Revista Contexto & Saúde
Editora Unijuí
Programa de Pós-Graduação em Atenção Integral à Saúde
ISSN 2176-7114 – v. 23, n. 47, 2023
http://dx.doi.org/10.21527/2176-7114.2023.47.14175

COMO CITAR:
Guiraldelli L, Fontanelli M de S, Correa GC, Migliorini FP, da Silva GS, Ulbrich GZ dos S. et al. Effects of handrail support usage during CPET on metabolic responses in healthy participants. Rev Contexto & Saúde, 2023;23(47):e14175

Effects of Handrail Support Usage During CPET on Metabolic Responses in Healthy Participants

Luciano Guiraldelli[1], Matheus de Souza Fontanelli[2], Gabriel Couto Correa[3], Frederico Pauzer Migliorini[4], Guilherme Santos da Silva[5], Gustavo Zampier dos Santos Ulbrich[6], Anderson Zampier Ulbrich[7]

Highlights:

(1) Holding on to a treadmill support during CPET was linked to multiple parameters changes.
(2) This finding overestimate metabolic variables analyzed.
(3) It is suggested that, during CPET, it be performed without using the hands to support.

ABSTRACT

Background: Using the support of a handrail during cardiopulmonary exercise testing (CPET) may alter physiologic parameters. The purpose is investigate the effects of handrail usage during the CPET in the metabolic parameters outcomes of young adults. Material and Methods: 39 young adults (age in years, 20.8 ± 2.9) of both sexes, 17 woman and 22 men performed two treadmill CPET on Ellestad protocol, in non-consecutive days. The first (T1) offered access to the support of a handrail; after 7 days, the second (T2) was performed without it. Differences between protocols for metabolic variables were compared using paried the t-test and repeated measures ANOVAS with interaction. Results: Regardless of sex, all participants exhibited superior results of metabolic parameters at T2 in contrast to T1. During T2, there was a major perception of respiratory and muscular effort, as well as a higher respiratory quotient for both sexes. When comparing T1 with T2, the $VE/VCO_{2\ slope}$ was also significantly higher for women (29.31 ± 4.7 and 27.27 ± 4.53). For both sexes, when comparing the tests by stages, it was observed in stages 2, 3 and 4 higher values in the metabolic parameters for T2. The percentile difference for both sexes was 17% higher in S3 for women (T1=26.20±4.1 ml.kg-1.min-1;T2 28.79±4.2 ml.kg-1.min-1) and men (T1= 40.07±6.6 ml.kg-1.min-1; T2 45.92±4.8 ml.kg-1.min-1).Conclusion: The holding of the handrail attenuated the participants' cardiorespiratory and metabolic responses by more than 15% during CPET.

Keywords: cardiopulmonary; cardiorespiratory fitness; exercise test; oxygen uptake.

EFEITO DO ATO DE SEGURAR NA ESTEIRA DURANTE O TECP NA APTIDÃO CARDIORRESPIRATÓRIA DE ADULTOS

RESUMO

Introdução: O uso de barras de suporte da esteira durante o teste de esforço cardiopulmonar (TECP) pode alterar parâmetros fisiológicos. O objetivo foi investigar os efeitos do uso da barra durante o TECP nos componentes metabólicos de adultos jovens. ***Materiais e métodos:*** 39 jovens (idade em anos, 20,8 ± 2,9) de ambos os sexos, 17 mulheres e 22 homens realizaram dois TECP em esteira (ATL Imbramed) no protocolo ***Ellestad***, em dias não consecutivos. O primeiro (T1) oferecia acesso ao apoio de uma barra de suporte da esteira; após 7 dias, o segundo (T2) foi realizado sem segurar. As diferenças entre os protocolos das variáveis metabólicas foram comparadas por meio do teste ***t*** pareado e ANOVAS de medidas repetidas com interação. *Resultados*: Independentemente do sexo, todos os participantes exibiram resultados superiores dos parâmetros metabólicos em T2 em contraste com T1. Durante o T2 verificou-se maior percepção do esforço respiratório e muscular, bem como maior quociente respiratório para ambos os sexos. Ao comparar T1 com T2, o $VE/VCO_{2\ slope}$ também foi significativamente maior para as mulheres (29,31 ± 4,7 e 27,27 ± 4,53). Para ambos os sexos, quando comparados os testes por estágios, observou-se, nos estágios 2, 3 e 4, maiores valores nos parâmetros metabólicos para o T2. A diferença percentílica para ambos os sexos foi 17% maior em S3 para mulheres (T1=26.20±4,1 $ml.kg^{-1}.min^{-1}$;T2 28.79±4,2 $ml.kg^{-1}.min^{-1}$) e homens (T1= 40.07±6,6 ml.kg-1.min-1;T2 45.92±4,8 ml.kg-1.min-1). ***Conclusão***: O uso do corrimão atenuou em mais de 15% as respostas cardiorrespiratórias e metabólicas dos participantes durante o TECP.

Palavras-chave: cardiopulmonar; aptidão cardiorrespiratória; teste de esforço; captação de oxigênio.

[1] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0001-8754-5537
[2] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0001-5134-854X
[3] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0002-4309-5818
[4] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0002-3237-9348
[5] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0002-6739-7140
[6] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0002-4462-0522
[7] Federal University of Parana – UFPR. Curitiba/PR, Brazil. https://orcid.org/0000-0001-6602-0010

INTRODUCTION

Cardiopulmonary exercise testing (CPET) allows individualized assessment of exercise training and provides diagnostic and prognostic information in clinical practice[1]. The CPET is considered the gold standard for identifying the ventilatory threshold by non-invasive monitoring oxygen uptake (VO_2) and other metabolic parameters[2].

The dynamics of VO_2 during maximal CPET may be affected by the handrail support, when patients and half people use frontal or side handrail during the test that present mechanical change in the walking/running pattern as well as a marked variation in VO_2, HR, VE and systolic blood pressure (SBP), in comparison to subjects that do not use them[3-4]. Furthermore, other hemodynamic and biomechanics parameters are likewise influenced upon use of safety bars during the CPET, such as heart rate (HR), respiratory exchange ratio (RER)[3-4], walking pattern, energy cost and total time test[4-5].

