both groups (P < 0.001 and P < 0.001, respectively).

Conclusion:

These results suggest that exercise capacity in preterm is primarily reduced by impaired convective, rather than diffusive, oxygen transport. Moreover, healthy preterm adults may experience blunted hypoxia-induced impairments during maximal exercise compared to their term counterparts.

Effects of Pre-Term Birth on the Cardio-Respiratory Responses to Hypoxic Exercise in Children

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Abstract:

Pre-term birth is associated with numerous cardio-respiratory sequelae in children. Whether these impairments impact the responses to exercise in normoxia or hypoxia remains to be established. Fourteen prematurely-born (PREM) (Mean \pm SD; gestational age 29 ± 2 weeks; age 9.5 ± 0.3 years), and 15 full-term children (CONT) (gestational age 39 ± 1 weeks; age 9.7 ± 0.9 years), underwent incremental exercise tests to exhaustion in normoxia ($\text{FiO}_2 = 20.9\%$) and normobaric hypoxia ($\text{FiO}_2 = 13.2\%$) on a cycle ergometer. Cardio-respiratory variables were measured throughout. Peak power output was higher in normoxia than hypoxia (103 ± 17 vs. 77 ± 18 W; $p < 0.001$), with no difference between CONT and PREM (94 ± 23 vs. 86 ± 19 W; $p = 0.154$). VO_2 peak was higher in normoxia than hypoxia in CONT (50.8 ± 7.2 vs. 43.8 ± 9.9 mL \cdot kg $^{-1}\cdot$ min $^{-1}$; $p < 0.001$) but not in PREM (48.1 ± 7.5 vs. 45.0 ± 6.8 mL \cdot kg $^{-1}\cdot$ min $^{-1}$; $p = 0.137$; interaction $p = 0.044$). Higher peak heart rate (187 ± 11 vs. 180 ± 10 bpm; $p = 0.005$) and lower stroke volume (72 ± 13 vs. 77 ± 14 mL; $p = 0.004$) were observed in normoxia *versus* hypoxia in CONT, with no such differences in PREM ($p = 0.218$ and >0.999 , respectively). In conclusion, premature birth does not appear to exacerbate the negative effect of hypoxia on exercise capacity in children. Further research is warranted to identify whether prematurity elicits a protective effect, and to clarify the potential underlying mechanisms.

Cardiac stroke volume in females and its correlation to blood volume and cardiac dimensions

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Abstract:

We aimed to continuously determine the stroke volume (SV) and blood volume (BV) during incremental exercise to evaluate the individual SV course and to correlate both variables across different exercise intensities. Twenty-six females with heterogeneous endurance capacities performed an incremental cycle ergometer test to continuously determine the oxygen uptake ($\dot{V}O_2$), cardiac output (\dot{Q}) and changes in BV. \dot{Q} was determined by impedance cardiography and resting cardiac dimensions by 2D echocardiography. Hemoglobin mass and BV were determined using a carbon monoxide-rebreathing method. $\dot{V}O_{2\max}$ ranged from 32 to 62 mL·kg⁻¹·min⁻¹. \dot{Q}_{\max} and SV_{\max} ranged from 16.4 to 31.6 L·min⁻¹ and 90-170 mL, respectively. The SV significantly increased from rest to 40% and from 40% to 80% $\dot{V}O_{2\max}$. Changes in SV from rest to 40% $\dot{V}O_{2\max}$ were negatively ($r = -0.40$, $p = 0.05$), between 40% and 80% positively correlated with BV ($r = 0.45$, $p < 0.05$). At each exercise intensity, the SV was significantly correlated with the BV and the cardiac dimensions, i.e., left ventricular muscle mass (LVMM) and end-diastolic diameter (LVEDD). The BV decreased by 280 ± 115 mL (5.7%, $p = 0.001$) until maximum exercise. We found no correlation between the changes in BV and the changes in SV between each exercise intensity. The hemoglobin concentration [Hb] increased by 0.8 ± 0.3 g·dL⁻¹, the capillary oxygen saturation (ScO₂) decreased by 4.0% ($p < 0.001$). As a result, the calculated arterial oxygen content significantly increased (18.5 ± 1.0 vs. 18.9 ± 1.0 mL·dL⁻¹, $p = 0.001$). A 1 L higher BV at $\dot{V}O_{2\max}$ was associated with a higher SV_{\max} of 16.2 mL ($r = 0.63$, $p < 0.001$) and \dot{Q}_{\max} of 2.5 L·min⁻¹ ($r = 0.56$, $p < 0.01$). In conclusion, the SV strongly correlates with the cardiac dimensions, which might be the result of adaptations to an increased volume load. The positive effect of a high BV on SV is particularly noticeable at high and severe intensity exercise. The theoretically expected reduction in $\dot{V}O_{2\max}$ due to lower SV as a consequence of reduced BV is apparently compensated by the increased arterial oxygen content due to a higher [Hb].

