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Original article

Cardiorespiratory fitness during cardiopulmonary exercise testing in individuals with unilateral lower imputation

Aptidão cardiorrespiratória durante o teste cardiopulmonar de esforço de indivíduos com amputação unilateral de membro inferior

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ABSTRACT

Introduction: The lower limb amputation impacts the mobility of individuals, which can lead to low cardiorespiratory fitness. Maximum oxygen consumption (VO_{2max}) is traditionally used to describe cardiorespiratory fitness. However, its achievement is not always feasible in populations with functional limitations and, therefore, analysis at submaximal levels of effort can be an efficient strategy. **Objective:** To test the hypothesis that individuals with unilateral lower limb amputation have lower cardiorespiratory fitness at different effort intensities compared to individuals without amputation. **Methods:** Cross-sectional study with 6 individuals with lower limb amputation and 10 individuals without amputation. Cardiorespiratory fitness was investigated by the cardiopulmonary exercise test, considering absolute and relative VO_{2peak}, ventilatory threshold 1 (VT1) and Optimal Cardiorespiratory Point (POC). **Results:** The amputees had lower absolute and relative VO_{2peak} than non-amputates. The absolute value of POC, time and load did not differ between groups, but the group with amputation presented the POC in a higher percentage of VO_{2peak} ($p = 0.007$) and in a lower relative and absolute VO_2 ($p = 0.004$ and $p = 0.009$, respectively). In LV1, there was no difference between groups in time, load and percentage of VO_{2peak}, however amputees had lower relative and absolute VO_2 ($p = 0.046$ and $p = 0.032$, respectively). **Conclusion:** Individuals with lower limb amputation had lower cardiorespiratory fitness at different effort intensities when compared to individuals without amputation, but they had the highest efficiency between the respiratory and circulatory systems in a higher $\%VO_{2peak}$.

Keywords: disabled persons; oxygen consumption; rehabilitation.

RESUMO

Introdução: A amputação de membros inferiores impacta na mobilidade dos indivíduos, podendo levar a uma baixa aptidão cardiorrespiratória. O consumo máximo de oxigênio ($VO_{2máx}$) é tradicionalmente utilizado para descrever a aptidão cardiorrespiratória. Contudo, a sua obtenção nem sempre é viável em populações com limitações funcionais e, por isso, análises em níveis submáximos de esforço podem ser uma estratégia eficiente. **Objetivo:** Testar a hipótese de que indivíduos com amputação unilateral de membro inferior possuem aptidão cardiorrespiratória menor em diferentes intensidades de esforço comparados a indivíduos sem amputação. **Métodos:** Estudo seccional com 6 indivíduos com amputação de membro inferior e 10 indivíduos sem amputação. A aptidão cardiorrespiratória foi investigada pelo teste de esforço cardiopulmonar, sendo considerados: VO_{2pico} absoluto e relativo, limiar ventilatório 1 (LV1) e Ponto Ótimo Cardiorrespiratório (POC). **Resultados:** Os indivíduos amputados apresentaram menor VO_{2pico} absoluto e relativo que os não amputados. O valor absoluto do POC, o tempo e a carga, não se diferiram entre os grupos, porém o grupo com amputação apresentou o POC em um maior percentual do VO_{2pico} ($p = 0,007$) e em um menor VO_2 relativo e absoluto ($p = 0,004$ e $p = 0,009$, respectivamente). No LV1, não houve diferença entre os grupos no tempo, carga e percentual do VO_{2pico}, contudo os amputados apresentaram menor VO_2 relativo e absoluto ($p = 0,046$ e $p = 0,032$, respectivamente). **Conclusão:** Indivíduos com amputação de membro inferior apresentaram menor aptidão cardiorrespiratória em diferentes intensidades de esforço quando comparados com indivíduos sem amputação, porém apresentaram a maior eficiência entre os sistemas respiratório e circulatório em um maior $\%VO_{2pico}$.

Palavras-chave: pessoa com deficiência; consumo de oxigênio; reabilitação.