Using the support of handrails on the treadmill during CPET by simply touching the bars or even gripping them firmly can modify the dynamics of oxygen uptake and other metabolic variables. Although it may affect the results of the CPET, protocols or recommendations on how to quantify the gripping strength to handrails are scarce in the literature[6-7]. A study pointed out that the differences found in the VO_2 dynamics during CPET may result from the amount of muscle mass recruited in the test, which is greater when the bar support is not used[8].

Although, the use of handrails support might influence metabolic and respiratory rates and consequently interfere with VO_2, carbon dioxide production (VCO_2), ventilatory equivalent for carbon dioxide ($VE/VCO_{2\ slope}$), and other parameters[1,9]. The $VE/VCO_{2\ slope}$ analyzed in a stress test has shown to have a higher prognostic value than the peak VO_2[1] and can be identified on the onset of pulmonary hyperventilation while the $VO_{2\ peak}$ reflects the participant's effort throughout the test, as well as the contribution of peripheral metabolism to the energy supply during CPET[10].

In this context, the purpose of the present study was to investigate the effects of holding to a safety bar on a treadmill on cardiorespiratory and metabolic responses during maximal exercise testing in healthy young adults.

METHODS

Study design and Participants

This experimental study addressed cardiorespiratory and metabolic parameters upon the use of handrail support of a treadmill during CPET in a convenience sample. Participants included undergraduate students who underwent CPET in the Laboratory of Exercise Medicine at Federal University of Paraná (UFPR), Curitiba, Brazil. Thirty-nine healthy and nonsmoking volunteers (men, n = 22 20.4 ± 2.4 years; women, n = 17 (21.2 ± 3.6 years) were asked to undergo a series of tests on two nonconsecutive days. They were informed they could withdraw from participating in the study at any time.

On the first day, each participant was submitted to the following evaluation: anamnesis, anthropometry and CPET with the handrail support. Upon returning after seven days, the same volunteer underwent another CPET, but this time following recommendations by American Heart Association (AHA)[11], which does not state the use of a handrail.

Volunteers with cardiac disease, pregnant, presenting orthopedic problems, severe visual impairment, or comorbidities that would impair their ability to perform the test safely, those who refused or had issues to walk on the treadmill prior to baseline testing were excluded.

Ethical Approval

Written informed consent was obtained prior to performing any testing. This study was conducted at the School Unit of Health Promotion of UFPR (SU-HP/UFPR) and approved by the Research Ethics Committee (CAAE, 71645617.4.0000.0102) of UFPR. All procedures were performed in accordance with the Declaration of Helsinki.

Anthropometric measurements

Body mass (kg), height (cm), waist circumference (cm) and skinfold (mm) were measured according to the standardization of the International Society for the Advancement of Kinanthropometry[12].

Skinfold thickness was measured with a scientific skinfold caliper (Cescorf, Porto Alegre, Brazil) in the following anatomic points: triceps, biceps, subscapular, suprailiac, abdomen, thigh, and calf)[12-13].

Cardiopulmonary exercise testing (CPET) with Ellestad protocol

The CPET was performed on a treadmill (ATL, Imbramed, Porto Alegre, Brazil) to evaluate participant's cardiorespiratory fitness. The test comprised two steps. First, the volunteer was asked to hold on to the handrails of the treadmill (T1). In the second step, performed seven days after the first one, the volunteer was asked not to rest or lean on the handrails during the test (T2).

All participants were instructed to interrupt CPET if they did not feel well or presented trouble for breathing, fatigue in the lower limbs or any other symptom related to physical exertion. CPET was carried out under the supervision of at least one researcher with experience in stress testing and two undergraduate students from the school of medicine under the supervision of a cardiologist.

The volunteers were asked to not exercise 24 hours previously to the test, wear appropriate clothing for physical activity and not to be fasted. Participants for both T1 and T2 were verbally stimulated to perform CPET with maximum effort, considering the RER ≥ 1.10, suggested by stress testing guidelines[13-14].

The study followed the *Ellestad* protocol[14] with Ergospirometry system K5 (COSMED®, Rome, Italy) and HR transfer monitor (Garmin HRM-DUAL, Kansas, United States). The following CPET parameters were measured during maximum oxygen uptake, for instance time to exhaustion, work rate, VO_2, VCO_2, metabolic units (METs), HR, RER, ventilation (VE), ventilation oxygen consumption (VE/VO_2), ventilation carbon dioxide output (VE/VCO_2), end-expiratory pressure O_2 ($PetO_2$) and CO_2 ($PetCO_2$) and V-Slope[14]. Other CPET variables collected intra-test and upon maximum effort included systolic and diastolic blood pressure, Borg muscle and dyspnea scale [0-10][15] and were discontinued when the participant reported any discomfort or clinical symptoms, such as fatigue and/or dyspnea.

Blood pressure (Sphygmomanometer Missouri®) and Borg scale [15] were measured at rest, at the final of each phase of protocol; and at the first, third and fifth minute of recovery. All tests were supervised by experienced exercise physiologists, and participants were stimulated to exercise until they reached maximum capacity.

Statistical analysis

Firstly, for statistical analysis, we performed a normality test (Smirnov Kolmogorov), followed by a descriptive analysis of the data. This analysis was carried out through central tendency measures with mean and standard deviation (SD) for the continuous variables. We also performed frequency analysis (relative and absolute percentage) for categorical variables.

The baseline characteristic of the anthropometric measures of study participants, we used independent *Student t*-test. In order to verify the difference between the methods of application in the tests, *Student t*-test for paired data was used for paired data in hemodynamic measures at rest and maximal metabolic responses. Then, the mean metabolic responses at each stage were analyzed in each test and compared using a *two-way* ANOVA for each sex separately. As a supplementary analysis, the same statistical test was performed for each sex separately. Statistical analysis was performed using IBM SPSS Statistics for Windows version 21 (IBM Corp, Armonk, NY) and GraphPad Prism version 6.01 (GraphPad Software, San Diego, CA) and MatLab R2016b, considering p<0.05.

