sustainability

MDPI

Article

Comparison between Different Prescription Methods for Aerobic Training in Young Adults

Fernando Policarpo [1], Pedro Valdivia-Moral [2,*], Maria do Socorro Luna-Cruz [3], Alex Véliz-Burgos [4], Juan Mansilla-Sepulveda [5] and Juan Guillermo Estay-Sepulveda [5,6]

1 Laboratório de Biociências do Movimento Humano LABIMH/UFRJ, Rio de Janeiro 21941-901, Brazil; fernandopolicarpo65@gmail.com
2 Faculty of Education Sciences, University of Granada, 18011 Granada, Spain
3 Faculdad de Ciencias da Salud do Trairi. FACISA/UFRN, Santa Cruz Rio Grande do Norte 59200-000, Brazil; socorrolcruz@gmail.com
4 Department of Social Science, Universidad de Los Lagos, Puerto Montt 548000, Chile; alex.veliz@ulagos.cl
5 Department of Education, Universidad Católica de Temuco, Temuco 4780000, Chile; jmansilla@uct.cl (J.M.-S.); juanguillermoestay@yahoo.com (J.G.E.-S.)
6 Department of Research Nucleus History, Universidad Adventista de Chile, Chillán 3780000, Chile
* Correspondence: pvaldivia@ugr.es

Received: 23 September 2019; Accepted: 5 November 2019; Published: 15 November 2019

check for updates

Abstract: Anaerobic threshold and respiratory compensation are used to determine the intensity of aerobic exercise. This study aims to compare heart rate values relative to the percentages of 50%, 60%, 70%, and 80%, a comparison calculated through the reserve heart rate (HRR) and reserve oxygen consumption (VO_2R) equations corresponding to the oxygen consumption obtained by the direct method. The sample was composed of 11 men and 10 women: mean age, 21.4 ± 2.8 years. Volunteers performed a maximal treadmill test in which oxygen uptake was measured using the VO2000® metabolic analyzer. The mean body fat percentage was 15.68 ± 8.02% corresponding to a lean body mass of 54.8 ± 13.0 kg and a maximal oxygen uptake (VO_2max) of 56.0 ± 8.4 mL/Kg·min^{-1}. The measured intensities (50%, 60%, 70% and 80% of VO_2max) presented significant differences ($p < 0.05$) for each reference value. Mean values calculated by the HRR equation demonstrated a tendency to underestimate the intensities, while the values calculated by the VO_2R equation showed a tendency to overestimate the intensities. As the main conclusion, it is pointed out that both methods were effective for determining the intensity of aerobic training. However, they presented significant differences, and the equations should be adjusted to increase precision. Thus, the use of HRR is recommended for the determination of training intensities.

Keywords: oxygen uptake; heart rate; prescription; aerobic exercise

1. Introduction

Aerobic exercise plays an important role in sports training, health care exercise programs and cardiac rehabilitation [1–3]. The adaptations induced by aerobic exercise are directly related to workloads, i.e., the intensity of the training sessions [4–6]. The correct determination of intensity provides tissue adaptations: increasing the number of mitochondria, as well as hypertrophy in the mitochondrial crest, resulting in an improved activity in enzymatic tetrahydro-carboxylic cycle [1,7,8]. Additionally, a better blood perfusion in muscle fibers due to capillary perfusion has being observed [9,10].

In recent years, there have been questions about what is the best way to determine the intensities of aerobic exercise. Prescription should follow the results of the cardiopulmonary exercise test (CPET) or may use indirect methods (%Maximum Heart Rate—HRmax (max heart rate) or %Reserve Heart Rate—HRR) [11,12].

Indirect methods are related to the physiological responses that occur during the CPET, in which ventilatory thresholds I and II are determined. Usually, the two thresholds are at 50% and 80% of the maximal oxygen uptake (VO_2max) [6,11–14]. Due to the logistical and financial difficulties of performing the CPET, the American College of Sports Medicine (ACSM) [14] established that the intensities of aerobic exercise should be by means of %VO_2max, %HRmax and %reserve heart rate (HRR) combined with the perceived effort index [11,14–17].

In the late 90s, Swain and Leutholtz proposed a new method to prescribe the intensity of aerobic exercise through the percentage of reserve oxygen consumption (VO_2R) [18]. According to Perk, De Backer [19], VO_2R is recommended primarily for the prescription of the intensities of aerobic exercise for individuals with low physical fitness. However, as mentioned above, there are doubts about the accuracy of indirect methods to determine the intensities of aerobic exercise [20].