Central and peripheral response to incremental cycling exercise in older untrained active men: a comparison of those in-between

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Abstract:

The aim of this study was to compare the central and peripheral components of cardiorespiratory fitness during incremental to maximal exercise between older men who were either recreational athletes (RA) or leisurely active (LA) men, i.e., those who fall between trained and untrained. This was a cross-sectional study in which all subjects completed an exercise test on a cycle ergometer. Maximal oxygen consumption (VO_{2max}) and ventilatory threshold (VT) were assessed using gas analysis, and central components of VO_{2max} were assessed using a non-invasive thoracic bio-impedance device. VO_{2max} (RA: 45.1±4.8 ml/kg/min; LA: 32.2±4.6 ml/kg/min, $p < 0.001$) and SV at maximal exercise (RA: 133.5±24.96 ml/beat; LA: 107.9±17.6 ml/beat, $p = 0.005$) were higher in the RA group compared to the LA group. A plateau in SV occurred between 30-45 % of maximal exercise capacity in the RA group. No differences in SV were observed across workloads in the LA group. No differences in the calculated arterio-venous oxygen difference ((a-v)O_{2diff}) were observed between groups. In conclusions, training volume appears to influence central components of cardiorespiratory fitness among a matched sample of older men who are neither trained nor untrained. This builds a case for increasing the volume of training to preserve cardiorespiratory fitness among older men.

● A randomized crossover study on the effects of a custom-made mouthguard on cardiopulmonary parameters and cortisol differences in a validated handball specific course

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Abstract:

Background

The importance of mouthguards for handball players has been proven however, most players are reluctant to use it. The impact on physical capacity is assessed heterogeneously in the literature. This study aimed to investigate the influence of custom-made mouthguards (CMGs) under handball specific stress.

Methods

This randomized crossover study used data from 15 youth professional handball players (age 17.0 ±0.5 years, weight 85.1±8.0 kg and height 191.2±6.9 cm) who performed a validated handball specific course and a lung function test. Pulmonary (spirometry), metabolic (blood lactate), and cortisol parameters were observed using a normal custom-made mouthguard without (nCMG) and with respiratory channels (CMGvent) in comparison to no mouthguard (Co).

Results

In resting spirometry, no differences in the parameter peak flow were observed using the CMGvent (9.57±1.59 l·s⁻¹) and nCMG (9.17±1.03 l·s⁻¹) in comparison to the Co (9.38±1.26 l·s⁻¹). Under maximum stress, there were no differences in ventilation using CMGvent (151.2±15.64 L·min⁻¹), nCMG (148.6±12.51 l·min⁻¹), and without mouthguard (145.8±14.32 l·min⁻¹). Similar oxygen uptake was observed when using a CMGvent (45.51±4.14 L·min⁻¹·kg⁻¹), nCMG (45.50±5.06 ml·min⁻¹·kg⁻¹), and without CMG (Co 43.90±4.02 mL·min⁻¹). The parameters of HR (CMGvent 185.2±11.63 bpm vs. Co 179.4±13.24 bpm p=0.46, nCMG 178.2±11.54 bpm vs. Co p=0.97; CMGvent vs. nCMG p=0.08) and in the blood lactate values (CMGvent: 9.66±2.3 mmol·l⁻¹ vs. Co 9.07±2.1 mmol·l⁻¹ p=0.63; nCMG 9.39±2.8 mmol·l⁻¹ vs. Co p=0.87; CMGvent vs. nCMG p=0.91) displayed no differences. The cortisol production under stress showed no differences in the performance with the CMGvent (1.78±3.58 ng/ml), nCMG (0.74±4.52 ng/mL), and in the procedure without mouthguard (0.25. ±5.01 ng/ml).

Conclusion:

The results showed that under stress, there were no differences in the cortisol, ventilation, cardiac, and metabolic responses for all three conditions. Finally, the study shows that the use of a custom-made mouthguard does not negatively affect handball specific performance. Due to the preventive aspect of the mouthguard, the use of a custom-made mouthguard in handball is strongly recommended.

Facemask Use During High Intensity Interval Exercise in Temperate and Hot Environments

PMID: 35608826 DOI: 10.1097/JOM.0000000000002461

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Abstract:

Objective

The purpose of this study was to investigate the effects of surgical mask use during high intensity interval exercise (HIIE) on physiological and perceptual responses in hot and temperate environments.

Methods

In a randomized fashion, 10 healthy participants completed two HIIE sessions in a 36°C hot (HUE-HOT) and two HIIE sessions in a 23°C temperate environment (HIIE-TEMP) while wearing (MASK) and not wearing a surgical mask (CON).

Results

No differences in physiological variables were found between MASK and CON during HIIE. An increase in perceived dyspnea and average RPE was found comparing MASK and CON. Interaction effects showed the greatest changes in perceived dyspnea and average RPE occurred in the HIIE-HOT/MASK condition.

Conclusion:

Wearing a surgical mask during HIIE increases the perception of dyspnea and exertion with the greatest effect occurring in hot environments.