RESULTS

The anthropometric characteristics of the study participants are summarized in Supplement (Table 1). All 39 participants were healthy young adults, being 17 (43.58%) women and 22 (56.41%) men. Women presented superior anthropometric measurements when compared to men; the total body fat values were higher in the female group when compared to the male group; nevertheless, the BMI was similar between the groups. When classified by BMI, 23.5% and 45.5% of women and men, respectively, were considered overweight. According to the percentage of total body fat evaluated through skinfolds, 35.3% and 40.9% of the woman and men, respectively, were categorized as presenting high body fat[13].

The metabolic parameters obtained at rest and maximum effort at CPET for T1 and T2 were analyzed separately between according to gender and presented in (Table 1). At rest, all variables did not differ significantly between the groups for both genders. During the maximum treadmill test for men and women, the total test time (TT) and the maximum speed (km/h) were higher in T1 than T2. However, the total inclination of the treadmill in (%) was only higher for the women in the group T1 when holding on to the treadmill, which did not differ for the men group when comparing T1 with T2. Another parameter addressed was the perception of respiratory and muscular effort (Borg scale), which was higher for both tests for women and men in T2. The mean of maximal oxygen uptake (VO_{2max}) was 4.64% and 3.52% higher in T1 in contrast to T2, for women and men, respectively Table 1.

TABLES

Table 1 – Characteristics of hemodynamic and metabolic response at two different CPET for both sexes

	Female (n=17)			**Male (n=22)**		
	T1	**T2**	***p-value***	**T1**	**T2**	***p-value***
Rest						
HR at rest, (*bpm*)	102.35 ± 22.5	98.23 ± 14.30	**.343**	92.59 ± 14.82	89.45 ± 15.51	**.420**
SBP at rest, (*mmHg*)	115.64 ± 11.02	117.17 ± 6.55	**.583**	117.27 ± 9.41	116.09 ± 10.9	**.474**
DBP at rest, (*mmHg*)	85.29 ± 8.68	80.70 ± 7.31	**.118**	77.63 ± 9.12	79.18 ± 7.65	**.582**
BS (*Lung*) at rest	0.32 ± 0.74	0.32 ± 0.46	**1.000**	0.04 ± 0.21	0.15 ± 0.35	**.096**
BS (*Muscle*) at rest	0.11 ± 0.28	0.17 ± 0.39	**.543**	0	0.15 ± 0.35	**.051**
Max Treadmill Test						

TT, (*sec*)	543.41±95,51*	402 ± 58.33	**<.001**	731.55 ± 127.68*	620.50 ± 120.03	**<.001**
Max S, (*km.h*$^{-1}$)	8.09 ± 0.38*	7.44 ± 0.78	**.004**	9.18 ± 1.25*	8.51 ± 0.92	**.017**
Max I, (*%*)	12.05 ± 2.53*	10.00 ± 0	**.004**	14.77 ± 1.06	14.09 ± 1.97	**.083**
Max HR, (*bpm*)	188.70 ± 12.06	187.82 ± 10.81	**.502**	189.63 ± 7.53*	187.13 ± 9.41	**.020**
Max SBP, (*mmHg*)	145.52 ± 15.69	140.0 ± 16.82	**.346**	162.90 ± 17.1*	150.90 ± 20.44	**.004**
Max DBP, (*mmHg*)	85.29 ± 8.68	80.70 ± 7.13	**.118**	80.63 ± 8.58	82.63 ± 10.09	**.448**
BS (*Lung*) max	5.94 ± 1.78	8.11 ± 1.49*	**.001**	6.86 ± 1.52	8.09 ± 1.15*	**.002**
BS (*Muscle*) max	6.58 ± 1.73	7.82 ± 1.59*	**.012**	7.40 ± 1.62	8.27 ± 0.98*	**.024**
VO_2 abs max (*ml.min*$^{-1}$)	2465.3±376.3*	2320.1 ± 328.0	**.038**	3892.04 ± 744.6	3787.25 ± 667.61	**.364**
VCO_2 abs max (*ml.min*$^{-1}$)	2513.1 ± 407.3	2533.96 ± 417.2	**.770**	3901.52 ± 701.05	4150.21±623.46*	**.045**
$PetO_2$ (*mmHg*)	99.82 ± 3.5	100.17 ± 6.08	**.687**	99.40 ± 4.62	100.81 ± 3.59	**.203**
$PetCO_2$ (*mmHg*)	34.82 ± 4.34	36.17 ± 5.75	**.083**	34.86 ± 4.27	35.40 ± 4.33	**.637**
VO_2 rel max (*ml.kg*$^{-1}$*.min*$^{-1}$)	40.08 ± 5.9*	38.22 ± 6.3	**.049**	51.42 ± 7.92*	49.61 ± 8.08	**.022**
RER at VO_2max	1.02 ± 0.09	1.09 ± 0.10*	**.003**	1.01 ± 0.10	1.09 ± 0.09*	**.010**
$METs_{max}$	11.44 ± 1.72	10.92 ± 1.82	**.088**	14.69 ± 2.26*	14.17 ± 2.30	**.021**
VE / VO_2 slope	33.93 ± 4.58	35.70 ± 8.42	**.149**	33.84 ± 5.40	36.67 ± 7.17	**.141**
HR / VO_2 slope (*beats.ml per min*)	5.63 ± 0.66	5.51 ± 1.24	**.544**	5.77 ± 1.16*	5.23 ± 0.74	**.049**
VE/VCO_2 slope	29.31 ± 4.7*	27.27 ± 4.53	**.019**	27.07 ± 4.47*	25.29 ±2.87	**.032**
OUES	2610.4 ±421.9*	2400.76± 397.3	**.028**	3910.63 ± 761.53*	3687.50 ± 649.38	**.002**

