Hemodynamic Adaptations Induced by Short-Term Run Interval Training in College Students

Patricia C. García-Suárez 1, Iván Rentería 1, Priscilla García Wong-Avilés 1, Fernanda Franco-Redona 1, Luis M. Gómez-Miranda 2, Jorge A. Aburto-Corona 2, Eric P. Plaisance 3, José Moncada-Jiménez 4 and Alberto Jiménez-Maldonado 1,*

1 Facultad de Deportes, Universidad Autónoma de Baja California-Ensenada, Boulevard Zertuche s/n. Fraccionamiento Valle Dorado, Ensenada 22890, Baja California, Mexico; patricia.garcia@uabc.edu.mx (P.C.G.-S.); irenteria@uabc.edu.mx (I.R.); garcia.priscilla@uabc.edu.mx (P.G.W.-A.); francofer022@gmail.com (F.F.-R.)
2 Facultad de Deportes Tijuana, Universidad Autónoma de Baja California, Avenida Macllovio Herrera #4080, Colonia Francisco Villa, Tijuana 22615, Baja California, Mexico; luismariouabc@gmail.com (L.M.G.-M.); jorge.aburto@uabc.edu.mx (J.A.A.-C.)
3 Department of Human Studies, University of Alabama at Birmingham, Education Building 901, 13th Street South, Birmingham, AL 35294, USA; plaisep@uab.edu
4 Human Movement Sciences Research Center (CIMOHU), University of Costa Rica, Ave. 31 Pavas, San José 1200, Costa Rica; jose.moncada@ucr.ac.cr
* Correspondence: jimenez.alberto86@uabc.edu.mx

Received: 26 April 2020; Accepted: 20 May 2020; Published: 27 June 2020

Abstract: Perceived lack of time is one of the most often cited barriers to exercise participation. High intensity interval training has become a popular training modality that incorporates intervals of maximal and low-intensity exercise with a time commitment usually shorter than 30 min. The purpose of this study was to examine the effects of short-term run interval training (RIT) on body composition (BC) and cardiorespiratory responses in undergraduate college students. Nineteen males (21.5 ± 1.6 years) were randomly assigned to a non-exercise control (CON, n = 10) or RIT (n = 9). Baseline measurements of systolic and diastolic blood pressure, resting heart rate (HRrest), double product (DP) and BC were obtained from both groups. VO2max and running speed associated with VO2peak (sVO2peak) were then measured. RIT consisted of three running treadmill sessions per week over 4 weeks (intervals at 100% sVO2peak, recovery periods at 40% sVO2peak). There were no differences in post-training BC or VO2max between groups (p > 0.05). HRrest (p = 0.006) and DP (p ≤ 0.001) were lower in the RIT group compared to CON at completion of the study. RIT lowered HRrest and DP in the absence of appreciable BC and VO2max changes. Thereby, RIT could be an alternative model of training to diminish health-related risk factors in undergraduate college students.

Keywords: sprint interval training; VO2max; body composition; running; double product; heart rate

1. Introduction

A robust negative relationship exists between weekly amounts of physical activity and cardiometabolic disease morbidity and mortality [1]. The American College of Sports Medicine (ACSM) recommends performing 150 min/week of moderate-intensity or ≥75 min/week of vigorous-intensity physical activity. Although achieving physical activity recommendations is a proven strategy to improve health, undergraduate students, like much of the adult population in developed countries do not meet these recommendations [2–4], and report lack of time as the main barrier to achieving these recommendations [5]. In addition, undergraduate students have unhealthy eating habits [6,7]
and high levels of psychological stress (e.g., school burnout, anxiety, depression) [8–10]. All of these conditions are considered powerful risk markers for cardiovascular disease (CVD) [11,12].

Emerging evidence indicates that high intensity interval exercise training (HIIT), may promote similar benefits as longer duration continuous moderate-intensity exercise which may have important implications for individuals with limited time for exercise [13,14]. For instance, HIIT is characterized by performing relatively short bursts of vigorous activity (e.g., 80% to 100% of the maximal heart rate [HRmax] or 80% to 95% peak oxygen consumption [VO_{2peak}]). Intense exercise is interspersed by passive rest or active low-intensity exercise recovery periods (e.g., 40% HRmax) [15,16].

In fact, HIIT is classified based on interval duration, work intensity, session volume and protocol duration [17]. HIIT is exercise modality usually performed in cycle ergometer, motorized treadmill, or running track [13,18,19]. Several reports indicate that HIIT sessions usually consist of 4–8 bouts of high intensity and recovery sessions typically lasting <30 min [20], highlighting the utility of this form of training as it relates to time barriers [21]. Evidence suggests that short-term cycle ergometer interval training interventions (≤4 weeks) improve physiological markers associated with health (e.g., skeletal muscle oxidative capacity and VO_{2max}) in male undergraduate students [13,22,23]. The effects of cycle ergometer interval training on body composition have also been reported [24], with a report of lower body fat percentage following 12 cycle-ergometer interval training sessions [24]. Nevertheless, the metabolic demands of the exercise modalities are different in cycling compared to running [25]; thus, previous findings cannot be generalized to run interval training (RIT). In fact, there are only a few studies reporting the effects of short-term high intensity RIT on cardiorespiratory fitness and body composition in undergraduate students [18,26,27]. Moreover, we are unaware of any studies which have examined the impact of short-term RIT on hemodynamic responses in undergraduate students. Therefore, the aim of the present study was to determine the effects of short-term RIT performed on a motorized treadmill on hemodynamic variables, cardiorespiratory fitness, and body composition in young adult undergraduate students. We hypothesized that 12 sessions of RIT would improve cardiorespiratory fitness, hemodynamic, and body composition variables in exercise participants compared to a non-exercise control condition.