Intensity-dependent cardiopulmonary response during and after strength training

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Abstract:

Whereas cardiopulmonary responses are well understood in endurance training, they are rarely described in strength training. This cross-over study examined acute cardiopulmonary responses in strength training. Fourteen healthy male strength training-experienced participants (age 24.5 ± 2.9 years; BMI 24.1 ± 2.0 kg/m²) were randomly assigned into three strength training sessions (three sets of ten repetitions) with different intensities (50%, 62.5%, and 75% of the 3-Repetition Maximum) of squats in a smith machine. Cardiopulmonary (impedance cardiography, ergo-spirometry) responses were continuously monitored. During exercise period, heart rate (HR 143 ± 16 vs. 132 ± 15 vs. 129 ± 18 bpm, respectively; $p < 0.01$; η^2_p 0.54) and cardiac output (CO: 16.7 ± 3.7 vs. 14.3 ± 2.5 vs. 13.6 ± 2.4 l/min, respectively; $p < 0.01$; η^2_p 0.56) were higher at 75% of 3-RM compared to those at the other intensities. We noted similar stroke volume (SV: $p = 0.08$; η^2_p 0.18) and end-diastolic volume (EDV: $p = 0.49$). Ventilation (V_E) was higher at 75% compared to 62.5% and 50% (44.0 ± 8.0 vs. 39.6 ± 10.4 vs. 37.6 ± 7.7 l/min, respectively; $p < 0.01$; η^2_p 0.56). Respiration rate (RR; $p = .16$; η^2_p 0.13), tidal volume (VT: $p = 0.41$; η^2_p 0.07) and oxygen uptake (VO_2 : $p = 0.11$; η^2_p 0.16) did not differ between intensities. High systolic and diastolic blood pressure were evident (62.5% 3-RM $197 \pm 22.4/108.8 \pm 13.4$ mmHG). During the post-exercise period (60 s), SV, CO, V_E , VO_2 , and VCO_2 were higher ($p < 0.01$) than during the exercise period, and the pulmonary parameters differed markedly between intensities (V_E $p < 0.01$; RR $p < 0.01$; VT $p = 0.02$; VO_2 $p < 0.01$; VCO_2 $p < 0.01$). Despite the differences in strength training intensity, the cardiopulmonary response reveals significant differences predominantly during the post-exercise period. Intensity-induced breath holding induces high blood pressure peaks and cardiopulmonary recovery effects after exercise.

Effect of home-based online training and activity feedback on oxygen uptake in patients after surgical cancer therapy: a randomized controlled trial

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Abstract:

Background

Exercise training is beneficial in enhancing physical function and quality of life in cancer patients. Its comprehensive implementation remains challenging, and underlying cardiopulmonary adaptations are poorly investigated. This randomized controlled trial examines the implementation and effects of home-based online training on cardiopulmonary variables and physical activity.

Methods

Of screened post-surgical patients with breast, prostate, or colorectal cancer, 148 were randomly assigned (1:1) to an intervention (2 × 30 min/week of strength-endurance training using video presentations) and a control group. All patients received activity feedback during the 6-month intervention period. Primary endpoint was change in oxygen uptake after 6 months. Secondary endpoints included changes in cardiac output, rate pressure product, quality of life (EORTC QoL-C30), C-reactive protein, and activity behavior.

Results

One hundred twenty-two patients (62 intervention and 60 control group) completed the study period. Change in oxygen uptake between intervention and control patients was 1.8 vs. 0.66 ml/kg/min (estimated difference after 6 months: 1.24; 95% CI 0.23 to 2.55; $p = 0.017$). Rate pressure product was reduced in IG (estimated difference after 6 months: - 1079; 95% CI - 2157 to - 1; $p = 0.05$). Physical activity per week was not different in IG and CG. There were no significant interaction effects in body composition, cardiac output, C-reactive protein, or quality of life.

Conclusion:

Home-based online training among post-surgery cancer patients revealed an increase of oxygen uptake and a decrease of myocardial workload during exercise. The implementation of area-wide home-based training and activity feedback as an integral component in cancer care and studies investigating long-term effects are needed.

Cardiopulmonary response to exercise in adults born very preterm

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Abstract:

This study aims to compare cardiopulmonary response to aerobic exercise between young adults born very preterm, including a subgroup with bronchopulmonary dysplasia (BPD), and term controls. Seventy-one adults (18-29 years) born <30 weeks' gestational age (24 with BPD) and 73 term controls were recruited. Assessment included cardiopulmonary exercise testing with impedance cardiography. We compared group differences in peak O₂ consumption (peak VO₂) and in ventilatory and cardiovascular responses to exercise using linear regression analyses. Preterm participants had reduced peak VO₂ (mean difference -2.7; 95% CI -5.3, -0.1 mL·kg⁻¹ lean body mass·min⁻¹) versus controls. Those with BPD achieved lower peak work-rate compared to term controls (-21; 95% CI -38, -5 watts). There was no difference across groups in breathing reserve, ventilatory efficiency, peak heart rate and cardiac output. VO₂ to work-rate relationship (Δ VO₂/ Δ WR) was reduced in preterm versus term. Peak systolic blood pressure and circulatory power (systolic blood pressure*VO₂) were also lower in BPD versus term controls. In the preterm group, longer NICU stay and lower peak cardiac output were associated with lower peak VO₂. Results suggest limitations with peripheral O₂ uptake in the muscle with reduced Δ VO₂/ Δ WR and peak circulatory power, but normal cardiac output. Investigations into skeletal muscle perfusion and O₂ use during exercise are warranted to better understand mechanisms of exercise limitation.