Note: Values are mean ± SD; ***Student t-test** *p<0.05*; HR: heart rate rest; SBP: systolic blood pressure (***mmHg***) rest; DBP: diastolic blood pressure (***mmHg***) rest; BS: Borg scale (***Lung***) rest ; BS: Borg scale (***Muscle***) rest; TT: time of test, (***sec***); MaxS: Max speed, (***km.h***$^{-1}$); MaxI: Max inclination, (*%*); Max HR, (***bpm***): maximum heart rate; Max SBP, (***mmHg***): maximal systolic blood pressure; Max DBP, (***mmHg***): maximal diastolic blood pressure; BS: Borg scale (***Lung***) max; BS: Borg scale (***Muscle***) max; VO_2 abs max (***ml.min***$^{-1}$): VO_2 absolute max ; VCO_2 abs max (***ml.min***$^{-1}$): VCO_2 absolut max; $PetO_2$ (***mmHg***): end-expiratory oxygen partial pressure; $PetCO_2$ (***mmHg***): end-tidal carbon dioxide partial pressure; VO_2 rel max (***ml.kg***$^{-1}$***.min***$^{-1}$): maximum oxygen consumption; RER_{max}: respiratory exchange ratio at VO_2max ; $METs_{max}$: metabolic units; VE/VO_2 Slope: minute ventilation/oxygen production slope; HR / VO_2 slope (***beats.ml per min***): heart rate ratio by vo_2 slope; VE/VCO_2 Slope: minute ventilation/ carbon dioxide production slope; OUES: oxygen uptake efficiency slope.

Figure 1 shows that the dynamic oxygen uptake in T2 is higher than T1 for woman (Fig 1A) and men (Fig 1B). When these values are presented in averages by stages, there are differences in all stages and for both sexes. The ratios are showed as percentages difference between stages for males and females during the CPET. The biggest difference was observed in stages 2 and 3 for women; and in stages 3 and 4 for men, respectively.

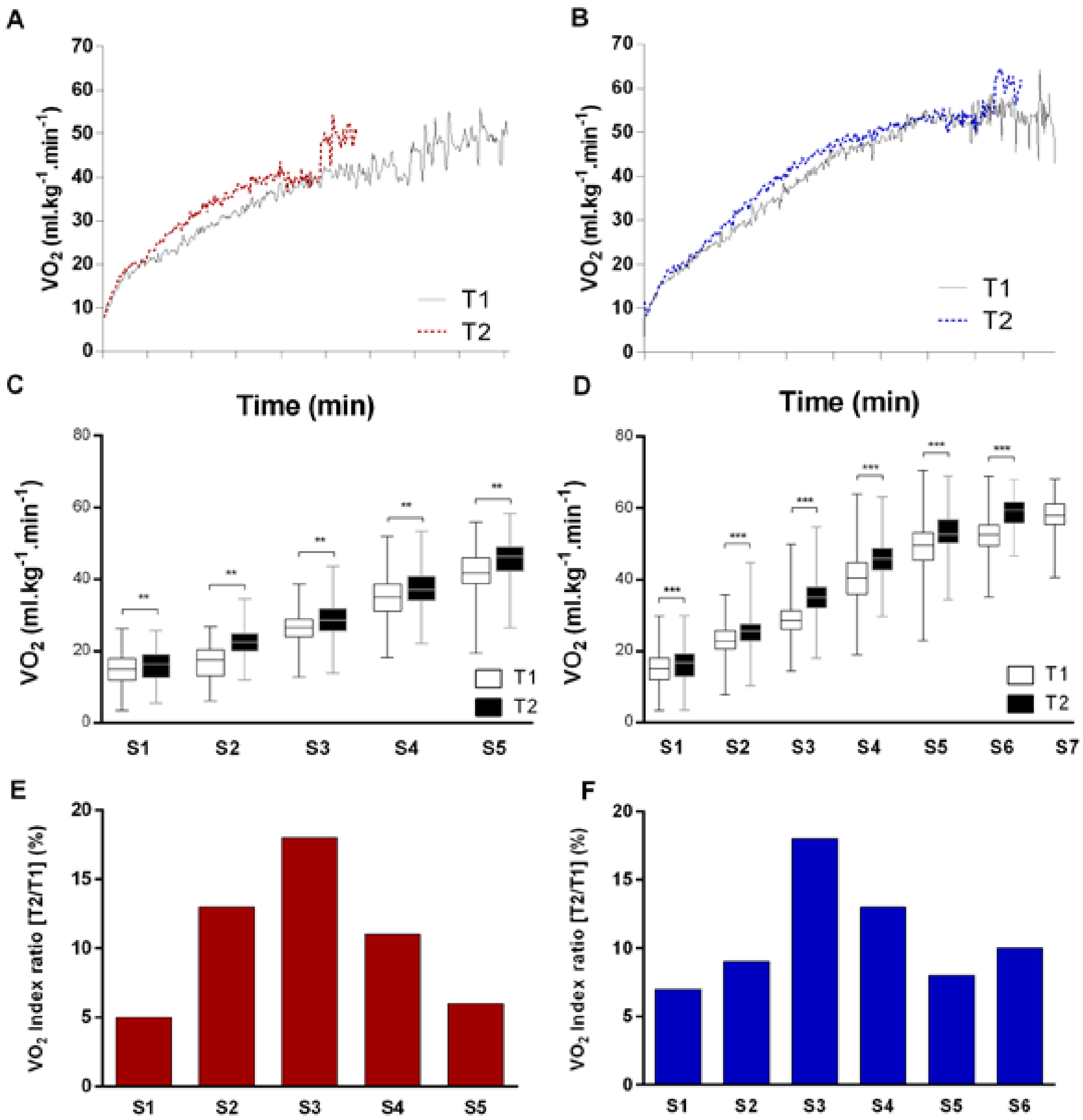

Figure 1 – Effect of the use of a handrail support on VO_2 dynamics based on Breath-by-Breath measurement for woman (A) and men (B). VO_2 mean by stage for woman (C) and men (D). T2/T1: Calculation of the ratio of the mean value of T2 to T1 of the relative VO2 values (ml.kg^{-1}.min^{-1}). Value presented in percentile differences of one test over the other. Two-way ANOVA; **P < 0.05; ** P<0.01; *** P<0.0001 indicate* significant differences between stages at T1 and T2. VO_2 (ml.kg^{-1}.min.$^{-1}$): relative oxygen uptake in millimeters of oxygen per kilogram per minute; T1: group handrail support; T2: without handrail support; S: stage of *Ellestad* protocol; %: percentage

According to AHA[11], the effect of holding to handrails on a treadmill may attenuate the cardiorespiratory fitness (CRF) and may modify the outcomes for the classification for men and woman (Supplement 2 - S1 Fig).