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Introduction

Amputation of lower limbs has clinical and functional problems that negatively affect mobility [1]. Impaired mobility, associated or not with the inadaptation of prostheses and orthotics, and the reduced number of equipment and accessible spaces for physical exercise contribute to inadequate daily physical activity levels in the population of individuals with amputation. Other factors that contribute to this process are emotional problems such as low self-esteem, self-image, and self-confidence [2,3]. In this context, it is known that one of the main problems related to a sedentary lifestyle is the increased risk of cardiovascular morbidity and mortality [4], as individuals with amputations naturally already present this increased risk [5].

On the other hand, good cardiorespiratory fitness is associated with better general health status, with the direct measure of maximum oxygen consumption (VO_{2max}) being the gold standard for its quantification. The VO_{2max} is an important predictor of mortality [6,7], and its achievement depends on the performance of a maximum effort. However, in individuals with functional limitations, this level of intensity is not always reached, with the effort being commonly interrupted by peripheral factors [8] and limiting the interpretation and application of results. In situations like this, oxygen consumption at peak effort (VO_{2peak}) is used.

To minimize this problem, Ramos et al. [9] proposed the Cardiorespiratory Optimal Point (COP), the lowest value of the ventilatory equivalent of oxygen during exertion. Reflects the ventilatory economy for obtaining oxygen to meet the metabolic demands of active muscles during exercise. The analysis of COP has already been described in the population of non-athlete men and women, without obesity and cardiorespiratory diseases [9], and professional adult soccer players [10]. But interestingly, in searches previously carried out in the scientific databases PubMed/MEDLINE and SciELO, no evidence was found about its application in populations with physical limitations, particularly in individuals with amputation.

Physical-motor disability is the second most prevalent in Brazil [11]. Considering the negative repercussions on general health status related to low energy expenditure commonly described in individuals with amputations [2], strategies and measures must be taken to promote an active lifestyle in this group. In this context, knowing the cardiorespiratory fitness of people with amputation is relevant, as professionals who deal directly with this audience need to know the characteristics and physiological demands to plan and prescribe exercises properly. Understanding that the maximum effort in individuals with functional limitations is not always reached, the use of COP can be a good strategy since its analysis is performed at submaximal intensities. The study of COP in individuals with an amputation will be an original approach in the scientific literature and may provide support for further studies in this area of knowledge. In this sense, this study aims to test the hypothesis that individuals with unilateral lower limb amputation have lower cardiorespiratory fitness at different effort intensities compared to individuals without amputation.

Methods

Study design and sample

A comparative observational cross-sectional study was carried out with 16 individuals divided into two groups: with amputation (N = 6) and without amputation (N = 10). The amputated group was composed of men aged 18 years or over, with unilateral transtibial or transfemoral amputation and physically active (all recreational paracanoe practitioners, with a minimum time of three months). The sample was selected for convenience because it was all participants in a sports project of the modality in Rio de Janeiro, Brazil. Information related to the amputation of the participants is described in Table I. Smokers and individuals with musculoskeletal limitations that could make it impossible to carry out the protocol were excluded from the study. For comparison purposes, a group of individuals without amputation was also considered respecting the same inclusion and exclusion criteria, except for amputation and the practice of paracanoeing. The physical activity level in the non-amputee group was investigated by completing the International Physical Activity Questionnaire (IPAQ) short version [12], including individuals classified as "active" or "very active" who practice aerobic and strength training. The outcome variables considered for the cardiorespiratory fitness assessment were VO_{2peak}, ventilatory threshold 1 (VT1), and COP.

Table I - Variables related to the amputation of each participant

N	Type of amputation	Cause	Amputation time (years)
1	Transtibial	Vehicle accident	13
2	Transtibial	Osteomyelitis	18
3	Transfemural	Vehicle accident	5
4	Transtibial	Osteomyelitis	6
5	Transtibial	Osteomyelitis	7
6	Transtibial	Exposed fracture	16

The study was submitted and approved by the institutional Research Ethics Committee (CAAE: 17691113.1.0000.5235), and all participants signed an informed consent form to participate in the study.