Exercise induced plasma volume expansion lowers cardiovascular strain during 15-km cycling time-trial in acute normobaric hypoxia

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Abstract:

The purpose of our study was to assess the influence of a single high-intensity interval exercise (HIIE) bout in normoxia on plasma volume (PV) and consequent cycling performance in normobaric hypoxia (0.15 FiO₂, simulating ~2,500 m). Eight males (VO₂peak: 48.8 ± 3.4 mL/kg/min, 24.0 ± 1.6 years) completed a hypoxic 15 km cycling time trial (TT), followed by a crossover intervention of either HIIE (8x4 min cycling bouts at 85% of VO₂peak) or CON (matched kJ production from HIIE at 50% of VO₂peak). 48 hours post intervention, an identical TT was performed. Cardiovascular parameters were measured via impedance cardiography during each TT. Changes in PV was measured 24 and 48 hours post HIIE and CON. HIIE increased PV at 24 (4.1 ± 3.9%, P = 0.031) and 48 (6.7 ± 1.7, P = 0.006) hours post, while no difference was observed following the CON (1.3 ± 1.1% and 0.3 ± 2.8%). The higher PV led to an increased stroke volume (P = 0.03) and cardiac output (P = 0.02) during the hypoxic TT, while heart rate was not changed (P = 0.49). We observed no changes in time to completion (-0.63 ± 0.57 min, P = 0.054) and power output (7.37 ± 7.98 W, P = 0.078) between TTs. In the absence of environmental stress, a single bout of HIIE was an effective strategy to increase PV and reduce the cardiovascular strain during a cycling TT at moderate simulated altitude but did not impact hypoxic exercise performance. Trial registration: Clinical Trials ID: NCT05800808.

3.2 PHARMACOLOGY

Ephedrine Fails to Accelerate the Onset of Neuromuscular Block by Vecuronium

Anesth Analg 2003; 97:480-483

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Abstract:

The onset time of neuromuscular blocking drugs is partially determined by circulatory factors, including muscle blood flow and cardiac output. We thus tested the hypothesis that a bolus of ephedrine accelerates the onset of vecuronium neuromuscular block by increasing cardiac output. A prospective, randomized study was conducted in 53 patients scheduled for elective surgery. After the induction of anesthesia, the ulnar nerve was stimulated supramaximally every 10 s, and the evoked twitch response of the adductor pollicis was recorded with accelerometry. Patients were maintained under anesthesia with continuous infusion of propofol for 10 min and then randomly assigned to ephedrine 210 µg/kg ($n = 27$) or an equivalent volume of saline ($n = 26$). The test solution was given 1 min before the administration of 0.1 mg/kg of vecuronium. Cardiac output was monitored with impedance cardiography. Ephedrine, but not saline, increased cardiac index (17%; $P = 0.003$). Nonetheless, the onset of 90% neuromuscular block was virtually identical in the patients given ephedrine (183 ± 41 s) and saline (181 ± 47 s). There was no correlation between cardiac index and onset of the blockade. We conclude that the onset of the vecuronium-induced neuromuscular block is primarily determined by factors other than cardiac output. The combination of ephedrine and vecuronium thus cannot be substituted for rapid-acting nondepolarizing muscle relaxants.

Implication:

Ephedrine increased cardiac index but failed to speed onset of neuromuscular block with vecuronium. We conclude that ephedrine administration does not shorten the onset time of vecuronium.

Short-term Vasomotor Adjustments to Post Immersion Dehydration are Hindered by Natriuretic Peptides

UHM 2004, Vol. 31, No. 2 - Vasomotor regulation in post-immersion dehydration

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Abstract:

Short-term vasomotor adjustments to post immersion dehydration are hindered by natriuretic peptides. *Undersea Hyperb Med* 2004, 31(2) :000-000. Many studies have described the physiology of water immersion (WI), whereas few have focused on post WI physiology, which faces the global water loss of the large WI diuresis. Therefore, we compared hemodynamics and vasomotor tone in 10 trained supine divers before and after two 6h sessions in dry (DY) and head out WI environments. During each exposure (DY and WI) two exercise periods (each one hour 75W ergometer cycling) started after the 3rd and 5th hours. Weight losses were significant (-2.24 ± 0.13 kg and -2.38 ± 0.19 kg, after DY and WI, respectively), but not different between the two conditions. Plasma volume was reduced at the end of the two conditions (-9.7 ± 1.6 % and -14.7 ± 1.6 %, respectively; $p < 0.05$). This post-WI decrease was deeper than post DY ($p < 0.05$). Cardiac output (CO) and mean arterial blood pressure were maintained after the two exposures. Plasma levels of noradrenaline, antidiuretic hormone and ANP were twofold higher after WI than after DY ($p < 0.05$). After DY total peripheral resistances (TPR) were increased ($p < 0.05$) and heart rate (HR) was reduced ($p < 0.05$). After WI there was a trend for a decrease in stroke volume ($p = 0.07$) with unchanged TPR and HR, despite more sizeable increases in plasma noradrenaline and vasopressin than after DY. We hypothesized that the higher levels of plasma natriuretic peptides after WI were likely counteracting the dehydration-required vasomotor adjustments