Figure 2 shows the changes of HR overtime. HR is higher in T2 compared to T1, for both genders. Analyzing HR mean values over multiple stages of protocol, high valors was observed in T2 than compared with T1 for both sexes (Fig 2C and Fig 2D). The index ratio difference was observed at all stages for both female and male participants during CPET. Stage 2 (S2) and S3 of protocol exhibited the main differences on HR overtime for the female group, whereas largest difference was found in S3 for male participants.

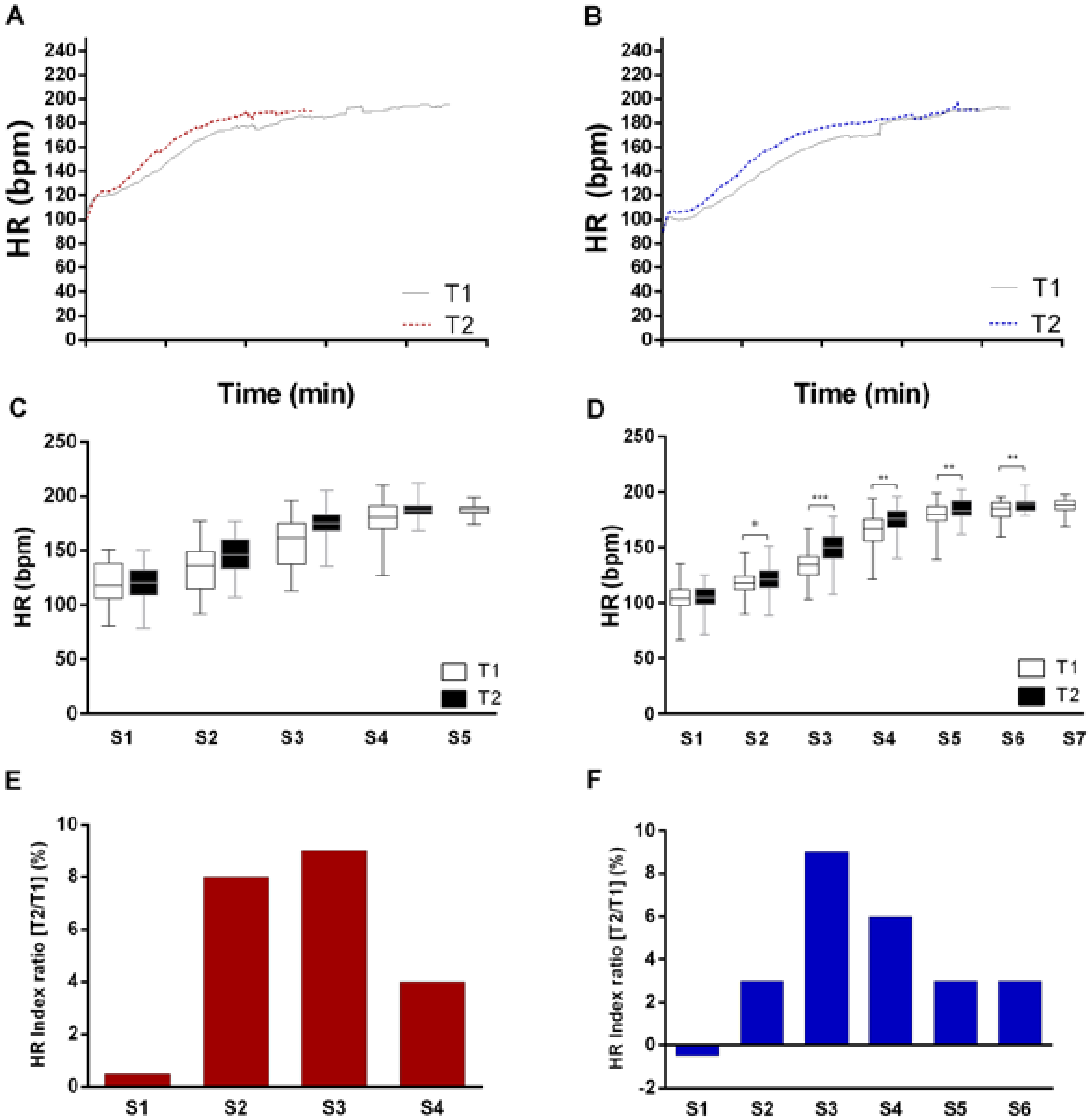

Figure 2 – HR and use of handrail during CPET for women (A, C, E) and men (B, D, F). (A) Systematic evaluation of the HR of each Breath-by-Breath for women (A) and men (B). HR average by stage for women (C) and men (D). T2/T1: Calculation of the ratio of the mean value of T2 to T1 of the HR values BPM (beats per minute). Value presented in percentile differences of one test over the other. Two-way ANOVA; **P < 0.05*; ** *P<0.01*; *** *P<0.0001* indicated significant difference between stages at T1 and T2. HR (bpm): relative oxygen uptake in millimeters of oxygen per kilogram per minute; T1: group handrail support; T2: without handrail support; S: stage of ***Ellestad*** protocol; %: percentage

Supplement 3 shows the influence of using a front bar to RER in the CPET for both genders. The panel (Fig 3A and 3B) displays outcomes for women and men, respectively, and higher RER amplitudes observed in the second day (T2) when compared to T1. Observing the test stage-by-stage the outcomes were different for the women (Fig 3C) between S1 and S4. Male presented (Fig 3D) differences between stages S1 and S6. There were higher RER findings in T2 for both groups, with important differences at the S3 point for women (~10%) and men (~8%) in contrast with T1.