Cardiopulmonary exercise testing

The cardiopulmonary exercise test (CPET) was performed in a cycle ergometer for upper limbs (TopExcite; TechnoGym; Italy) in an environment with controlled temperature (≈22°C) and humidity (≈60%) [13]. The protocol adopted was an initial load of 20w and successive increments of 5w every minute, with cycling between 50-60 rpm [14]. Participants were verbally encouraged to perform maximum effort, and CPET was interrupted by maximum voluntary exhaustion or upon the appearance of some criterion under recommendations proposed by the American College of Sports Medicine [15].

During CPET, the metabolic analysis of respiratory gases was performed using a gas analyzer (VO2000; MedGraphics; Brazil), in which the readings of pulmonary ventilation (VE; L/min) and the expired fractions of oxygen (FeO_2; %) and carbon dioxide ($FeCO_2$; %) were taken to calculate the ventilatory variables: relative and absolute oxygen consumption (VO_2; $mL.kg^{-1}.min^{-1}$ and L/min, respectively) and ventilatory equivalents of oxygen (VE/VO_2) and carbon dioxide (VE/VCO_2). The information was recorded breath-by-breath and analyzed as a mean of 30 seconds. For standardization purposes, the highest value presented in the curve in the last minute of the test was considered as peak VO_2.

Ventilatory threshold 1 - VT1

To determine VT1, we opted for the graphic inspection of the behavior of ventilatory equivalents - VE/VO_2 and VE/VCO_2. VT1 was defined as the point on the curve at which there was an increase in the VE/VO_2 curve without the concomitant increase in VE/VCO_2 [16]. The analysis of VT1 was performed independently by two experienced evaluators, and then the evaluators' agreement in each test was verified. In case of disagreement, a third evaluator was consulted.

Cardiorespiratory Optimal Point (COP)

COP was defined as the lowest value on the VE/VO_2 curve during exercise, as described by Ramos et al. [9]. In addition to the absolute value of VE/VO_2, the VO_2 value (in $mL.kg^{-1}.min^{-1}$, in L/min, and as a percentage in relation to the peak), the load (w), and the time of effort (min:s) referring to the moment of identification of the COP.

Statistical procedures

The results were described as median (minimum value-maximum value). Given the sample size of the study subgroups, we chose to use a non-parametric statistical procedure for comparisons between subgroups. Thus, the Mann-Whitney test was applied considering the level of statistical significance of 5%. Analyzes were performed using the Statistical Package for Social Sciences (SPSS 20.0) (*Armonk, NY: International Business Machines Corporation*).

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Results

The groups of individuals with amputation (N = 6) and without amputation (N = 10) were comparable in terms of age, total body mass, Body Mass Index, and weekly frequency of physical exercise (Table II) and statistically different regarding the time of physical exercise practice.

Table II - Demographic, anthropometric and physical exercise characteristics of the study subgroups

	Individuals with amputation (N=06)	Individuals without amputation (N=10)	p-value*
Age (years)	38.0 21-52	33.5 22-40	0.664
Total body mass (kg)	87.8 62.70-125.4	85.6 71.5-102	0.914
Body mass index (kg/m²)	27.9 21.8-38.1	27.1 21.6-31.5	0.828
Physical exercise practice time (months)	3 3-12	12 6-18	0.006
Weekly frequency of physical exercise (days/week)	4 3-5	4 3-5	0.958

Data presented as average (minimum value – maximum value); *Mann-Whitney test; statistical significance when p-value < 0.05

The results regarding exercise cardiorespiratory capacity are shown in Table III. At the end of the exercise, the groups presented similar total time and total effort load ($p = 0.386$ and $p = 0.785$, respectively). When analyzing the VO_{2peak}, we noticed a higher median value among individuals without amputation, both in absolute and relative to body mass analysis. All study participants, regardless of the group, reported peripheral fatigue (upper limbs) as a reason for effort interruption.