The divergence identified in the study as the accuracy of indirect methods resulted in the hypothesis that the %VO_2R will overestimate the intensity studied when compared to %HRR, as pointed out in the study [20]. It is noteworthy that other studies that contradict VO_2R have tended to overestimate the intensities [21].

This controversy indicates that it is necessary for further studies to identify the accuracy of the methods to determine the intensities of aerobic training. Given the evidence, the present study aims to compare relative heart rate values with the percentages of 50%, 60%, 70%, and 80% calculated by the HRR and VO_2R equations, using values of heart rate corresponding to the consumption obtained through direct metabolic gas analysis, as in the reference.

2. Materials and Methods

2.1. Ethical Principles of the Study

This study was approved by the Castelo Branco University's Ethics Committee, in Rio de Janeiro, in accordance with Brazilian law number 196/96 and the Declaration of Helsinki. All subjects signed an informed consent and clarified, after explanation, all doubts about the test.

Subjects and Design

The present study had a descriptive cross-sectional exploratory design conducted to verify the relationship between different relative methods for determining aerobic training intensities [5,22]. The study included an intentional sample of students from the physical education undergraduate course of the Catholic University of Brasília—UCB (men = 11 and women = 10; mean age = 21.4 ± 2.6) who were invited to participate in the study. To be included in the sample, they could not have cardiopulmonary or musculoskeletal diseases that compromise the performance of the cardiopulmonary progressive stress test (CPET). Tests were performed at the Laboratory of Physical Assessment and Training—LAFIT UBC. The subjects who reached the LAFIT filled out a form (Par-Q), and those who reported no health problems received information related to the benefits and possible risks involved in making the CPET and were instructed to perform a clinical examination in the medical doctor's lab to identify possible heart problems. For the rest, a resting electrocardiogram was performed, as described in the protocol below.

A resting electrocardiogram (ECG) was then conducted by the physician of the laboratory in order to verify any possible cardiac problems. Individuals remained lying down for five minutes in dorsal decubitus before the examination. Subsequently, resting blood pressure was measured using a sphygmomanometer (BECTON DICKINSON®), and the resting ECG was performed using a MARQUETTE HELLIGE©, Medical Systems device, Cardio Smart model, version 3.0 CS-MI. Individuals who presented clinical problems were substituted.

2.2. Measures

After the clinical examination, all the selected individuals were submitted to the following tests.

Anthropometry: Body composition was performed in accordance with the following stages: (a) body mass, measured with a TOLEDO® scale with a precision of 50 g; (b) stature, measured with a stadiometer from COUNTRY TECNOLOGY INC, Gays Mills, Wl. (model 67034) with a millimeter scale; and (c) to estimate body composition, the Jackson and Pollockc protocol of three skin folds for men and women was applied [23]. The calculations were performed using the MICROMED® GALILEO program, version 3.0.10.100 1999. Effort test: Three different protocols were performed to determine the maximum oxygen uptake (VO_2max) and the maximal heart rate (HRmax). Maximal effort tests were carried out on a treadmill, model Super ATL (INBRAMED, Porto Alegre, RS, Spain). A metabolic analysis of gases was performed using the VO2000®, which presented a coefficient of variation (CV; 14.2%–15.8%) [24]. Before the beginning of the tests, the metabolic gas analyzer was calibrated with a gas composition of 17% O_2 and 5% CO_2, with a nitrogen balance approved by the Centro de Controle Qualidade de Gases Especiais (WHITES MARTINS) according to the specifications of the manufacturer. The analyzer was connected to the ERGOPC Elite® version 2.0 computerized system (MICROMED©, Brasília, DF, Spain).

2.3. Procedure

An incremental grade CPET protocol was up to maximal effort (respiratory coefficient ≥ 1.1) as recommended by the ATS/ERS CPET [25]. Every incremental grade lasted 1 min. The initial speed was 6 km/h with a slope of 0%; gas collection was carried out in 15 s intervals. Speed and incline were increased every minute by 1 km/h and 0.5%, respectively. The final speed was 16 km/h, and the slope had a maximum of 6%. This was the standard protocol used in the laboratory [26]. This protocol fits perfectly with the 8–12 min CPET recommendations in healthy individuals, as suggested by the ATS guidelines [25].