Figure 3 shows that participants exhibited a higher respiratory efficiency when holding the frontal bar of the treadmill compared to those who did not hold it, for both sexes. The group comprised of women at T1 (A) presented $VE/VCO_{2\ slope}$ of 29.32 ± 4.78 when holding the frontal bar; against 27.27 ± 4.53 when not holding on to treadmill T2 (A) which represents an increase of 7.51 % in T1 when comparing T2. For male participants, in T1 (B) the $VE/VCO_{2\ slope}$ was 26.54 ± 3.81, against 25.83 ± 3.89 in T2 (B), with an increase in T1 of 2.74%.

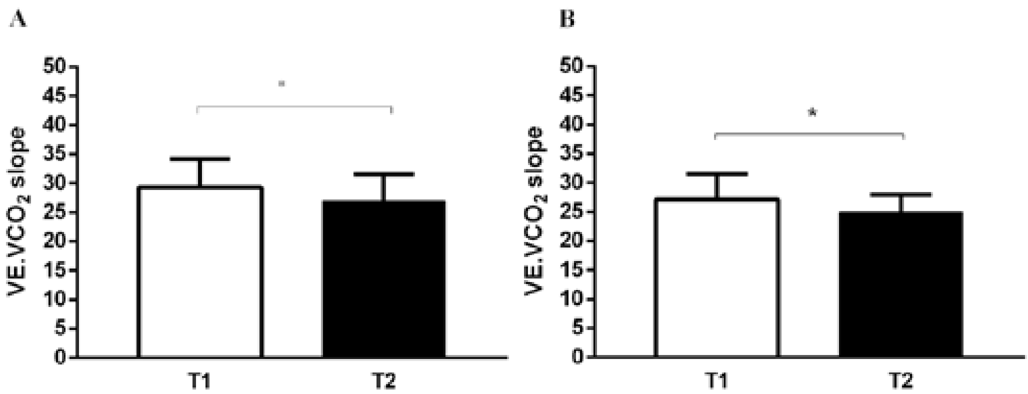

Figure 3 – Bar graphs of the mean values for $VE/VCO_{2\ slope}$ in two different protocols: T1 (holding to the handrail showed with white bar) vs T2 (not holding to the handrails showed with black bar), for both genders, during CPET. (A) graphic of woman; (B) graphic of man. **P < 0.05* indicates significant differences between T1 and T2. $VE/VCO_{2\ slope}$: minute ventilation/carbon dioxide production

We performed many statistical tests on the metabolic responses (Supplement 1 to 11- S1-11 Fig) for: Baseline characteristic (Suppl. 01); Classification of Cardiorespiratory Fitness (Suppl. 02); Respiratory Exchange Ratio (Suppl. 03); Absolute VO_2 (Suppl. 04); Absolute VCO_2 (Suppl. 05); VE/VO_2 ratio (Suppl. 06); VE/VCO_2 ratio (Suppl. 07); $PetO_2$ (Suppl. 08); $PetCO_2$ (Suppl. 09); METs (Suppl. 10); Comparation between genders of the percentile difference between T1 and T2 of VO_2 levels reached in each stage of CPET (Suppl. 11).

DISCUSSION

In summary, holding on to a treadmill bar during CPET was linked to multiple changes in metabolic, cardiovascular and ventilatory parameters in young adults. Among the variables analyzed, there was also a longer CPET execution time when the participant had access to a handrail compared with those who did not. This finding overestimate metabolic variables analyzed, the same verified in other study[16].

Other variables such outcomes from the Borg scale and HR displayed lower scores at the end of the CPET when the handrail support was used. This can be explained by decreased muscle and respiratory engagement in maxim progressive stress tests when safe on the treadmill to the detriment mainly of tilting[6].

The HR values increased linearly in T1 and T2 and presenting different outcomes in the early stages. These findings are corroborated by similar other studies that also addressed the HR response[3,9,17]. Nevertheless, only one study reported differences in HR at the last stage of the CPET[6]. Oliveira and colleagues[16] examined the progressive increase in HR values and holding to the treadmill bar on the modulation of the autonomic function in the parasympathetic and sympathetic system during the CPET. They found that when participants did not used the handrail support, there was a greater alteration on HR when compared to T1[16]. The act of not holding on the treadmill does not result in increased vagal activity due to a lower respiratory fluctuation, mainly because the chronotropic action of circulating catecholamines[18]. Moreover, the increase/control of HR during CPET is also regulated by baroreflex arteries[19] and, the recruitment of group III/IV afferent muscle fibers that are activated by the exercise pressor reflex (negative feedback mechanism). This reflex triggers neurons in the nucleus of the solitary tract which are rich in Gaba neurotransmitters, what suggests a contribution of Gaba neurotransmitters to the adjustment of HR regulated by exercise intensity[20].

Examining VO_2 consumption in different CPET procedures, there was a significant difference of ~17% in the dynamics of VO_2 in T2, which was higher in stages 3 and 4. Study that advised the use of a treadmill aid bar during CPET pointed that this aid significantly attenuated physiological parameters for the entire submaxim of workload[7], with the exception of the first and last stages of the test[6], which endorses the present findings. In addition, a study [6] done without the analysis of gas consumption and using the handrail support it was estimated that the value of ~1 metabolic unit (METs) should be added to the predict the value of because the results are normally result is underestimated. Thus, it is recommended the subjects performing CPET do not use, the treadmill handles for accurate VO_2 results[6,21].

A study[17] claims that holding the treadmill bar contributes to decrease energy expenditure by ~31.8%, what is partially explained by the fact the subject walking leans backwards, assuming a posture that generates an almost perpendicular angle between the body and the treadmill (upright walk without inclination). Besides, a consequence of this reclining posture is the use of additional strength from the upper body[17]. Zeimetz et al.[3], demonstrated that as higher is the strength used to grab the treadmill bar, the lower is the VO_2 levels, that may can be reduced by up to 30%.

Using a treadmill bar also affected RER parameters for both tests, resulting in lower metabolic acidosis, lower muscle and respiratory recruitment and greater contribution of fatty acid metabolism[1,22]. Consequently, the respiratory compensation point was later, suggesting a temporary reduction in anaerobic metabolism and lower HR, causing a longer total test time with this method[3,9].