2. Materials and Methods

2.1. Participants

Nineteen physically active (self-reported International Physical Activity Questionnaire [IPAQ] short form: 6819.3 ± 4505.2 METs; minimum value: 1626, maximum value: 15,813) undergraduate male students (age = 21.5 ± 1.6 yr.) from the Sports Faculty of the Universidad Autónoma de Baja California (UABC) participated in the study. Inclusion criteria were: (a) non-smoking, (b) free from any known metabolic or cardiovascular disease, and (c) not taking any medications known to affect hemodynamic or other physiological variables. The procedures were explained to each participant, who agreed to complete the study after reading and signing an institutionally approved informed consent in accordance with the Declaration of Helsinki and previously approved by the Research Ethics Committee of the Escuela de Ciencias de la Salud of UABC (register number 002-2019).

2.2. Experimental Design

Participants were given three appointments to the laboratory separated by 24 h. Each participant was instructed to refrain from performing strenuous exercise the day before arrival to the laboratory. The first visit included a complete demonstration of the treadmill (ProForm, Logan, UT, USA), the bioelectrical impedance (BIA) analyzer (Inbody 770, Biospace Corporation, Seoul, South Korea), and the metabolic cart (COSMED Quark CPET, Rome, Italy). Body composition measures were recorded during the second visit, and the graded exercise test (GXT) during the third visit. All laboratory tests were performed between 0900 and 1200 h. Following baseline measurements, participants were assigned by simple randomization to a non-exercise control (CON, n = 10) or an exercise (RIT, n = 9)
The participants started the 12 session RIT program 24 h after the GXT. During the training program, participants in both groups were allowed to engage in normal leisure and school physical activities. The CON group only visited the laboratory during the baseline measurements and at the end of the program. Both groups were assessed in the same order as described above 24 h after the last exercise session (Figure 1).

**Figure 1.** Flow chart of study procedures. Training sessions are depicted as open bars and the numbers inside bars indicate the interval ratio (high–low intensity) and bold numbers represent the 2 min “all out” sprints performed during each session. Cardiovascular measures, bioelectrical impedance (BIA) and graded exercise tests (GXT) were performed 24 h before and after the RIT protocol.

### 2.3. Body Composition Analysis

Height was measured using a stadiometer (Biospace Corporation, Seoul, South Korea) to the nearest ±1 mm. Body composition measures (i.e., body weight [kg], body fat mass [%], muscle mass [kg], leg lean mass [kg], and body mass index [BMI = kg/m²]) were recorded by BIA [28]. For quality control, participants were instructed to refrain from eating and drinking for at least 2 h and to void their bladders 60 min prior to performing BIA.

### 2.4. Graded Exercise Test (GXT)

Participants performed a GXT until volitional fatigue to determine fitness level (VO₂max) [29]. The GXT followed a standard protocol reported before [30,31] with minor modifications. Briefly, the test started with a warm-up run at 5.0 km/h with 1% incline. Then, the treadmill speed was increased by 1 km/h every 2 min until participant’s exhaustion. During the GXT, members of the research team encouraged participants to give their maximal effort. Breath-by-breath samples of expired CO₂ were collected during the test. The VO₂ value recorded at the last stage of the GXT was considered the VO₂peak (Supplementary Figure S1). The running speed associated with the VO₂peak (sVO₂peak) was used to design the RIT program. Immediately following the last stage of the GXT, a 4 min cool-down run was performed at 5.0 km/h with 1% incline. The GXT was considered maximal if the participants reached three of the following criteria: (a) respiratory exchange ratio (RER) > 1.10, (b) HRmax within 10 beats of the age-predicted HRmax (220-age), and (c) a VO₂ plateau despite an increase in workload or running speed [32,33], and/or (d) when the participant requested to stop the test because of volitional exhaustion [34]. The exhaustion time, HRmax and VO₂max were recorded at the end of the GXT.

### 2.5. Hemodynamic Responses

Participants rested while sitting comfortably in a chair upon arrival to the laboratory. After 5-min, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded by a digital blood pressure monitor (Omron, Omron Healthcare, Inc., Bannockburn, IL, USA). Resting heart
rate (HRrest) was measured by telemetry (Polar FT1, Kempele, Finland). HR recordings during the exercise sessions were registered at the end of each high-intensity bout. Baseline double product (DP \( [\text{mmHg} \cdot \text{bpm/100}] = \text{SBP} \times \text{HRrest} \)) was calculated as an index of myocardial oxygen consumption (\( \text{MVO}_2 \)) [35–37].

2.6. Run Interval Training

The RIT program consisted of 12 exercise sessions, with a progressively increasing training volume. Weekly training sessions were performed on Monday, Wednesday, and Friday for four weeks. All training sessions were performed from 0900 to 1300 h in the student’s personal leisure time between classes. The initial three sessions started with a 2 min run warm-up at 40% \( \text{sVO}_2 \text{peak} \). Then, a high-intensity interval was performed for 2 min at 100% \( \text{sVO}_2 \text{peak} \), for a total of three high-intensity and low-intensity bouts. The mean intensity was calculated using the equation reported by Billat et al., (2001): \((100 + 40)/2 = 70\% \text{sVO}_2 \text{peak}\). The high:low interval ratio for these sessions was 2:2 = 1 [38], and the total training time was 12 min. The next four sessions consisted of four cycles of RIT. The high:low interval ratio was 2:1 = 2, for a total duration of 12 min. Finally, for the last five sessions, the number of cycles increased to five (Supplementary Figure S1), the high:low interval ratio was 2:1 = 2, for a total duration of 15 min. This protocol can be considered as moderate-volume (MV-HIIT), and short duration intervention (ST-HIIT) [17]. To confirm the effect of the workload changes during the intervention, the total distance (km) covered in each exercise session was recorded for volume and intensity. Finally, the HR was monitored continuously throughout all exercise sessions.