The absolute value of COP, time and load at the time of occurrence did not differ between groups ($p = 0.786$; $p = 0.212$ and $p = 0.240$, respectively), but individuals with amputation presented this point at a higher percentage of VO_{2peak} ($p = 0.007$) and in a lower relative and absolute VO_2 ($p = 0.004$ and $p = 0.009$, respectively). In both groups, COP preceded the occurrence of VT1.

VT1 was identified in all participants in the amputee group, while in the non-amputated group, in 70%. There was no difference between the groups about time and load at the time of reaching VT1 ($p = 0.253$ and $p = 0.170$, respectively) and percentage of VO_{2peak} ($p = 0.568$). However, amputees had lower relative and absolute VO_2 at this time ($p = 0.046$ and $p = 0.032$, respectively).

Table III - Variables related to the cardiopulmonary exercise test of the study subgroups

	Individuals with amputation (N=06)	Individuals without amputation (N=10)	p-value*
Total effort time (min:s)	17:59 (11:23-24:13)	17:30 (13:09-22:00)	0.386
Load at the end of effort (w)	102.50 (70.00-135.00)	100.00 (80.00-125.00)	0.785
VO_{2peak} (ml.kg^{-1}.min^{-1})	15.75 (6.06-19.65)	32.31 (25.39-39.71)	0.001
VO_{2peak} (L/min)	1.23 (0.70-1.46)	2.88 (2.01-4.01)	0.001
Time in COP (min:s)	4:03 (1:30-6:11)	2:49 (2:00-4:20)	0.212
Load in COP (w)	37.50 (25.00-50.00)	32.50 (30.00-40.00)	0.240
Lower VE/ VO_2 (COP)	15.30 (13.30-20.00)	15.30 (12.60-20.00)	0.786
VO_2 in COP (ml.kg^{-1}.min^{-1})	7.07 (3.03-8.00)	9.03 (7.50-18.13)	0.004
VO_2 in COP (L/min)	0.53 (0.35-0.81)	0.81 (0.60-1.60)	0.009
%VO_{2peak} in COP (%)	45.83 (39.63-55.44)	28.55 (21.35-51.98)	0.007
Time in VT1 (min:s)	10:41 (6:51-15:05)	10:01 (3:19-14:26)	0.253
Load in VT1 (w)	67.50 (40.00-90.00)	52.50 (30.00-75.000	0.170
VO_2 in VT1 (ml.kg^{-1}.min^{-1})	9.24 (3.46-14.27)	16.27 (9.33-31.00)	0.046
VO_2 in VT1 (L/min)	0.72 (0.40-1.06)	1.50 (0.72-2.73)	0.032
%VO_{2peak} in VT1 (%)	57.85 (56.76-72.62)	56.45 (34.21-88.00)	0.568

COP = Cardiorespiratory Optimal Point; VT1 = Ventilatory threshold 1; *Mann-Whitney test; statistical significance = 5%. Data presented as (minimum value – maximum value); *Mann-Whitney test; statistical significance when p-value < 0.05

Discussion

The present study aimed to test the hypothesis that individuals with unilateral lower limb amputation have lower cardiorespiratory fitness at different effort intensities compared to individuals without amputation. The main findings were that the group with amputation had lower VO_{2peak} for the same effort intensity when compared to the group without amputation, as well as the VO_2 at submaximal effort intensities, that is, in COP and VT1. However, the amputated group reached COP and VT1 in percentage values of VO_{2peak} similar to the group without amputation.

The VO_{2max} is the variable that best represents the aerobic capacity of an individual, with higher values being associated with a lower risk of fatal and non-fatal cardiovascular events [6,7]. In the present study, in the two investigated groups, none of the participants reached VO_{2max}. This may be related to the type of ergometer used, which, among other factors, influences the maximum metabolic response [17,18]. Particularly about the cycle ergometer for upper limbs, it is known that 1) it mobilizes a smaller amount of muscle groups when compared to other ergometers such as the treadmill and the ergometric bicycle; and 2) the gestures of movement are less familiar than the gestures in the ergometers mentioned above, in addition to not being muscle groups commonly used in daily activities, a fact that can facilitate the interruption of the test due to peripheral muscle fatigue. All study participants reported upper limb fatigue as the main cause for cessation of exertion. These factors, taken together, may have contributed to achieving VO_{2peak} instead of VO_{2max}.