Calculation of Relative Intensities

The calculation of the relative intensities of the measured VO_2max were 50%, 60%, 70% and 80%, and HR was based on the mean of gas collection relative to a 1 min interval. Subsequent to the CPET, intensity calculations were performed by means of reserved heart rate performed by the equation (HRR) proposed by Karvonen, Kentala [27] and the oxygen reserve consumption (VO_2R) described by Swain and Leutholtz [18]. For the percentage of the VO_2R calculation, it was inferred that all individuals suffered from the same oxygen uptake at rest (3.5 mL/kg·min^{-1}). The resting heart rate (HRr) was measured during the 5 min before starting the CPET while the individual was standing by means of the ECG.

Equation (HRR) [27]:

$$HHR = [(HRmax - HRr) \times \%] + HRr$$

Equation (VO_2R) [18]:

$$VO_2R = [(VO_2max - VO_2r) \times \%] + VO_2r$$

2.4. Statistical Analysis

The analysis was performed using "Statistical Package for Social Sciences" (SPSS 22.0) with an adopted significance level of $p < 0.05$. The following statistical methods were used to analyze the variables: (a) central tendency measures, mean and standard deviation (SD); (b) multiple analysis test corrected by the Bonferroni method and (c) estimation error (EE).

3. Results

The analysis of data distribution was normal ($p > 0.05$), and outliers were not found for the studied variables (the anthropometric characteristics of the sample are shown in Table 1). Body composition was considered normal for men and women. The sample had a below average fat percentage for gender and age. The low percentage of fat classified the sample subjects as healthy and physically active.

Table 1. General characteristics of the sample of university students (n = 21); data are presented as mean and standard deviation.

	Men	Women
Age (years)	22.5 ± 2.1	20.3 ± 3.2
Stature (cm)	176.7 ± 5.6	162.7 ± 6.0
Body Weight (Kg)	73.6 ± 10.1	55.3 ± 4.6
Fat Free Mass (Kg)	65.9 ± 6.3	42.6 ± 4.3
Fat Mass (Kg)	7.2 ± 4.7	12.4 ± 2.3
%Fat	9.4 ± 4.9	22.6 ± 4.0
BMI (Kg/m^2)	23.3 ± 2.0	20.7 ± 1.2

The variables obtained during the CPET are described in Table 2. The resting heart rate (HRr) values, although averaging 77.2 ± 10.7 bpm, were within normal limits (Table 2). This above-normal response may have been related to the subjects' nervousness at the pre-test evaluation. The measured VO_2max confirmed the level of physical fitness of the subjects, as both the men and women coincided with the excellent level of cardiorespiratory fitness. The values obtained for HRmax were 97% of the estimated HRmax for age, indicating that the test had maximum effort characteristics (Table 2).

Table 2. The results of the cardiopulmonary exercise test of university students (n = 21); data are presented as mean and standard deviation.

	Men	Women
Maximal ventilation (L)	170.7 ± 23.0	104.2 ± 13.9
VO_2max (mL/kg·min^{-1})	61.0 ± 8.4	50.6 ± 3.7
HR resting (bpm)	76.0 ± 11.5	82.9 ± 4.7
HRmax (bpm)	193.8 ± 8.6	194.8 ± 6.3

Because the HRR and VO_2R equations do not distinguish between sex for the intensities calculation, it was decided to present the results in general. The values for the calculated intensities showed significant differences ($p < 0.05$) in relation to the reference values, confirming the hypothesis of the study in which VO_2R was expected to overestimate the studied intensities. In the specific case of HRR, it tended to underestimate the intensities. The results for intensities are shown in Table 3. The tendency of VO_2R to overestimate intensities may have been related to the use of resting oxygen consumption of 3.5 mL/kg·min^{-1}. It can be seen that both intensities calculated by the HRR as the VO_2R value tended to approach the reference values with an increased intensity. A HR relative to 80% of the VO_2R presented the smallest estimation error (Table 3).

Table 3. Results of comparison between measured and estimated values for different intensities of aerobic training in a sample of university students (n = 21); data are presented as mean and standard deviation.