2.7. Statistical Analysis

Statistical analysis was performed using IBM SPSS version 20.0 (IBM SPSS-Statistics, Armonk, NY, USA). Data are reported as means ± standard deviation (SD). Distribution of the data was assessed with the Shapiro-Wilk’s test. Independent samples \( t \)-test compared mean baseline anthropometry and body composition between CON and RIT groups. One-way ANOVA was computed to examine mean differences in distance run and HRmax responses in the training sessions S1 (start of program), S6 (middle of the program), and S12 (end of program). Two-way ANOVA with Tukey post-hoc testing was computed to evaluate \( \text{VO}_2 \text{max} \), hemodynamic, and body composition variables over time (pre vs. post) and groups (CON vs. RIT). Pearson correlation was used to analyze the association among the change (\( \Delta \% \)) in the HRrest and SBP. Effect sizes were computed as Cohen’s \( \text{d} \), and were interpreted as small \((0.2–0.5)\), moderate \((0.5–0.8)\) and large \( (>0.8)\). The 95% confidence intervals (95% CI) around the point estimates are reported. Statistical significance was set a priori at \( p \leq 0.05 \).

3. Results

Descriptive and inferential statistics of the participants in the CON and RIT groups are presented in Table 1. Following randomization, baseline age, height, weight, BMI, fat mass (%), muscle mass (kg) and lean leg mass (kg) were similar between CON and RIT groups (\( p > 0.05 \) for all). Distance run during RIT was different between the program stages (\( p = 0.002, \text{d} = 1.12, 95\%\text{CI} = 1.11, 1.12 \)). Post-hoc analysis showed that the distance run during S1 (2.8 ± 0.4 km) and S6 (3.0 ± 0.2 km) was similar (\( p = 0.091, 95\%\text{CI} = 0.0, 0.4 \)). The distance run during S1 was shorter than S12 (3.1 ± 0.2 km, \( p = 0.005, 95\%\text{CI} = 0.2, 0.6 \)), and the distance run during S12 was longer than S6 (\( p = 0.004, 95\%\text{CI} = 0.1, 0.2 \), Figure 2A). These data indicate the positive effects of the workload changes applied during the treatment. Mean HR response to high-intensity bouts was similar between S1, S6 and S12 (\( p = 0.543 \)) (Figure 2B). The mean HR recorded during S1, S6 and S12 were 90% of the HRmax reached during the GXT.
was found between \( \Delta \) was smaller in the RIT group compared to CON (\( p \leq 0.001, 95\% CI = 12.1, 34.3 \)) (Table 1).

There was no interaction between CON and RIT and measurement times for VO\(_{2\text{max}}\), exhaustion time, DBP, body weight, BMI, body fat %, muscle mass, and lean leg mass. Although not statistically significant, the RIT intervention showed a strong trend to reduce SBP compared to the post-test of the CON group (\( p = 0.07, d = -1.98, 95\% CI = -2.11, -1.85 \)) (Table 1). There was an interaction between CON and RIT and measurement times on HRrest (\( p \leq 0.001, d = 2.21, 95\% CI = 2.07, 2.35 \)). Follow-up analysis showed that HRrest increased in the CON group (\( p = 0.031, 95\% CI = 0.7, 13.1 \)) and decreased in the RIT group (\( p = 0.001, 95\% CI = 5.6, 17.4 \)) after the program. Mean HRrest following the program was smaller in the RIT group compared to CON (\( p = 0.006, 95\% CI = 4.3, 21.2 \)) (Table 1). A correlation was found between \( \Delta \)HRrest and \( \Delta \)SBP (\( r = 0.52, p = 0.02, d = 0.27, 95\% CI = 0.09, 0.79 \)) (Figure 3). There was an interaction between CON and RIT and measurement times on DP (\( p \leq 0.001, d = 2.06, 95\% CI = -19.90, 24.02 \)). Follow-up analysis showed that DP increased in the CON group (\( p = 0.012, 95\% CI = 3.2, 22.7 \)) and decreased in the RIT group (\( p = 0.005, 95\% CI = 4.8, 23.4 \)) after the program. Mean DP was lower in the RIT group compared to CON following the program (\( p \leq 0.001, 95\% CI = 12.1, 34.3 \)) (Table 1).
In this study, we report that a short-term RIT protocol reduced HRrest; these data are in agreement with other authors that used short-term interval training in cycling exercises [45]. In the current study, heart rate variability was not measured; thus, we cannot determine whether the lower HRrest resulted from an elevated vagal activity following training. Others have previously demonstrated that the physiological mechanism induced by short-term interval training responsible for reducing HRrest is an intrinsic adaptation of the sinoatrial node rather than autonomic activity changes [45]. Therefore, it is possible that similar physiological adaptations might have occurred in our participants to reduce HRrest. Contrary, the CON group increased HRrest, despite this outcome, their values match with previous HRrest data reported in healthy young adults [46–48].

**Figure 3.** Scatter plot for the correlation analysis between ΔHRrest and ΔSBP. \( \Delta = ([\text{Post-intervention} - \text{Pre-intervention values}] / \text{Pre-intervention values}) \times 100 \). Dashed lines are the 95% CI around the regression line. \( r = 0.52, p = 0.02 \).