Regarding VO_{2peak}, it was observed that individuals with amputation had a median value approximately 50% lower than individuals without amputation, reflecting lower integrity of the respiratory, circulatory, and muscle systems, determinants of cardiorespiratory fitness [16]. This difference was noticed both in the absolute analysis, in L/min, and in the body mass (ml.kg.min-1). To achieve the same intensity at the end of the effort, amputees probably resorted to a higher percentage of contribution of the glycolytic anaerobic system for the generation of ATP since the aerobic system did not rise as much as the non-amputee group. It is known that variables such as age, level of daily physical activity, and body size influence VO_{2max} [8]. Even if amputees practiced physical exercises recreationally on average three times a week, it is believed that in their daily lives, due to the lower mobility commonly caused by the removal of the limb, these individuals have a lower energy expenditure, leading to lower fitness cardiorespiratory when compared with congeners without amputation. Recently, a study including the participation of 72 individuals with lower-limb amputations – mostly men, with amputation at the transtibial level, and with a mean age of 53.6 years – showed that 61% of the participants did not have enough physical activity daily to be classified as sufficiently active, and 33% was classified as sedentary [3].

Considering the submaximal effort intensities, this study considered the following moments: 1) COP and 2) VT1. COP was first described in 2012 by a team of Brazilian researchers [9], following the assessment of healthy men and women on a treadmill. The authors noted that COP was achieved, on average, at 44% of VO_{2max} and before VT1. In professional soccer players, the COP was reached between 48.4% and 57% of the VO_{2max}, this variation being related to the position on the field – particularly the goalkeepers reached the COP in a higher percentage of the VO_{2max} and a lower VO_{2max} [10]. In the present study, amputees achieved COP in a higher % of VO_{2peak} compared to non-amputates (median amputees' group = 45.83; non-amputates = 28.55), with values like those described by Ramos et al. [9], which averaged 44%. However, even if there was a difference, the two groups reached the COP in a % of the VO_{2peak} close to what is reported in the literature, that is, between 30 and 50% [9].

COP values lower than 22, assessed through the effort performed on a cycle ergometer for lower limbs by healthy individuals and with chronic diseases, were associated with a lower risk of mortality [19]. Taking this value alone as a reference, we could suggest amputees would have a good clinical prognosis (median COP = 15.30; lowest value = 13.3; highest value = 20.0). However, this result must be interpreted with caution considering the following issues: 1) metabolic adjustments during physical effort are dependent, among others, on the ergometer and the exercise protocol. Therefore, there may be differences between the COP obtained in efforts performed with the upper and lower limbs, reflecting the number of mobilized muscle groups and differences in fiber types [8] and 2) the group had low VO_{2peak}, which is indicative of low cardiorespiratory fitness. Ramos and Araújo [19] evaluated maximal cardiorespiratory capacity on a cycle ergometer for lower limbs in 3331 adults with and without chronic diseases. Through the combination of COP [stratified at < 22 (low), 22-30 (medium) and > 30 (high)] and VO_{2max} [stratified at < 15.75 (low); 15.76-30 (medium) and > 30 (high) ml.kg.min-1] it was found through the analysis of the Kaplan-Meier survival curve, that regardless of the COP classification (low, medium or high), when in the presence of a low VO_{2max}, the risk of death is greater (the higher the COP and the lower the VO_{2max}, the greater the mortality).

Another approach that highlights the lower cardiorespiratory fitness in amputees is related to VT1. VT1 represents the moment of effort when the transition from aerobic to anaerobic metabolism begins. From this moment on, exercise ceases to be almost exclusively aerobic and starts to have an increase in the contribution of anaerobic mechanisms in the energy production process [8]. Progressive efforts performed above VT1 are associated with decreased effort tolerance [20].