	Mean ± Sd	EE	% or Error
VO_2 (mL/kg·min^{-1})	28.0 ± 2.2	—	—
HR_VO_2_50%	143.0 ± 10.1	2.2	—
HRR_50%	136.6 ± 5.3 **	1.2	5.6
HR_VO_2R_50%	148.9 ± 11.7 **	2.6	−5.2
VO_2 (mL/kg·min^{-1})	33.6 ± 5.0	—	—
HR_VO_2_60%	155.4 ± 10.0	2.2	—
HRR_60%	148.1 ± 5.4 **	1.2	6.4
HR_VO_2R_60%	158.9 ± 11.2 **	2.4	−3.0
VO_2 (mL/kg·min^{-1})	39.2 ± 5.9	—	—
HR_VO_2_70%	165.8 ± 8.7	1.9	—
HRR_70%	159.7 ± 5.7 **	1.3	5.2
HR_VO_2R_70%	168.6 ± 9.3 **	2.0	−2.6
VO_2 (mL/kg·min^{-1})	44.8 ± 6.7	—	—
HR_VO_2_80%	176.5 ± 8.0	1.8	—
HRR_80%	171.2 ± 6.2 **	1.4	4.6
HR_VO_2R_80%	178.5 ± 9.1 **	2.0	−1.3

HR_VO_2_50% = heart rate relative to oxygen uptake at 50% VO_2max intensity; HRR_50% = reserve heart rate for 50% intensity; HR_VO_2R_50% = heart rate corresponding to 50% intensity calculated by reserve oxygen uptake; ** = significant statistical difference ($p < 0.01$).

4. Discussion

The aim of this study was to compare the values of heart rate corresponding to the relative oxygen uptake in the intensities of 50%, 60%, 70% and 80% of the VO_2max calculated by the HRR and VO_2R equations. The hypothesis was accepted, since %VO_2R tended to overestimate intensities, while %HRR tended to underestimate intensities.

The relationship between oxygen consumption and work performed during physical exercise was described by Radak, Zhao [28], showing a direct association between workloads and physical exercise, which led to the bases for aerobic exercise intensity determination [14,29,30]. Nevertheless, one of the biggest problems of training prescription is the determination of the training loads while respecting biological individuality in order not to overload the physiological capacities of each individual. In this sense, the literature has been increasingly focused on the interaction between different regulating systems of the human body [29,31].

The results of the current study show that intensities determined by the VO_2R overestimate workloads. This contradicts the recommendations of Swain and Leutholtz [18] and Solheim, Keller [20], who highlighted the importance of this procedure for sedentary individuals. According to Miller, O'Connor [32] and the ACSM [14], training at high intensities tends to reduce adhesion to the exercise program.

On this basis, a study examined the relationship between the percentages of the VO_2max, the VO_2R, and HRR in cardiac patients [33]. Brawner, Keteyian [33] showed that VO_2R presented a tendency to overestimate the exercise intensities, and the authors recommended the use of HRR to determine the intensities. In the study of Azevedo, Perlingeiro [6], men with high cardiorespiratory fitness performed exercise intensity based on %HRmax and %HRR in relation to ventilatory thresholds, which were 78%–93% and 70%–93%, respectively. The authors mentioned that there was no influence of age, although the absolute heart rate at ventilatory thresholds decreased with advancing age. The result described by Azevedo et al. corroborated the idea that the HRR can be a reliable method to estimate the intensity of aerobic exercise [33].

The ACSM now recommends VO_2R in the prescription of aerobic training intensities on the basis of the results highlighted by Swain and Leutholtz (1997) [14]. In their study, Swain and Leutholtz described that the relationship between the percentages of the VO_2max and the percentages of HRR is weak, which is questionable. However, Solheim, Keller [20] obtained a correlation of 0.31 between %VO_2R and %HRR for 50% of the VO_2max intensity. A lack of other studies that demonstrate a better linearity between the percentages of VO_2R and the reference values makes this recommendation a target that requires further academic research [13].

Alternatively to the percentages calculated for HRR, there have been several studies that point to an association with percentages of the VO_2max [20,34–36]. It could be observed that the relative heart rate associated with oxygen consumption estimated by the VO_2R equation overestimated the intensities by around −3.12 ± 1.28%, while the relative heart rate of the intensities calculated by HRR demonstrated a tendency to underestimate the intensities by around 5.45 ± 0.63%. These results corroborate those presented by Kenney, Wilmore [36], demonstrating that the values estimated by HRR have a tendency to underestimate the percentages of the VO_2max. Though previous studies have highlighted a linear relationship between these percentages, this tendency can be explained by the possible use of the equation "220—age" for the calculation of the chronotropic reserve [34]. The literature has shown that the equation "220—age" presents a tendency to overestimate the values of HRmax, which leads to a better relationship between the percentages [34].