Sildenafil Inhibits Altitude-induced Hypoxemia and Pulmonary Hypertension

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Abstract:

Exposure to high altitude induces pulmonary hypertension that may lead to life-threatening conditions. In a randomized, double-blind, placebo-controlled study, the effects of oral sildenafil on altitude-induced pulmonary hypertension and gas exchange in normal subjects were examined. Twelve subjects (sildenafil [SIL] n = 6; placebo [PLA] n = 6) were exposed for 6 days at 4,350 m. Treatment (3 x 40 mg/day) was started 6 to 8 hours after arrival from sea level to high altitude and maintained for 6 days. Systolic pulmonary artery pressure (echocardiography) increased at high altitude before treatment (+29% versus sea level, p < 0.01), then normalized in SIL (-6% versus sea level, NS) and remained elevated in PLA (+21% versus sea level, p < 0.05). Pulmonary acceleration time decreased by 27% in PLA versus 6% in SIL (p < 0.01). Cardiac output and systemic blood pressures increased at high altitude then decreased similarly in both groups. Pa_O₂ was higher and alveolar-arterial difference in O₂ lower in SIL than in PLA at rest and exercise (p < 0.05). The altitude-induced decrease in maximal O₂ consumption was smaller in SIL than in PLA (p < 0.05). Sildenafil protects against the development of altitude-induced pulmonary hypertension and improves gas exchange, limiting the altitude-induced hypoxemia and decrease in exercise performance.

Keywords:

- Cardiac output,
- Exercise,
- Gas exchange,
- Hypoxia

Sildenafil Improves Cardiac Output and Exercise Performance during Acute Hypoxia, but not Normoxia

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Abstract:

Sildenafil causes pulmonary vasodilation, thus potentially reducing impairments of hypoxia-induced pulmonary hypertension on exercise performance at altitude. The purpose of this study was to determine the effects of Sildenafil during normoxic and hypoxic exercise. We hypothesized that 1) sildenafil would have no significant effects on normoxic exercise, and 2) Sildenafil would improve cardiac output, arterial oxygen saturation, and performance during hypoxic exercise. Ten trained males performed 1 practice and 3 experimental trials at sea level (SL) and simulated high altitude (HA) of 3,874 m. Each cycling test consisted of a set work rate portion (55% $Watts_{peak}$: 1 h SL, 30 min HA) followed immediately by a time-trial (10 km SL, 6 km HA). Double-blinded capsules (placebo, 50, or 100 mg) were taken 1 h prior to exercise in a randomly, counterbalanced order. For HA testing, subjects also began breathing hypoxic gas (12.8% O₂) 1 h prior to exercise. At SL, Sildenafil had no effects on any cardiovascular or performance measures. At HA, Sildenafil increased stroke volume (measured by electrical impedance cardiography), cardiac output (Q), and arterial oxygen saturation (Sao₂) during set work rate exercise. Sildenafil lowered 6 km time-trial time by 15% ($P < 0.05$). Sao₂ was also higher during the time trial ($P < 0.05$) in response to Sildenafil, despite higher work rates. Post-hoc analyses revealed two subject groups, Sildenafil responders and non-responders, who improved time-trial performance by 39% ($P < 0.05$) and 1.0%, respectively. No dose-response effects were observed. During cycling exercise in acute hypoxia, Sildenafil can greatly improve cardiovascular function, arterial oxygen saturation, and performance for certain individuals.

Keywords:

- Phosphodiesterase-5 inhibitor,
- Simulated altitude,
- Viagra,
- Physioflow,
- Pulmonary hypertension

Side-effects of L-dopa on Venous Tone in Parkinson's Disease: a Leg-weighing Assessment

Clinical Science (2006) 110, (369–377) (Printed in Great Britain)

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Abstract:

In the present study, the effects of L-dopa treatment on cardiovascular variables and peripheral venous tone were assessed in 13 patients with Parkinson's disease (PD) with Hoehn and Yahr stages 1–4. Patients were investigated once with their regular treatment and once after 12 h of interruption of L-dopa treatment. L-Dopa intake significantly reduced systolic and diastolic blood pressure, heart rate and plasma noradrenaline and adrenaline in both the supine and upright (60°) positions. A significant reduction in stroke volume and cardiac output was also seen with L-dopa. The vascular status of the legs was assessed through thigh compression during leg weighing, a new technique developed in our laboratory. Healthy subjects were used to demonstrate that this technique provided reproducible results, consistent with those provided by strain gauge plethysmography of the calf. When using this technique in patients with PD, L-dopa caused a significant lowering of vascular tone in the lower limbs as shown, in particular, by an increase in venous distensibility. Combined with the results of the orthostatic tilting, these findings support that the treatment-linked lowering of plasma noradrenaline in patients with PD was concomitant with a significant reduction in blood pressure, heart rate and vascular tone in the lower limbs. These pharmacological side-effects contributed to reduce venous return and arterial blood pressure which, together with a lowered heart rate, worsened the haemodynamic status.