The guideline [14] also suggest that for the CPET to be considered effective, individuals taking the test must reach at least 85% of VO_2, which is normally considered the ventilatory threshold (VT)[1,14]. The literature points that the slope of the VCO_2 curve called V-slope, is a measure for respiratory efficiency[1,23]. So, the V-slope quantification method is a strategy to minimize errors in the estimation of VT in healthy subjects. Because upon the excessive production of VCO_2 there is a fast increase in the concentration of blood lactate, what is associated with poor buffering of hydrogen pumps (H^+) and decrease in the concentration of sodium bicarbonate (HCO_3^-)[24]. In this scenario, the literature has highlighted that not every individual e can reach the maximum capacity (plateau of VO_2) during CPET[14,24]. However, the present study indicates that the act of holding on to the treadmill has likely been linked to the late identification of the occurrence of the V-slope in healthy subjects for both sexes.

Findings on the V-slope exhibited a high correlation (r=0.98) with VT in patients with Chronic Obstructive Pulmonary Disease (COPD), with a marked decrease in circulating concentrations of sodium bicarbonate (HCO_3^- >2.5 mEq/L) [25]. Mezzani et al.[26], identified VT in patients with cardiac disease based on the VCO_2 and VO_2 ratio from the CPET. The volume of ventilation and VCO_2 indicated ventilatory efficiency, by estimating the volume of air require to eliminate 1L of CO_2[26]. So, the V-slope method was able provide reliable data about the actual health condition of the patients [26]. Other investigative groups[27-28] examined poor V-slope values for patients with heart failure and the association with increased mortality and[27] cardiovascular events[28]. Although these studies have important clinical relevance, they lack information on how the CPTE was performed.

Although we followed the methods proposed, this study has limitations. We did not track the level of physical activity among the participants, what may affect physiological variables when comparing the act of holding and not holding to the treadmill aid bar during the CPET. Neither the strength used to grab the bar nor the position of the participant's hand holding the bar was studied, which is been demonstrated to having a significant influence on VO_2[3] outcomes.

CONCLUSION

Summing up, the present study found that the act of holding on to the treadmill attenuated cardiorespiratory and metabolic responses during the tests. Particularly when the participant did not have the support of the bar during the CPET, changes in the V-slope were found to be related to the real ventilatory efficiency when compared to VO_2. Therefore, it is critical to clarify the adequate protocol for the ideal exercise prescription, interpretation in diagnosis and prognosis in healthy subjects and patients.

It is suggested that, when possible, during CPET, it be performed without using the hands to support the treadmill protection bars, since changes in metabolic and respiratory parameters were observed in the present study.

REFERENCES

[1] Mezzani A. Cardiopulmonary exercise testing: Basics of methodology and measurements. Ann Am Thorac S. 2017;14:S3-S11. DOI: https://doi.org/10.1513/AnnalsATS.201612-997FR

[2] Milani RV, Lavie CJ, Mehra MR. and Ventura HO. Understanding the basics of cardiopulmonary exercise testing. Mayo Clin Proc. 2006;81(12):1.603-1.611. DOI: https://doi.org/10.4065/81.12.1603

[3] Zeimetz G, McNeill J, Hall J. and Moss R. Quantifiable changes in oxygen uptake, heart rate, and time to target heart rate when hand support is allowed during treadmill exercise. J Cardiac Rehabil. 1985;5(11):525-529.

[4] Ijmker T, Lamoth CJ, Houdijk H, Tolsma M, Van Der Woude, LHV, Daffertshofer A, et al. Effects of handrail hold and light touch on energetics, step parameters, and neuromuscular activity during walking after stroke. J Neuroeng Rehabil. 2015;12(1):70. DOI: https://doi.org/10.1186/s12984-015-0051-3

[5] Whitman M, Sabapathy S, Jenkins C. and Adams L. Handrail support produces a higher rate pressure product in apparently healthy non-treadmill users during maximal exercise testing. Physiol Meas. 2019;40(2):02NT01. DOI: https://doi.org/10.1088/1361-6579/ab0565

[6] Duvillard SPV, Pivirotto JM. The effect of front handrail and non-handrail support on treadmill exercise in healthy women. J Cardiopulm Rehabil. 1991;11(3):164-168.

[7] Christman SK, Fish AF, Bernhard L, Frid DJ, Smith BA, and Mitchell L. Continuous handrail support, oxygen uptake, and heart rate in women during submaximal step treadmill exercise. Res Nurs Health. 2000;23(1):35. DOI: https://doi.org/10.1002/(SICI)1098-240X(200002)23:1<35::AID-NUR5>3.0.CO;2-I

[8] Howley ET, Colacino DL, and Swensen TC. Factors affecting the oxygen cost of stepping on an electronic stepping ergometer. Med Sci Sports Exer. 1992;24 (9):1.055-1.058.

[9] Ragg KE, Murray TF, Karbonit LM, and Jump DA. Errors in predicting functional capacity from a treadmill exercise stress test. Am Heart J. 1980;100(4):581-583. DOI: https://doi.org/10.1016/0002-8703(80)90676-6

[10] Arena R, Myers J, Aslam SS, Varughese EB, and Peberdy MA. Peak VO_2 and $VE/VCO_{2\ slope}$ in patients with heart failure: a prognostic comparison. Am Heart J. 2004;147(2):354-360. DOI: https://doi.org/10.1016/j.ahj.2003.07.014

[11] Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation. 2001;104(14):1.694-1.740. DOI: https://doi.org/10.1161/hc3901.095960

[12] Silva VSD, and Vieira MFS. International Society for the Advancement of Kinanthropometry (ISAK) Global: international accreditation scheme of the competent anthropometrist. Rev Bras Cineantropom Desempenho Hum. 2020;22:70.517. DOI: https://doi.org/10.1590/1980-0037.2020v22e70517

[13] Lohman TG. Advances in body composition assessment. Hum Kinet. 1992;1-23.