The tendency of HRR to underestimate the intensity was also described in the study by Solheim et al. [20]. However, the presented result may have been influenced by the measurement of the resting HR. Solheim et al. [20] mentioned that the volunteers remained lying down for 10 min, and this position favors a venous return, generating a lower HR. This would not be considered a normal physiological response, since heart rate rises less than oxygen consumption [20]. HR is directly related to catecholamine responses, which also induces alterations in respiratory rate and peripheral vasodilation [20]. In addition, an increase in HR is related to the mechanism of the removal of metabolic waste.

Though the training intensity could be determined by the percentages of the VO_2max or by VO_2R, professionals can also control the level of effort using the speed on a treadmill or ergometric bicycle, as the bike pedal revolutions per minute are used in the control of intensity [21]. Though any of the above-mentioned control methods could be observed or obtained during the effort test [14], the values of heart rate that indicate the training zones have also been observed on ergometers used in gyms (treadmills and bicycles) or on panels [37]. These values (zones) are based on the linearity between the percentages of the VO_2max and the percentages of HRmax, estimated by the equation 220—age; this is extremely practical, since the measure of heart rate is the most common method in the control of intensity of activities proposed in gyms. The limitations of this study are the small number of studies that have sought to assess the association between the percentage of VO_2max and the estimated intensities of VO_2R for the prescription of aerobic exercise. Determining resting oxygen consumption is another limiting factor, as this study assumed that all individuals had the same resting oxygen consumption, i.e., 3.5 mL/kg·min^{-1} [13]. Another important point is the sample size and age limit, reducing the possibility of result extrapolation to other age groups.

5. Conclusions

The main conclusions are that the values of 50%, 60%, 70% and 80% of the VO_2max estimated by the two indirect VO_2R and HRR methods have a tendency to overestimate and underestimate the reference values (%VO_2Max), respectively. These differences were significant in all the studied intensities. In this sense, further studies are recommended to adjust the regression curves and the use of HRR in the prescription of aerobic training intensities in sedentary individuals.

Author Contributions: The authors F.P. and M.d.S.L.-C.: participated in the writing of the article. The author P.V.-M.: participated in the review and final writing of the article. The authors A.V.-B., J.M.-S. and J.G.E.-S.: performed the translation process.