Keywords:

- Nitroglycerine,
- Noradrenaline,
- Orthosympathetic control,
- Parkinson's disease,
- Vascular tone,
- Vascular plethysmography

Abbreviations:

- AFI: arterial flow index;
- BP: blood pressure;
- CO: cardiac output;
- C_{slope}: slope of compliance;
- CV: coefficient of variation;
- DBP: diastolic BP;
- HR: heart rate;
- NG: nitroglycerine;
- PD: Parkinson's disease;
- SBP: systolic BP;
- SGP: strain gauge plethysmography;
- SV: stroke volume;
- TC: thigh compression;
- VDI: venous distensibility index

Influence of beta-blocker on cardiac output in a maximum exercise bicycle ramp test.

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Abstract:

Fikenzer S, Drechsler K, Falz R, Tegtbur U, Thomas M, Schultze A, Bressau K, Hoppe St, Busse M. Influence of beta-blocker on cardiac output in a maximum exercise bicycle ramp test. Klinische Sportmedizin/Clinical Sports Medicine – Germany KCS2007 8 (1) 1-7.

Keywords:

- Arterial hypertension,
- Students, exercise test,
- Cardiac output,
- Bisoprolol,
- Beta blocker.

Objective:

One of the most important risk factors for illness of the heart-circulation-system is arterial hypertension (8). In this study, the influence of Beta-Blocker on exercise and cardiac output (CO) in the special collective of the students was investigated.

Material & Methods:

5 students (age mean=25,4 yrs, BMI mean=23.98 kg/m², RRrest mean=141,2/80,8 mmHg) with hypertension and pre-hypertension and no history of respiratory disease of the University of Leipzig participated in the study. The participants performed 2 maximum exercise tests. The first test was without medical intervention the second test was performed after 3 days of received 5mg/d bisoprolol. For analyzing the CO we used the system "PhysioFlow" which is based on an impedance technology. The results were analyzed from 0% to 100% of maximum work load using 10% intervals and during recovery after the 1st, 3rd and 5th minute.

Results:

- beta blocker does not influence cardiac output
- beta blocker does not influence maximum workload
- beta blocker does not influence maximum oxygen uptake

Evaluation of a method utilizing PhysioFlow®, a novel signal morphology-based form of impedance cardiography, to measure cardiac output in the conscious beagle

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Available online xxxx

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Abstract:

Currently, standard methods for measuring cardiac output are either invasive (i.e. flowprobe) or are limited in terms of short measurement intervals and measurement variability (i.e. echocardiography). The ability to reliably measure cardiac output in a non-invasive manner in large animals would provide a valuable tool to expand functional cardiovascular endpoints in preclinical safety studies. PhysioFlow® is a novel method that uses waveform analysis of an impedance signal to measure cardiac output non-invasively. Unlike cardiac impedance techniques in the past, PhysioFlow® is not dependant on thoracic structure or basal thoracic impedance (Z0) and therefore this methodology is transferrable from human to animal models.

Keywords:

- Acepromazine
- Beagle
- Cardiac output
- Dobutamine
- Dog
- Methods
- Minoxidil
- PhysioFlow®

Methods:

Three tool compounds with known effects on cardiac output were administered to conscious beagle dogs to determine if the non-invasive PhysioFlow® system could detect the expected changes in stroke volume and cardiac output as determined by literature references using the current standard methodologies (e.g. aortic blood flow and thermodilution).

Conclusion:

The PhysioFlow® system was able to detect increases in cardiac output when dosed with 20 µg/kg of Dobutamine, a decrease in cardiac output when dosed with 0.1 mg/kg of Acepromazine, and no significant change in cardiac output when dosed with 2 mg/kg of Minoxidil. These results are within expected ranges based on published literature (Stepien et al., 1995; Taylor et al., 2007). Discussion: PhysioFlow®, a signal morphology-based impedance

Discussion:

PhysioFlow®, a signal morphology-based impedance cardiography, can be utilized to reliably and non-invasively measure cardiac output in beagle dogs.

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4

EORTA/VASCULAR STIFNESS

4.1 EORTA/VASCULAR STIFFNESS

Assessment of aortic stiffness by local and regional methods

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Abstract:

The stiffness of large arteries has an important role in cardiovascular hemodynamics. Aortic stiffness (AoStiff) can be assessed non-invasively with regional and local methods. In this paper, we compared these two techniques for evaluating AoStiff. Our subjects comprised of 118 consecutive patients (85 men, mean age: 49±14 years). We evaluated regional AoStiff with carotid-femoral pulse wave velocity (PWV) measured with a tonometric technique and by bioelectrical impedance (BI) wave velocity (IWV). The local AoStiff was calculated from BI signals recorded at the chest. We used glyceryl trinitrate (GTN) to test the effect of peripheral vasodilatation on both methods in a subgroup of 52 patients (37 men, mean age: 52±11 years). We found a significant correlation between IWV and PWV measurements ($r=0.88$, $P<0.0001$) as well as between AoStiff and PWV measurements ($r=0.75$, $P<0.0001$). GTN administration decreased mean arterial blood pressure by 4% (95% confidence interval: 2–8%, $P=0.002$) without significant changes in AoStiff and regional IWV. Local AoStiff is correlated with regional measurements and is not influenced by changes in arterial pressure because of systemic peripheral vasodilatation.