4. Discussion

The aim of the current study was to determine the effects of short-term RIT on cardiorespiratory fitness, hemodynamic responses, and body composition in healthy undergraduate students. The main finding of the study was a significant reduction in DP and HRrest following 4 weeks of RIT. However, the 12 sessions of RIT did not modify fitness levels or body composition.

The total training volume throughout all sessions averaged ≤15 min, which agrees with the training duration suggested for HIIT or SIT [39]. The HR reached during each high-intensity bout was approximately 90% of HRmax. Since the high-intensity bouts were performed at 100% of sVO2peak, our results show that monitoring HR is not a good indicator for controlling the intensity of interval training, this phenomena was also previously reported in healthy young adults [40–42]. In contrast to previous reports, VO2max was not increased following short-term training compared to CON [18,27]. Participants in the current study showed higher baseline VO2max values than those previously reported [18,27], which could partially explain the lack of significant changes in aerobic power. Others have suggested a similar hypothesis [41]. Moreover, although the studies that reported an improvement in VO2max directly had comparable intervention durations (12 sessions over 4 weeks) compared with the current study, the sessions’ design were completely different (short-interval vs. moderate interval in the current study) [17,18,27]. These data suggest that interval duration is relevant to increase cardiorespiratory fitness in young adults [24,43]. Finally, although we did not examine peripheral adaptations, other reports show that 18 sessions of interval training improved VO2max in undergraduate students by inducing skeletal muscle adaptations [26,44].

In this study, we report that a short-term RIT protocol reduced HRrest; these data are in agreement with other authors that used short-term interval training in cycling exercises [45]. In the current study, heart rate variability was not measured; thus, we cannot determine whether the lower HRrest resulted from an elevated vagal activity following training. Others have previously demonstrated that the physiological mechanism induced by short-term interval training responsible for reducing HRrest is an intrinsic adaptation of the sinoatrial node rather than autonomic activity changes [45]. Therefore, it is possible that similar physiological adaptations might have occurred in our participants to reduce HRrest. Contrary, the CON group increased HRrest, despite this outcome, their values match with previous HRrest data reported in healthy young adults [46–48].
The RIT program designed for the present study produced a decrease in SBP compared to CON, yet, this finding did not reach statistical significance. The trend observed agrees with a recent report that showed the efficacy of short-term interval training to reduce blood pressure [45]; additionally, a recent meta-analysis identified a significant benefit of interval training to improve daytime resting blood pressure [12]. It has been reported that peripheral vascular adaptations are the main interval training-related mechanisms responsible for reducing resting blood pressure [49,50]. Cross-sectional studies have reported that abnormal blood pressure values (e.g., pre-hypertension, hypertension) are common in young adult populations [51,52]. In undergraduate students, high blood pressure is a consequence of higher sympathetic tone [53], and our data are in agreement with this physiological mechanism, where a lower HRrest was associated with lower SBP (Figure 3). Therefore, RIT could be an effective strategy to regulate resting blood pressure in a predisposed population of students characterized by having high-levels of sedentary time, lack of time for physical activity/exercise, and high levels of school burnout [53,54]. In addition, resting DP changed differentially in the RIT and CON groups. DB was lower at the end of the study in the RIT and higher in the CON (within-group analysis), and DP was lower in the RIT compared to the CON following intervention (between-group analysis). These data are in concordance with a lower HRrest [55] (Table 1). The DP is a non-invasive method to estimate MVO$_2$ [56]. Others have reported lower resting DP after long-term resistance training in hypertensive women [57]; however, the effects of short-term interval training on resting and exercise DP have not been reported. The usefulness of DP at rest has been previously suggested in the context of MVO$_2$ [58,59] in that a higher DP at rest was more strongly associated with cardiovascular disease (CVD) mortality, and non-CVD mortality than other cardiovascular biomarkers (e.g., SBP, DBP, HRrest) [53]. A low MVO$_2$ is an indicator of improvement in left ventricular relaxation, and changes in myocardial substrate metabolism [60,61]. Although we did not evaluate MVO$_2$ directly, our data suggest that 12 RIT sessions may have induced metabolic changes in the heart that lead to lower estimates of cardiac muscle VO$_2$.

In the present study, body composition did not change with 12 sessions of RIT. Our results are in agreement with others who employed a similar short-term running interval training protocols [18]. In contrast, studies using longer interval training programs (≥6 weeks) have reported positive changes in body composition [19,26,62]. These findings suggest that the length of the training program is a relevant variable to induce positive changes in body composition. It is worth noting that in the current study, the calorie intake and composition were not controlled, which may have dampened the training effects on body composition [63,64].

A potential limitation of the current study was that we only included males. Additional short- and long-term studies examining both men and women in parallel cohorts will be important in future studies to further examine hemodynamic and cardiorespiratory responses to exercise. In addition, participants in the current study had high baseline fitness levels which along with the short duration of the study could have limited the magnitude of improvement in both fitness and body composition. In addition, we did not monitor changes in physical activity levels throughout the study; however, participants were instructed to maintain unchanged their physical activity levels throughout the duration of the study. Perhaps accelerometry might be used in future studies to accurately confirm habitual physical activity levels. Finally, this study did not determine ventilatory thresholds (VT), a variable used to assess functional capacity in individuals [65]. Scientific evidence indicates significant changes in VT after long and mid-term interval training [27,66,67]; therefore, we do not discard the possibility that RIT could modify VT in the participants.