[14] Riebe D, Ehrman Jk, Liguori G, and Magal M. ACSM's guidelines for exercise testing and prescription. American College of Sports. Wolters Kluwer, 10th Edition, 185-215. Philadelphia, 2018. (Print Version)

[15] Borg G. Psychophysical Bases of Perceived Exertion. Med Sports Exer. 1982;14(5):377-381. DOI: https://doi.org/10.1249/00005768-198205000-00012

[16] de Oliveira GL, Marques AH, da Fonseca VF, Pazzolo BA, Panacioni F, Santos TC, et al. Handrail support interference in cardiac autonomic modulation adjustments in young adults during maximal exercise testing. Sci Rep. 2020;10(1):1-9. DOI: https://doi.org/10.1038/s41598-020-68155-3

[17] Hofmann C, Dougherty C, Abkarian H, and Juris P. The reduction of metabolic cost while using handrail support during inclined treadmill walking is dependent on the handrail-use instruction. Int J Exer Sci. 2014;7 (4):10. Disponível em: https://digitalcommons.wku.edu/ijes/vol7/iss4/10

[18] Arai Y, Saul JP, Albrecht P, Hartley LH, Lily LS, Cohen RJ, et al. Modulation of cardiac autonomic activity during and immediately after exercise. Am J of Physiol-Heart C. 1989;256(1):H132-H141. DOI: https://doi.org/10.1152/ajpheart.1989.256.1.H132

[19] Benarroch EE. The central autonomic network: functional organization, dysfunction, and perspective. Mayo Clin Proc. 1993;68(10):988-1001. DOI: https://doi.org/10.1016/S0025-6196(12)62272-1

[20] Teixeira AL, Fernandes IA, and Vianna LC. Cardiovascular control during exercise: the connectivity of skeletal muscle afferents to the brain. Exerc Sport Sci Rev. 2020;48(2):83-91. DOI: 10.1249/JES.0000000000000218

[21] McConnell TR, and Clark BA. Prediction of maximal oxygen consumption during handrail-supported treadmill exercise. J Cardiopulm Rehabil. 1987;7(7):324-331.

[22] Wasserman K. The Anaerobic Threshold Measurement to Evaluate Exercise Performance. Am Rev Respir Dis. 1984;129:S35-S40. DOI: https://doi.org/10.1164/arrd.1984.129.2P2.S35

[23] Corrà U, Mezzani A, Giordano A, Bosimini E, and Gianuzzi P. Exercise haemodynamic variables rather than ventilatory efficiency indexes contribute to risk assessment in chronic heart failure patients treated with carvedilol. Eur Heart J. 2009; 30(24):3.000-3.006. DOI: https://doi.org/10.1093/eurheartj/ehp176

[24] Beaver WL, Wasserman K, and Whipp BJ. A New Method for Detecting Anaerobic Threshold by Gas Exchange. J Appl Physiol. 1986;60(6):2.020-20.277. DOI: https://doi.org/10.1152/jappl.1986.60.6.2020

[25] Sue DY, Wasserman K, Moricca RB, and Casaburi R. Metabolic acidosis during exercise in patients with chronic obstructive pulmonary disease: use of the V-slope method for anaerobic threshold determination. Chest. 1988;94(5):931-938. DOI: https://doi.org/10.1378/chest.94.5.931

[26] Mezzani A, Agostoni P, Cohen-Solal A, Corra U, Jegier A, Kouidi E, et al. Standards for the use of cardiopulmonary exercise testing for the functional evaluation of cardiac patients: a report from the Exercise Physiology Section of the European Association for Cardiovascular Prevention and Rehabilitation. Eur J Card Prev Rehabilitation. 2009;16(3):249-267. DOI: https://doi.org/10.1097/HJR.0b013e32832914c8

[27] Klaassen SH, Liu LC, Hummel YM, Damman K, van der Meer P, Voors, et al. Clinical and hemodynamic correlates and prognostic value of $VE/VCO_{2\ slope}$ in patients with heart failure with preserved ejection fraction and pulmonary hypertension. J Cardiac Fail. 2017;23(11):777-782. DOI: https://doi.org/10.1016/j.cardfail.2017.07.397

[28] Corrà U, Giordano A, Mezzani A, Gnemmi M, Pistono M, Caruso R, et al. Cardiopulmonary exercise testing and prognosis in heart failure due to systolic left ventricular dysfunction: a validation study of the European Society of Cardiology Guidelines and Recommendations (2008) and further developments. Eur J Prev Cardiol. 2012;19(1):32-40. DOI: https://doi.org/10.1177/1741826710393994

ABBREVIATIONS

CPET: cardiopulmonary exercise testing
HR: heart rate
METs: metabolic units
RER: respiratory exchange ratio
T1: test one
T2: test two
VCO_2: carbon dioxide production

$VE/VCO_{2\ slope}$: ventilatory equivalent for carbon dioxide
VO_2: oxygen uptake
VT: ventilatory threshold

Received: 19/3/2023
Accepted: 3/9/2023

Research Ethics Committee (CAAE, 71645617.4.0000.0102) – UFPR

Conflict of interest
The authors declare that there is no potential conflict of interest to be disclosed. This research was carried out without receiving any specific subsidy from development agencies in the public, commercial or for-profit sectors.

Authors' Contributions:
Literature review:
Frederico Pauzer Migliorini
Guilherme Santos da Silva
Luciano Guiraldelli
Anderson Zampier Ulbrich
Gabriel Couto Correa
Manuscript drafting:
Matheus de Souza Fontanelli
Gabriel Couto Correa
Luciano Guiraldelli
Intellectual manuscript review:
Gustavo Zampier dos Santos Ulbrich
Anderson Zampier Ulbrich
Study conception and design:
Anderson Zampier Ulbrich
Luciano Guiraldelli

All authors have approved the final version of the text.

Corresponding Author: Luciano Rogério Guiraldelli
Federal University of Parana – UFPR
Setor de Ciências da Saúde – Rua Padre Camargo, nº 280, Bairro Alto da Glória, Curitiba/PR, Brasil
E-mail: gabriel.cdia@hotmail.com

Dissertation for a Master's Degree, Federal University of Paraná, year 2021. Effects of Handrail Support Usage During CPET on Metabolic Responses in Healthy Subjects.

Financial Support: Internal research development funds from the Federal University of Paraná (UFPR).

Editor: Dra. Eliane Roseli Winkelmann
Editor-in-chief: Dra. Adriane Cristina Bernat Kolankiewicz