Keywords:

- Aorta
- Cardiovascular diseases
- Elasticity
- Peripheral resistance

Conclusion:

Although PWV and the AoStiff index are not strictly identical because of the inhomogeneous elastic properties of the arterial tree, both local and regional methods are well correlated, even in the presence of changes in arterial pressure due to systemic peripheral vasodilatation. In contrast to the regional methods, the local method assessed with the BI technique allows a differential analysis of the components of AoStiff (that is, resistance and distensibility). This technique could represent a useful tool for a more discriminating analysis of the effect of vasoactive drugs on the vasculature.

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Measurement of the local aortic stiffness by a non-invasive bioelectrical impedance technique

Med Biol Eng Comput - DOI 10.1007/s11517-011-0741-3

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Abstract:

Aortic stiffness measurement is well recognized as an independent predictor of cardiovascular mortality and morbidity. Recently, a simple method has been proposed for the evaluation of the local aortic stiffness (AoStiff) using a non-invasive bioelectrical impedance (BI) technique. This approach relies on a novel interpretation of the arterial stiffness where AoStiff is computed

from the measurement of two new BI variables:

(1) the local aortic flow resistance (AoRes) exerted by the drag forces onto the flow;

(2) the local aortic wall distensibility (AoDist). Herein, we propose to detail and compare these three indices with the reference pulse wave velocity (PWV) measurement and the direct assessment of the aortic drag forces (DF) and distensibility (DS) obtained by the magnetic resonance imaging technique. Our results show a significant correlation between AoStiff and PWV ($r = 0.79$; $P \setminus 0.0001$; 120 patients at rest; mean age 44 ± 16 years), and also between AoRes and DF ($r = 0.95$; $P = 0.0011$) and between AoDist and DS ($r = 0.93$; $P = 0.0022$) on eight patients at rest (mean age 52 ± 19 years). These first results suggest that local aortic stiffness can be explored reliably by the BI technique.

Keywords:

- Aorta
- Cardiovascular diseases
- Drag
- Elasticity
- Flow
- Magnetic resonance

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Modeling and interpretation of the bioelectrical impedance signal for the determination of the local arterial stiffness

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DOI: 10.1118/1.3213084

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Purpose:

Stiffness of the large arteries (e.g., aorta) plays an important role in the pathogenesis of cardiovascular diseases. To date, the reference method for the determination of regional arterial stiffness is the measurement of the carotid-femoral pulse wave velocity (PWV) by tonometric techniques. However, this method suffers from several drawbacks and it remains limited in clinical routine.

Keywords:

- Artery
- Cardiovascular diseases,
- Elasticity,
- Bioimpedance,
- Model

Methods:

In the present study, the authors propose a new method based on the analysis of bioelectrical impedance (BI) signals for the determination of the local arterial stiffness. They show, from a theoretical model, a novel interpretation of the BI signals and they establish the relationship between the variations in the BI signal and the kinetic energy of the blood flow in large arteries. From this model, BI signals are simulated in the thigh and compared to experimental BI data. Finally, from the model, they propose a new index (Ira) related to the properties of the large artery for the determination of the local arterial stiffness.

Results:

The results show a good correlation between the simulated and the experimental BI signals. The same variations for both of them with different characteristics for rigid and elastic arteries can be observed. The measurement of the Ira index on 20 subjects at rest (mean age of 44.16 yr) for the determination of the local aortic stiffness presents a significant correlation with the PWV reference method ($R^2=0.77$; $P<0.0001$ with the Spearman correlation coefficient and $Ira=4.25*PWV+23.54$).

Conclusion:

All the results suggest that the theoretical model and the new index could give a reliable estimate of local arterial stiffness.

Received 23 January 2009; revised 20 July 2009; accepted for publication 21 July 2009; published 4 September 2009

Time and Spatial Invariance of Impedance Signals in Limbs of Healthy Subjects by Time–Frequency Analysis

Annals of Biomedical Engineering, Vol. 36, No. 3, March 2008 (2008) pp. 444–451
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Abstract:

The bioelectric impedance technique is a noninvasive method that provides the analysis of blood volume changes in the arteries. This is made possible by an interpretation of the impedance signal variations. In this paper, time and spatial variations of such impedance signals are studied on recordings made on limbs of 15 healthy subjects at rest. For that purpose, the scalogram of each signal has been computed and quantitative measures based on energies were determined. The results show that the signals are statistically time invariant on three anatomical segments of the limbs: pelvis, thigh and calf. p Value varies between 0.20 and 0.52 for the absolute energies computed on scalograms of signals recorded at 5 min intervals. Moreover, the analysis made on the two legs of each subject shows that the signals are spatial invariant on the three anatomical segments. p Value varies between 0.0785 and 1.000 for the absolute energies computed on the scalograms of signals recorded simultaneously on the two legs. These conclusions will therefore help the clinicians in studying the temporal variations of physiological parameters on limbs with the impedance technique. Moreover, the results on the spatial invariance make possible the comparisons of these parameters with those given by other acquisition techniques.