5. Conclusions

Twelve RIT sessions performed over 4 weeks, and executed during short breaks of daily academic activities significantly decreased HRrest and an estimate of MVO$_2$ in male undergraduate students with high cardiorespiratory fitness levels. In contrast, the exercise intervention did not modify VO$_{2max}$ and body composition. Based on previous studies using longer exercise duration, it seems plausible
that a threshold training length is needed to observe positive changes in cardiorespiratory fitness and body composition. However, reduced heart rate and DP indicate that metabolic changes occur rapidly even in the absence of reductions in body weight or adiposity (at least in males). Further studies are needed to examine the time course of effects of RIT on cardiorespiratory fitness and body composition in male and female undergraduate students.

**Supplementary Materials:** The following are available online at http://www.mdpi.com/1660-4601/17/13/4636/s1, Figure S1: Exchange gas data during a graded exercise test (GXT).

**Author Contributions:** Conceptualization, P.C.G.-S. and A.J.-M.; methodology, P.C.G.-S., I.R., L.M.G.-M., J.A.A.-C., Almanza Reyes for his support in the ethics committee and his recommendations provided for the completion of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

**Funding:** This research was partially funded by the “20th Convocatoria Interna de Apoyo a Proyectos de Investigación” (Register number 431/2/C/39/20) to Iván Rentería. Priscilla García Wong Avilés received a scholar fellowship from PRODEP 2017 No. UABC-PTC 66.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

**References**

1. Garber, C.E.; Blissmer, B.; Deschenes, M.R.; Franklin, B.A.; Lamonte, M.J.; Lee, I.M.; Nieman, D.C.; Swain, D.P. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med. Sci. Sports Exerc.* 2011, 43, 1334–1359. [CrossRef] [PubMed]

2. Acebes-Sánchez, J.; Diez-Vega, I.; Rodríguez-Romo, G. Physical activity among spanish undergraduate students: A descriptive correlational study. *Int. J. Environ. Res. Public Health* 2019, 16, 2770. [CrossRef] [PubMed]

3. Parra-Saldivia, M.; Castro-Piñero, J.; Paredes, A.C.; Leal, X.P.; Martinez, X.D.; Rodríguez-Rodriguez, F. Active commuting behaviors from high school to university in Chile: A retrospective study. *Int. J. Environ. Res. Public Health* 2019, 16, 53. [CrossRef] [PubMed]

4. Varela-Mato, V.; Cancela, J.M.; Ayan, C.; Martín, V.; Molina, A. Lifestyle and health among spanish university students: Differences by gender and academic discipline. *Int. J. Environ. Res. Public Health* 2012, 9, 2728–2741. [CrossRef] [PubMed]

5. Justine, M.; Azizan, A.; Hassan, V.; Salleh, Z.; Manaf, H. Barriers to participation in physical activity and exercise among middle-aged and elderly individuals. *Singapore Med. J.* 2013, 54, 581–586. [CrossRef]

6. Bernardo, G.L.; Jomori, M.M.; Fernandes, A.C.; ProenÇa, R.P. Consumo alimentar de estudiantes universitarios. *Rev. Nutr. Rev. Nutr.* 2017, 30, 847–865. [CrossRef]

7. Lupi, S.; Bagordo, F.; Stefanati, A.; Grassi, T.; Piccinni, L.; Bergamini, M.; De Donno, A. Assessment of lifestyle and eating habits among undergraduate students in Northern Italy. *Ann. dell’Ist. Super. Sanita* 2015, 51, 154–161. [CrossRef]

8. Dos Santos Boni, R.A.; Paiva, C.E.; De Oliveira, M.A.; Lucchetti, G.; Fregnani, J.H.T.G.; Paiva, B.S.R. Burnout among medical students during the first years of undergraduate school: Prevalence and associated factors. *PLoS ONE* 2018, 13, e0191746. [CrossRef]

9. Altannir, Y.; Alnajjar, W.; Ahmad, S.O.; Altannir, M.; Yousuf, F.; Obeidat, A.; Al-Tannir, M. Assessment of burnout in medical undergraduate students in Riyadh, Saudi Arabia. *BMC Med. Educ.* 2019. [CrossRef] [PubMed]

10. Shankland, R.; Kotsou, I.; Vallet, F.; Bouteyre, E. Burnout in university students: The mediating role of sense of coherence on the relationship between daily hassles and burnout. *High. Educ.* 2019, 78, 91–113. [CrossRef]

11. May, R.W.; Sanchez-Gonzalez, M.A.; Fincham, E.D. School burnout: Increased sympathetic vasomotor tone and attenuated ambulatory diurnal blood pressure variability in young adult women. *Stress* 2014, 18, 11–19. [CrossRef] [PubMed]
12. May, R.W.; Seibert, G.S.; Sanchez-Gonzalez, M.A.; Fincham, F.D. School burnout and heart rate variability: risk of cardiovascular disease and hypertension in young adult females. *Stress* **2017**, *21*, 211–216. [CrossRef] [PubMed]

13. Gibala, M.J.; Little, J.P.; van Essen, M.; Wilkin, G.P.; Burgomaster, K.A.; Safdar, A.; Raha, S.; Tarnopolsky, M.A. Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *J. Physiol.* **2006**, *575*, 901–911. [CrossRef]

14. Thum, J.S.; Parsons, G.; Whittle, T.; Astorino, T.A. High-intensity interval training elicits higher enjoyment than moderate intensity continuous exercise. *PLoS ONE* **2017**, *12*, e0166299. [CrossRef] [PubMed]

15. Kliszczewicz, B.; Buresh, R.; Bechke, E.; Williamson, C. Metabolic biomarkers following a short and long bout of high-intensity functional training in recreationally trained men. *J. Hum. Sport Exerc.* **2017**, *12*, 710–718. [CrossRef]