In the present study, as much as amputees have reached VT1 in a percentage of VO_{2peak} within the expected range for the healthy population, that is, 50-60% [21] and similar to the non-amputee group, this percentage does not match a good cardiorespiratory fitness to the group given the VO_2 value at the time of VT1 (almost 50% lower than the non-amputee group). It can be suggested that although amputees have low cardiorespiratory fitness, it seems that they have a similar tolerance to non--amputates about the onset of the metabolism transition.

The present study has as a limitation the small sample size, which may limit the inference of the findings. However, as far as the authors are aware, this is the first approach involving the assessment of exercise-cardiorespiratory fitness in individuals with lower-limb amputations at different intensities. Specifically, this is the first investigation of COP in this population: a variable that reflects the efficiency of the integration between the cardiovascular and respiratory systems and with good applicability in populations that present functional limitations that prevent reaching maximum effort [9].

Whereas lower limb amputation is related to less participation in physical activities for reasons ranging from lack of accessibility, materials (prostheses and orthotics) and emotional issues such as problems with self-esteem, self-image, self-confidence, and motivation [22], knowledge of the cardiorespiratory fitness of individuals with amputation becomes necessary and relevant in the context of rehabilitation. The use of VO_{2peak}, VT1, and COP as a basis for exercise prescription allows stimuli to be effectively individualized according to demands and physiological conditions, a fact that will favor the occurrence of more consistent chronic adaptations.

As future perspectives, studies are expected to be carried out involving, among others: 1) larger sample size to increase the power of inferences; 2) the population of women since metabolic responses differ according to sex; 3) the creation of cut-off points for COP classification involving a cycle ergometer for upper limbs.

Conclusion

Individuals with unilateral lower limb amputation have lower cardiorespiratory fitness at different effort intensities when compared to individuals without amputation.

Potential conflict of interest
No potential conflicts of interest relevant to this article have been reported.

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Author contributions
Conception and research design: Costa RMR, Vigário PS, Mainenti MRM; **Data collection:** Costa RMR, Castro PMLA; **Data analysis and interpretation:** Vigário PS, Mainenti MRM, Santos MA; **Statistical analysis:** Vigário PS, Mainenti MRM; **Funding:** Vigário PS; **Writing of the manuscript:** Costa RMR, Vigário PS, Mainenti MRM, Castro PMLA; **Critical review of the manuscript for important intellectual content:** Lopes AJ, Santos MA.

References

1. Esfandiari E, Yavari A, Karimi A, Masoumi M, Soroush M, Saeedi H. Long-term symptoms and function after war-related lower limb amputation: A national cross-sectional study. Acta Orthop Traumatol Turc 2018;52(5):348–51. doi: 10.1016/j.aott.2017.04.00

2. Rimmer JH, Schiller W, Chen MD. Effects of disability-associated low energy expenditure deconditioning syndrome. Exerc Sport Sci Rev 2012;40(1):22-9. doi: 10.1097/JES.0b013e31823b8b82

3. Langford J, Dillon MP, Granger CL, Barr C. Physical activity participation amongst individuals with lower limb amputation. Disabil Rehabil 2019;41(9):1063–70. doi: 10.1080/09638288.2017.1422031

4. Mok A, Khaw KT, Luben R, Wareham N, Brage S. Physical activity trajectories and mortality: population based cohort study. BMJ 2019;365:l2323. doi: /10.1136/bmj.l2323

5. Mundell BF, Luetmer MT, Kremers HM, Visscher S, Hoppe KM, Kaufman KR. The risk of major cardiovascular events for adults with transfemoral amputation. J Neuroeng Rehabil 2018;15(1):58. doi: 10.1186/s12984-018-0400-0

6. Khan H, Kunutsor S, Rauramaa R, Savonen K, Kalogeropoulos AP, Georgiopoulou VV, *et al*. Cardiorespiratory fitness and risk of heart failure: A population-based follow-up study. Eur J Heart Fail 2014;16(2):180-8. doi: 10.1111/ejhf.37

7. Kunutsor SK, Kurl S, Khan H, Zaccardi F, Laukkanen JA. Associations of cardiovascular and all-cause mortality events with oxygen uptake at ventilatory threshold. Int J Cardiol 2017;1(236):444-50. doi: 10.1016/j.ijcard.2017.01.156

8. American Thoracic Society; American College of Chest Physicians. ATS/ACCP Statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med 2003;167(2):211-77. doi: 10.1164/rccm.167.2.211. Erratum in: Am J Respir Crit Care Med 2003 May 15;1451-2.