Keywords:

- Artery,
- Bioimpedance,
- Impedance,
- Limbs,
- Noninvasive measurement,
- Scalogram,
- Spatial invariance,
- Time invariance,
- Time–frequency representation.

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Effects of combined histamine H1 and H2 receptor blockade on hemodynamic responses to dynamic exercise in males with high-normal blood pressure

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Abstract:

While postexercise hypotension is associated with histamine H1 and H2 receptor-mediated postexercise vasodilation, effects of histaminergic vasodilation on blood pressure (BP) in response to dynamic exercise are not known. Thus, in 20 recreationally active male participants (10 normotensive and 10 with high-normal BP) we examined the effects of histamine H1 and H2 receptor blockade on cardiac output (CO), mean arterial pressure (MAP), aortic stiffness (AoStiff), and total vascular conductance (TVC) at rest and during progressive cycling exercise. Compared with the normotensive group, MAP, CO, and AoStiff were higher in the high-normal group before and after the blockade at rest, while TVC was similar. At the 40% workload, the blockade significantly increased MAP in both groups, while no difference was found in the TVC. CO was higher in the high-normal group than the normotensive group in both conditions. At the 60% workload, the blockade substantially increased MAP and decreased TVC in the normotensive group, while there were no changes in the high-normal group. A similar CO response pattern was observed at the 60% workload. These findings suggest that the mechanism eliciting an exaggerated BP response to exercise in the high-normal group may be partially due to the inability of histamine receptors. Novelty Males with high-normal BP had an exaggerated BP response to exercise. The overactive BP response is known due to an increase in peripheral vasoconstriction. Increase in peripheral vasoconstriction is partially due to inability of histamine receptors

Effects of chronic dietary grape seed extract supplementation on aortic stiffness and hemodynamic responses in obese/overweight males during submaximal exercise

2022 Jul;22(7):1057-1064.doi: 10.1080/17461391.2021.1923815. Epub 2021 May 20.

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Abstract:

We investigated the effect of chronic grape seed extract (GSE) on blood pressure and aortic stiffness (AoS) among overweight and obese males. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), stroke volume (SV), cardiac output (Q), total vascular conductance (TVC), and AoS were measured during two submaximal cycling exercises (40% and 60% VO₂max), after 7 consecutive days of GSE or placebo (PL) ingestion with one week washout period. Compared with PL, GSE supplementation significantly decreased MAP at rest (85 ± 3 mmHg vs. 82 ± 3 mmHg), 40% (102 ± 3 mmHg vs. 99 ± 3 mmHg), and 60% workloads (109 ± 3 mmHg vs. 107 ± 3 mmHg) ($P = 0.001$, ES = 0.2). AoS was significantly reduced (13.0 ± 1.9 AU vs. 10.2 ± 1.0 AU) at rest ($P = 0.002$, ES = 0.6). Q was decreased at rest and across all workloads, but there were no significant differences (7.5 ± 0.4 L/min vs. 7.1 ± 0.4 L/min; 20.4 ± 1.2 L/min vs. 19.6 ± 0.9 L/min; 26.3 ± 1.1 L/min vs. 25.5 ± 1.6 L/min, respectively). GSE had no effect on HR, TVC, and SV. Our study indicates that chronic supplementation with GSE reduces arterial pressure at rest and during exercise primarily via the substantial reduction in AoS. Thus, GSE can be a dietary supplement to treat augmented blood pressure responses in obese and overweight males at rest and during exercise.

2020;66(5):427-431.doi: 10.3177/jnsv.66.427.

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Abstract:

Recently, it has been reported that dietary supplementation with grape seed extract (GSE) ameliorates endothelial function and increase nitric oxide (NO) bioavailability. Thus, we investigated if elevated blood pressure and aortic stiffness (AoS) characterized in obese individuals are attenuated following acute GSE supplementation. Twenty men (obese=10; normal body weight (NBW)=10) participated in this study. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), stroke volume (SV), cardiac output (CO), total peripheral resistance (TPR), and AoS were compared 2 h after ingestion of GSE or placebo (PL) on different days, 1 wk apart. Compared with the PL, GSE supplementation significantly decreased SBP (NBW: 103±4 vs. 99±3 mmHg; obese: 118±3 vs. 112±5 mmHg) and MAP (NBW: 75±2 vs. 72±2 mmHg; obese: 86±3 vs. 84±3 mmHg) in both groups, while there were no differences in HR, SV, DBP, TPR, and AoS. GSE supplementation significantly decreased CO in only obese group. In NBW group, TPR tended to be decreased, but there was no significant difference. Our study suggests that acute supplementation with GSE reduced both SBP and MAP via a reduction in CO in obese individuals and decreased peripheral vasoconstriction in NBW group.