Funding: This research was conducted with funding from the authors.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gibala, M.J.; Little, J.P.; Macdonald, M.J.; Hawley, J.A. Physiological adaptations to low-volume, high-intensity interval training in health and disease. *J. Physiol.* **2012**, *590*, 1077–1084. [CrossRef]
2. Guiraud, T.; Nigam, A.; Gremeaux, V.; Meyer, P.; Juneau, M.; Bosquet, L. High-intensity interval training in cardiac rehabilitation. *Sports Med.* **2012**, *42*, 587–605. [CrossRef]
3. Wilson, M.G.; Ellison, G.M.; Cable, N.T. Basic science behind the cardiovascular benefits of exercise. *Br. J. Sports Med.* **2016**, *50*, 93–99. [CrossRef]
4. Azcárate, U.; Los Arcos, A.; Yanci, J. Efectos del entrenamiento compuesto íntegramente por tareas de fútbol en el rendimiento neuromuscular y cardiovascular de futbolistas amateurs. *J. Sport Health Res.* **2018**, *10*, 257–268.
5. Picón, M.; Chulvi Medrano, I.; Alonso-Aubin, D.A. Uso del entrenamiento con restricción del flujo sanguíneo en España: Un estudio transversal. *J. Sport Health Res.* **2019**, *11*, 171–186.
6. Azevedo, L.F.; Perlingeiro, P.S.; Brum, P.C.; Braga, A.M.; Negrao, C.E.; de Matos, L.D. Exercise intensity optimization for men with high cardiorespiratory fitness. *J. Sports Sci.* **2011**, *29*, 555–561. [CrossRef] [PubMed]
7. Egan, B.; Zierath, J.R. Exercise metabolism and the molecular regulation of skeletal muscle adaptation. *Cell Metab.* **2013**, *17*, 162–184. [CrossRef] [PubMed]
8. Meinild Lundby, A.K.; Jacobs, R.A.; Gehrig, S.; de Leur, J.; Hauser, M.; Bonne, T.C.; Fluck, D.; Dandanell, S.; Kirk, N.; Kaech, A.; et al. Exercise training increases skeletal muscle mitochondrial volume density by enlargement of existing mitochondria and not de novo biogenesis. *Acta Physiol.* **2018**, *222*, e12905. [CrossRef]
9. Joanisse, S.; Nederveen, J.P.; Snijders, T.; McKay, B.R.; Parise, G. Skeletal Muscle Regeneration, Repair and Remodelling in Aging: The Importance of Muscle Stem Cells and Vascularization. *Gerontology* **2017**, *63*, 91–100. [CrossRef]
10. Joyner, M.J.; Casey, D.P. Regulation of increased blood flow (hyperemia) to muscles during exercise: A hierarchy of competing physiological needs. *Physiol. Rev.* **2015**, *95*, 549–601. [CrossRef]
11. Guazzi, M.; Adams, V.; Conraads, V.; Halle, M.; Mezzani, A.; Vanhees, L.; Arena, R.; Fletcher, G.F.; Forman, D.E.; Kitzman, D.W.; et al. EACPR/AHA Scientific Statement. Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. *Circulation* **2012**, *126*, 2261–2274. [CrossRef] [PubMed]
12. Weatherwax, R.M.; Harris, N.K.; Kilding, A.E.; Dalleck, L.C. The incidence of training responsiveness to cardiorespiratory fitness and cardiometabolic measurements following individualized and standardized exercise prescription: Study protocol for a randomized controlled trial. *Trials* **2016**, *17*, 601. [CrossRef] [PubMed]
13. Mann, T.; Lamberts, R.P.; Lambert, M.I. Methods of prescribing relative exercise intensity: Physiological and practical considerations. *Sports Med.* **2013**, *43*, 613–625. [CrossRef] [PubMed]
14. Pescatello, L.S.; Riebe, D.; Thompson, P.D. *ACSM's Guidelines for Exercise Testing and Prescription*; ACSM: Indianapolis, IN, USA, 2014.
15. Cornelissen, V.A.; Verheyden, B.; Aubert, A.E.; Fagard, R.H. Effects of aerobic training intensity on resting, exercise and post-exercise blood pressure, heart rate and heart-rate variability. *J. Hum. Hypertens.* **2010**, *24*, 175–182. [CrossRef]
16. Morán-Navarro, R.; Mora-Rodríguez, R.; Rodríguez-Rielves, V.; De la Fuente-Pérez, P.; Pallarés, J. Heart rate reserve at ventilatory thresholds, maximal lactate steady state and maximal aerobic power in well-trained cyclists: Training application. *Eur. J. Hum. Mov.* **2016**, *36*, 150–162.
17. Pallarés, J.G.; Morán-Navarro, R. Propuesta metodológica para el entrenamiento de la resistencia cardiorrespiratoria. *J. Sport Health Res.* **2012**, *2*, 119–136.
18. Swain, D.P.; Leutholtz, B.C. Heart rate reserve is equivalent to %VO2 reserve, not to %VO2max. *Med. Sci. Sports Exerc.* **1997**, *29*, 410–414. [CrossRef]
19. Perk, J.; De Backer, G.; Gohlke, H.; Graham, I.; Reiner, Z.; Verschuren, M.; Albus, C.; Benlian, P.; Boysen, G.; Cifkova, R.; et al. European Guidelines on cardiovascular disease prevention in clinical practice (version 2012). The Fifth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of nine societies and by invited experts). *Eur. Heart J.* **2012**, *33*, 1635–1701. [CrossRef]