16. Gibala, M.J.; Jones, A.M. Physiological and performance adaptations to high-intensity interval training. *Nestle Nutr. Inst. Workshop Ser.* **2013**, *76*, 51–60. [CrossRef]

17. Wen, D.; Utesch, T.; Wu, J.; Robertson, S.; Liu, J.; Hu, G. Effects of different protocols of high intensity interval training for VO2max improvements in adults: A meta-analysis of randomised controlled trials. *J. Sci. Med. Sport* **2019**, *22*, 941–947. [CrossRef]

18. Mckie, G.L.; Islam, H.; Townsend, L.K.; Robertson-wilson, J.; Eys, M.; Hazell, T.J. Modified sprint interval training protocols: Physiological and psychological responses to four weeks of training. *Appl. Physiol. Nutr. Metab.* **2018**, *43*. [CrossRef]

19. Ouerghi, N.; Ben Fradj, M.K.; Bezrati, I.; Khammassi, M.; Feki, M.; Kaabachi, N.; Bouassida, A. Effects of high-intensity interval training on body composition, aerobic and anaerobic performance and plasma lipids in overweight/obese and normal-weight young men. *Biol. Sport* **2017**, *34*, 385–392. [CrossRef]

20. Gillen, J.B.; Percival, M.E.; Skelly, L.E.; Martin, B.J.; Tan, R.B.; Tarnopolsky, M.A.; Gibala, M.J. Three minutes of all-out intermittent exercise per week increases skeletal muscle oxidative capacity and improves cardiometabolic health. *PLoS ONE* **2014**, *9*, e0111489. [CrossRef]

21. Schubert, M.M.; Palumbo, E.; Seay, R.F.; Clarke, E. Energy compensation after sprint- and high-intensity interval training. *PLoS ONE* **2017**, *12*, e0189590. [CrossRef] [PubMed]

22. Burgomaster, K.A.; Hughes, S.C.; Heigenhauser, G.J.F.; Bradwell, S.N.; Gibala, M.J.; Kirsten, A.; George, J.F. Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *J. Appl. Physiol.* **2005**, *98*, 1985–1990. [CrossRef] [PubMed]

23. Burgomaster, K.A.; Heigenhauser, G.J.F.; Gibala, M.J.; Kirsten, A. Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. *J. Appl. Physiol.* **2006**, *100*, 2041–2047. [CrossRef] [PubMed]

24. Lee, C.L.; Hsu, W.C.; Cheng, C.F. Physiological Adaptations to Sprint Interval Training with Matched Exercise Volume. *Med. Sc. Sports Exerc.* **2017**, *49*, 86–95. [CrossRef]

25. Kriel, Y.; Askew, C.D.; Solomon, C. The effect of running versus cycling high-intensity intermittent exercise on local tissue oxygenation and perceived enjoyment in 18–30-year-old sedentary men. *PeerJ* **2018**, *6*, e5026. [CrossRef]

26. Macpherson, R.E.K.; Hazell, T.O.M.J.; Olver, T.D.; Paterson, D.O.N.H.; Lemon, P.W.R. Run Sprint Interval Training Improves Aerobic Performance but Not Maximal Cardiac Output. *Med. Sc. Sports Exerc.* **2011**, *43*, 115–122. [CrossRef]

27. Menz, V.; Marterer, N.; Amin, S.B.; Faulhaber, M.; Hansen, A.B.; Lawley, J.S. Functional vs. Running low-volume high-intensity interval training: Effects on vo2max and muscular endurance. *J. Sports Sci. Med.* **2019**, *18*, 497–504.

28. Ling, C.H.Y.; de Craen, A.J.M.; Slagboom, P.E.; Gunn, D.A.; Stokkel, M.P.M.; Westendorp, R.G.J.; Maier, A.B. Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in middle-aged adult population. *Clin. Nutr.* **2011**, *30*, 610–615. [CrossRef]

29. Racil, G.; Ben Ounis, O.; Hammouda, O.; Kallel, A.; Zouhal, H.; Chamari, K.; Amri, M. Effects of high vs. moderate exercise intensity during interval training on lipids and adiponectin levels in obese young females. *Eur. J. Appl. Physiol.* **2013**, *113*, 2531–2540. [CrossRef]