9. Ramos PS, Ricardo DR, Araújo CGS. Cardiorespiratory optimal point: A submaximal variable of the Cardiopulmonary Exercise Testing. Arq Bras Cardiol 2012;99(5):988-96. doi: /10.1371/journal.pone.0104932

10. Silva CGS, Castro CLB, Franca JF, Bottino A, Myers J, Araújo CGS. Ponto ótimo cardiorrespiratório em futebolistas profissionais: uma nova variável submáxima do exercício. Int J Cardiovasc Sci 2018;31(4):323-32. doi: 10.5935/2359-4802.20180030

11. IBGE. Censo demográfico: 2010: características gerais da população, religião e pessoas com deficiência [Internet]. Rio de Janeiro, 2012. [cited 2021 Sept 29]. Available from: https://biblioteca.ibge.gov.br/visualizacao/periodicos/94/cd_2010_religiao_deficiencia.pdf

12. Matsudo S, Araújo T, Matsudo V, Andrade D, Andrade E, Oliveira LC, *et al*. Questionário internacional de atividade física (IPAQ): estudo de validade e reprodutibilidade no Brasil. Rev Bras Ativ Fís Saúde 2012;6(2):5-18. doi: 10.12820/rbafs.v.6n2p5-18

13. Yazbek PJ, Carvalho RT, Sabbag LMS, Battistella LR. Ergoespirometria. Teste de Esforço Cardiopulmonar, Metodologia e Interpretação. Arq Bras Cardiol 1998;71(5):719-24. doi: 10.1590/s0066-782x1998001100014

14. Campos LFCC. Comparação entre métodos para mensuração da potência aeróbia em atletas tetraplégicos [Dissertação]. São Paulo: Faculdade de Educação Física da UNICAMP; 2013.

15. ACSM. Diretrizes do ACSM para os testes de esforço e sua prescrição. 10 ed. Rio de Janeiro: Guanabara Koogan; 2018.

16. Wasserman K. The anaerobic threshold measurement to evaluate exercise performance. Am Rev Respir Dis;129(2 Pt 2):S35-40. doi: /10.1164/arrd.1984.129.2P2.S35

17. Miranda EF, Malaguti C, Corso SD. Peripheral muscle dysfunction in COPD: lower limbs versus upper limbs. J Bras Pneumol 2011;37(3):380-8. doi: 10.1590/s1806-37132011000300016

18. Wasserman K, Hansen J, Sue DY, Casaburi R, Whipp B. Principles of exercise testing and interpretation. 3 ed. Baltimore: Lippincott, Williams & Wilkins; 1999.

19. Ramos PS, Araújo CGS. Cardiorespiratory optimal point during exercise testing as a predictor of all-cause mortality. Rev Port Cardiol 2017;36(4):261-9. doi: 10.1016/j.repce.2016.09.011

20. Sullivan MJL, Bishop SR, Pivik J. The Pain catastrophizing scale: development and validation. Psychol Assess 1995;4(7):524-32. doi: /10.1037/1040-3590.7.4.524

21. Roca J, Whipp BJ, Agustí AGN, Anderson SD, Casaburi R, Cotes JE, *et al*. Clinical exercise testing with reference to lung diseases: Indications, standardization and interpretation strategies. Eur Respir J 1997;10(11):2662-89. doi: 10.1183/09031936.97.10112662

22. Miller MJ, Jones J, Anderson CB, Christiansen CL. Factors influencing participation in physical activity after dysvascular amputation: a qualitative meta-synthesis. Disabil Rehabil 2019;41(26):3141-50. doi: 10.1080/09638288.2018.1492031

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