20. Solheim, T.J.; Keller, B.G.; Fountaine, C.J. VO2 Reserve vs. Heart Rate Reserve During Moderate Intensity Treadmill Exercise. *Int. J. Exerc. Sci.* **2014**, *7*, 311–317.
21. Garzon, M.; Gayda, M.; Nigam, A.; Comtois, A.S.; Juneau, M. Immersible ergocycle prescription as a function of relative exercise intensity. *J. Sport Health Sci.* **2017**, *6*, 219–224. [CrossRef]
22. Masse, L.C.; Dassa, C.; Gauvin, L.; Giles-Corti, B.; Motl, R. Emerging measurement and statistical methods in physical activity research. *Am. J. Prev. Med.* **2002**, *23*, 44–55. [PubMed]
23. Chambers, A.J.; Parise, E.; McCrory, J.L.; Cham, R. A comparison of prediction equations for the estimation of body fat percentage in non-obese and obese older Caucasian adults in the United States. *J. Nutr. Health Aging* **2014**, *18*, 586–590. [CrossRef] [PubMed]
24. Crouter, S.E.; Antczak, A.; Hudak, J.R.; DellaValle, D.M.; Haas, J.D. Accuracy and reliability of the ParvoMedics TrueOne 2400 and MedGraphics VO2000 metabolic systems. *Eur. J. Appl. Physiol.* **2006**, *98*, 139–151. [CrossRef] [PubMed]
25. Ross, R.M. ATS/ACCP statement on cardiopulmonary exercise testing. *Am. J. Respir. Crit. Care Med.* **2003**, *167*, 1451. [CrossRef] [PubMed]
26. Barbosa, F.P.; Cruz, M.S. Staggered vs ramp Protocol: Analysis of oxygen consumption and heart rate in young people. *Rev. Bras. Ciência Mov.* **2016**, *24*, 81–88. [CrossRef]
27. Karvonen, M.J.; Kentala, E.; Mustala, O. The effects of training on heart rate; a longitudinal study. *Ann. Med. Exp. Biol. Fenn.* **1957**, *35*, 307–315.
28. Radak, Z.; Zhao, Z.; Koltai, E.; Ohno, H.; Atalay, M. Oxygen consumption and usage during physical exercise: The balance between oxidative stress and ROS-dependent adaptive signaling. *Antioxid. Redox Signal.* **2013**, *18*, 1208–1246. [CrossRef]
29. Jones, A.M.; Poole, D.C. *Oxygen Uptake Kinetics in Sport, Exercise and Medicine*; Routledge: London, UK, 2013.
30. Wilson, J.M.; Marin, P.J.; Rhea, M.R.; Wilson, S.M.; Loenneke, J.P.; Anderson, J.C. Concurrent training: A meta-analysis examining interference of aerobic and resistance exercises. *J. Strength Cond. Res.* **2012**, *26*, 2293–2307. [CrossRef]
31. Robertson, C.V.; Marino, F.E. Cerebral responses to exercise and the influence of heat stress in human fatigue. *J. Therm. Biol.* **2017**, *63*, 10–15. [CrossRef]
32. Miller, F.L.; O'Connor, D.P.; Herring, M.P.; Sailors, M.H.; Jackson, A.S.; Dishman, R.K.; Bray, M.S. Exercise dose, exercise adherence, and associated health outcomes in the TIGER study. *Med. Sci. Sports Exerc.* **2014**, *46*, 69–75. [CrossRef]
33. Brawner, C.A.; Keteyian, S.J.; Ehrman, J.K. The relationship of heart rate reserve to VO2 reserve in patients with heart disease. *Med. Sci. Sports Exerc.* **2002**, *34*, 418–422. [CrossRef] [PubMed]
34. Albinet, C.T.; Boucard, G.; Bouquet, C.A.; Audiffren, M. Increased heart rate variability and executive performance after aerobic training in the elderly. *Eur. J. Appl. Physiol.* **2010**, *109*, 617–624. [CrossRef] [PubMed]
35. Cunha, F.A.; Midgley, A.W.; Monteiro, W.D.; Farinatti, P.T. Influence of cardiopulmonary exercise testing protocol and resting VO(2) assessment on %HR(max), %HRR, %VO(2max) and %VO(2)R relationships. *Int. J. Sports Med.* **2010**, *31*, 319–326. [CrossRef] [PubMed]
36. Kenney, W.; Wilmore, J.; Costill, D. *Physiology of Sport and Exercise*; Human Kinetics: Champaing, IL, USA, 2015.
37. Pymer, S.; Nichols, S.; Prosser, J.; Birkett, S.; Carroll, S.; Ingle, L. Does exercise prescription based on estimated heart rate training zones exceed the ventilatory anaerobic threshold in patients with coronary heart disease undergoing usual-care cardiovascular rehabilitation? A United Kingdom perspective. *Eur. J. Prev. Cardiol.* **2019**. [CrossRef] [PubMed]