30. Araujo Naves, J.P.; Silva Rebelo, A.C.; Bento, E.; Silva, L.R.; Silva, M.S.; Ramirez-Campillo, R.; Ramirez-Velez, R.; Gentil, P. Cardiorespiratory and perceptual responses of two interval training and a continuous training protocol in healthy young men. *Eur. J. Sport Sci.* **2019**. [CrossRef]
31. Cabral-Santos, C.; Castrillón, C.I.M.M.; Miranda, R.A.T.T.; Monteiro, P.A.; Inoue, D.S.; Campos, E.Z.; Hofmann, P.; Lira, F.S.; Cabral-Santos, C.; Castrillón, C.I.M.M.; et al. Inflammatory Cytokines and BDNF Response to High-Intensity Intermittent Exercise: Effect the Exercise Volume. *Front. Physiol.* 2016. [CrossRef] [PubMed]
32. 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]
33. Mcphee, J.S.; Williams, A.G.; Degens, H.; Baar, K.; Jones, D.A. Variability in the magnitude of response of metabolic enzymes reveals patterns of co-ordinated expression. *Exp. Physiol.* 2011, 699–707. [CrossRef]
34. Beltz, N.M.; Gibson, A.L.; Janot, J.M.; Kravitz, L.; Mermier, C.M.; Dalleck, L.C. Graded Exercise Testing Protocols for the Determination of VO₂ max: Historical Perspectives, Progress, and Future Considerations. *J. Sports Med.* 2016, 2016, 3968393. [CrossRef]
35. Nishimura, K.; Nagasaki, K.; Yamaguchi, H.; Yoshioka, A.; Nose, Y.; Takamoto, N. Circadian variations in anaerobic threshold. *Kinesiology* 2014, 46, 164–170.
36. Akizuki, K.; Yazaki, S.; Echizenya, Y.; Ohashi, Y. Anaerobic Threshold and Salivary α-amylase during Incremental Exercise. *J. Phys. Ther. Sci.* 2014, 26, 1059–1063. [CrossRef] [PubMed]
37. Czajkowska, A.; Mazurek, K.; Lutosławska, G.; ˙Zmijewski, P. Anthropometric and cardio-respiratory indices and aerobic capacity of male and female students. *Biomed. Hum. Kinet.* 2009, 1, 47–51. [CrossRef]
38. Billat, L.V. Interval Training for Performance: A Scientific and Empirical Practice. *Sports Med.* 2001, 31, 13–31. [CrossRef]
39. Gillen, J.B.; Gibala, M.J. Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? *Appl. Physiol. Nutr. Metab.* 2018, 39, 409–412. [CrossRef]
40. Shi, Q.; Tong, T.K.; Sun, S.; Kong, Z.; Kit, C. Influence of recovery duration during 6-s sprint interval exercise on time spent at high rates of oxygen uptake In fl uence of recovery duration during 6-s sprint interval exercise on time spent at high rates of oxygen uptake. *J. Exerc. Sci. Fit.* 2018, 16, 16–20. [CrossRef]
41. Astorino, T.A.; Edmunds, R.M.; Clark, A.; King, L.; Gallant, R.A.; Namm, S.; Fischer, A.; Wood, K.M. High-Intensity Interval Training Increases Cardiac Output and V-O2max. *Med. Sci. Sports Exerc.* 2017, 49, 265–273. [CrossRef] [PubMed]
42. Horn, T.; Roverud, G.; Sutzko, K.; Browne, M.; Parra, C.; Astorino, T.A. Single session of sprint interval training elicits similar cardiac output but lower oxygen uptake versus ramp exercise to exhaustion in men and women. *Int. J. Physiol. Pathophysirol. Pharmacol.* 2016, 8, 87–94. [PubMed]
43. Ikutomo, A.; Kasai, N.; Goto, K. Impact of inserted long rest periods during repeated sprint exercise on performance adaptation. *Eur. J. Sport Sci.* 2017, 18, 47–53. [CrossRef] [PubMed]
44. Raleigh, J.; David, M.; Giles, M.; Islam, H.; Nelms, M. Contribution of central and peripheral adaptations to changes in VO₂max following four weeks of sprint interval training. *Apppl. Physiol. Nutr. Metab.* 2018, 43, 1059–1068. [CrossRef]
45. Alansare, A.; Alford, K.; Lee, S.; Church, T.; Jung, H.C. The effects of high-intensity interval training vs. Moderate-intensity continuous training on heart rate variability in physically inactive adults. *Int. J. Environ. Res. Public Health* 2018, 15, 1508. [CrossRef] [PubMed]
46. Hajsadeghi, S.; Mohammadpour, F.; Manteghi, M.J.; Kordshakeri, K.; Tokazebani, M.; Rahmani, E.; Hassanzadeh, M. Effects of energy drinks on blood pressure, heart rate, and electrocardiographic parameters: An experimental study on healthy young adults. *Anatol. J. Cardiol.* 2016, 16, 94–99. [CrossRef] [PubMed]
47. Zhang, H.; Tao, J.; Lu, S.; Hu, Y.; Gu, Y. Effects of inverse moxibustion on the translocation of telomerase from cardiomyocyte mitochondria of growing mice following exercise. *Int. J. Clin. Exp. Med.* 2016, 9, 11268–11275. [CrossRef]
48. Costa, A.; Bosone, D.; Zoppo, A.; D’Apos Angelo, A.; Ghiotto, N.; Guasch ino, E.; Cotta Ramusino, M.; Fogari, R. Effect of diazepam on 24-hour blood pressure and heart rate in healthy young volunteers. *Pharmacology* 2018, 101, 86–91. [CrossRef]
49. Cocks, M.; Shaw, C.S.; Shepherd, S.O.; Fisher, J.P.; Ranasinghe, A.M.; Barker, T.A.; Tipton, K.D.; Wagenmakers, A.J.M. Sprint interval and endurance training are equally effective in increasing muscle microvascular density and eNOS content in sedentary males. *J. Physiol.* 2013, 591, 641–656. [CrossRef]
50. 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]
51. Drukteinis, J.S.; Roman, M.J.; Fabsitz, R.R.; Lee, E.T.; Best, L.G.; Russell, M.; Devereux, R.B. Cardiac and systemic hemodynamic characteristics of hypertension and prehypertension in adolescents and young adults: The Strong Heart Study. *Circulation* **2007**, *115*, 221–227. [CrossRef] [PubMed]

52. McEniry, C.M.; Hall, I.R.; Qasem, A.; Wilkinson, I.B.; Cockcroft, J.R. Normal vascular aging: Differential effects on wave reflection and aortic pulse wave velocity—The Anglo-Cardiff Collaborative Trial (ACCT). *J. Am. Coll. Cardiol.* **2005**, *46*, 1753–1760. [CrossRef] [PubMed]

53. May, R.W.; Seibert, G.S.; Sanchez-Gonzalez, M.A.; Fincham, F.D. Physiology of school burnout in medical students: Hemodynamic and autonomic functioning. *Burn. Res. Ther.* **2016**, *3*, 63–68. [CrossRef]

54. Gómez-López, M.; Gallegos, A.G.; Extremera, A.B. Perceived barriers by university students in the practice of physical activities. *J. Sports Sci. Med.* **2010**, *9*, 374–381.

55. Faria Terra, D.; Rabelo Mota, M.; Thomaz Rabelo, H.; Aguiar Bezerra, L.M.; Moreno Lima, R.; Garcia Ribeiro, A.; Henrique Vinalh, P.; Ritti Dias, R.M.; Martins da Silva, F. Reduction of arterial pressure and double product at rest after resistance exercise training in elderly hypertensive women. *Arch. Bras. Cardiol.* **2008**, *91*, 299–305.

56. Ansari, M.; Javadi, H.; Pourbehi, M.; Mogharrabi, M.; Rayzan, M.; Semnani, S.; Amini, A.; Abbaszadeh, M.; Barekat, M.; et al. The association of rate pressure product (RPP) and myocardial perfusion imaging (MPI) findings: A preliminary study. *Perfusion* **2012**, *27*, 207–213. [CrossRef] [PubMed]

57. Fleg, J.L.; Piña, I.L.; Balady, G.J.; Chaitman, B.R.; Fletcher, B.; Lavie, C.; Limacher, M.C.; Stein, R.A.; Williams, M.; Zoghbi, S.; Bazzarre, T. Assessment of Functional Capacity in Clinical and Research Applications. *Circulation* **2000**, *102*, 1591–1597. [CrossRef] [PubMed]

58. Kimura, G.; Inoue, N.; Mizuno, H.; Izumi, M.; Nagatoya, K.; Ohtahara, A.; Munakata, M.; Takano, H.; Saneshima, M.; Sakihara, T.; et al. Increased double product on Monday morning during work. *Hypertens. Res.* **2017**, *40*, 671–674. [CrossRef]

59. Inoue, R.; Okubo, T.; Kikuya, M.; Metoki, H.; Asahuma, K.; Kanno, A.; Obara, T.; Hori, T.; Harasawa, A.; Hoshi, H.; et al. Predictive value for mortality of the double product at rest obtained by home blood pressure measurement: The obasama study. *Am. J. Hypertens.* **2012**, *25*, 568–575. [CrossRef]

60. Peterson, L.R.; Herrero, P.; Schechtman, K.B.; Racette, S.B.; Waggoner, A.D.; Kisrieva-Ware, Z.; Dence, C.; Klein, S.; Marsala, J.; Meyer, T.; et al. Effect of Obesity and Insulin Resistance on Myocardial Substrate Metabolism and Efficiency in Young Women. *Circulation* **2004**, *109*, 2191–2196. [CrossRef]

61. Lin, C.H.; Kurup, S.; Herrero, P.; Schechtman, K.B.; Eagon, J.C.; Klein, S.; Dávila-Román, V.G.; Stein, R.I.; Dorn, G.W.; Il; Gropler, R.J.; et al. Myocardial Oxygen Consumption Change Predicts Left Ventricular Relaxation Improvement in Obese Humans After Weight Loss. *Obesity* **2011**, *19*, 1804–1812. [CrossRef]

62. Khammassi, M.; Queirgh, N.; Hadi-taieb, S.; Feki, M.; Thivel, D.; Bouassida, A. Impact of a 12-week physical exercise training on the double product break point in low-to-moderate risk adults. *Eur. J. Appl. Physiol.* **2011**, *111*, 313–318. [CrossRef] [PubMed]

63. Foster-Schubert, K.E.; Alfano, C.M.; Duggan, C.R.; Xiao, L.; Campbell, K.L.; Kong, A.; Bain, C.E.; Wang, C.Y.; Blackburn, G.L.; Mctiernan, A. Effect of diet and exercise, alone or combined, on weight and body composition in overweight-to-obese postmenopausal women. *Obesity* **2012**, *20*, 1628–1638. [CrossRef] [PubMed]

64. Layman, D.K.; Evans, E.; Baum, J.I.; Seyler, J.; Erickson, D.J.; Boileau, R.A. Dietary Protein and Exercise Have Additive Effects on Body Composition during Weight Loss in Adult Women. *J. Nutr.* **2018**, *135*, 1903–1910. [CrossRef] [PubMed]

65. Faria Terra, D.; Rabelo Mota, M.; Thomaz Rabelo, H.; Aguiar Bezerra, L.M.; Moreno Lima, R.; Garcia Ribeiro, A.; Henrique Vinalh, P.; Ritti Dias, R.M.; Martins da Silva, F. Reduction of arterial pressure and double product at rest after resistance exercise training in elderly hypertensive women. *Arch. Bras. Cardiol.* **2008**, *91*, 299–305.

66. Anderson, M.J.; Kauffman, M.F.; Johnson, D.; Wilcox, R.T.; paste, W.B.; Harries, R.; Wiernicki, T.; Yu, A.; Cooper, M.; et al. The influence of aerobic exercise training on wave reflection and aortic pulse wave velocity—The Anglo-Cardiff Collaborative Trial (ACCT). *J. Am. Coll. Cardiol.* **2005**, *46*, 1753–1760. [CrossRef] [PubMed]

67. Ansari, M.; Javadi, H.; Pourbehi, M.; Mogharrabi, M.; Rayzan, M.; Semnani, S.; Amini, A.; Abbaszadeh, M.; Barekat, M.; et al. The association of rate pressure product (RPP) and myocardial perfusion imaging (MPI) findings: A preliminary study. *Perfusion* **2012**, *27*, 207–213. [CrossRef] [PubMed]