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# Demographic/anthropometric factors and physiological performance-related parameters associated with the six-minute walk test in bariatric surgery candidates, from Valdivia, Chile

*Fatores demográficos/antropométricos e parâmetros fisiológicos relacionados ao desempenho associados ao teste de caminhada de seis minutos em candidatos à cirurgia bariátrica, de Valdivia, Chile*

*Factores demográficos/antropométricos y parámetros fisiológicos relacionados con el desempeño en la prueba de la marcha de seis minutos de candidatos a cirugía bariátrica de Valdivia, Chile*

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**ABSTRACT |** The six-minute walk test (6MWT) is widely used to measure functional capacity in special populations. However, the factors associated with its performance in candidates for bariatric surgery are unclear. Therefore, this study aimed to investigate the influence of anthropometric and physiological factors in the 6MWT performance in bariatric surgery candidates. This cross-sectional study included 107 candidates for bariatric surgery. Anthropometric factors considered: gender, weight, height, body mass index (BMI), waist-to-hip, and waist-to-height ratios. Along with distance covered during 6MWT, physiological factors such as ratings of perceived exertion (RPE) and heart rate reserve percentage used (%HRR) were recorded. Among the 107 patients (mean age: 39.6 years), 83 volunteers were accepted to perform the 6MWT. No gender differences were observed in terms of distance covered, %HRR, and RPE during the 6MWT. Moreover, BMI and %HRR explained 21% of the 6MWT distance covered. Furthermore, participants with BMI ≤41.5 kg/m$^2$ walked ~50 meters more than their peers above this level (p=0.05). Interestingly, heart rate increase during the 6MWT was lower than described for healthy populations. BMI and %HRR partially explain the variability of the 6MWT performance in bariatric surgery candidates.

Keywords | Bariatric Surgery; Exercise Test; Obesity; Motor Activity; Heart Rate.

**RESUMO |** O teste de caminhada de seis minutos (TC6) é uma ferramenta amplamente usada para medir a capacidade funcional em populações especiais. No entanto, os fatores associados ao seu desempenho em candidatos à cirurgia bariátrica não são claros. Portanto, o objetivo deste estudo foi investigar a influência de fatores antropométricos e fisiológicos no desempenho do TC6 em candidatos à cirurgia bariátrica. Este estudo transversal incluiu 107 candidatos à cirurgia bariátrica. Os fatores antropométricos incluíram: sexo, peso, altura, índice de massa corporal (IMC) e índices cintura-quadril e altura-cintura. Além da distância percorrida durante o TC6, foram registrados fatores fisiológicos, como sensação subjetiva de esforço (SSE) e a porcentagem de frequência cardíaca de reserva utilizada (% FCR). Dos 107 pacientes (idade média: 39,6 anos), 83 voluntários concordaram em realizar o TC6. Não foram observadas diferenças por sexo em termos de distância percorrida, % FCR e SSE durante o TC6. Além disso, IMC e% FCR explicaram 21% da distância percorrida no TM6M. Além disso, indivíduos

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com IMC≤41,5 kg/m2 andaram ~50 metros a mais do que seus pares acima desse nível (p=0,05). Curiosamente, os aumentos na frequência cardíaca durante o TC6 foram inferiores aos descritos em populações saudáveis. IMC e %FCR foram fatores que explicaram parte da variabilidade do desempenho da TC6 em candidatos submetidos à cirurgia bariátrica.
Descritores | Cirurgia Bariátrica; Teste de Esforço; Obesidade; Atividade Motora; Frequência Cardíaca.

**RESUMEN |** La prueba de la marcha de seis minutos (PM6) es una herramienta muy utilizada para medir la capacidad funcional en ciertas poblaciones. Sin embargo, poco se conoce sobre los factores asociados a su desempeño en candidatos a cirugía bariátrica. Ante esto, el objetivo de este estudio fue evaluar la influencia de factores antropométricos y fisiológicos en el desempeño de la PM6 en candidatos a cirugía bariátrica. En este estudio transversal participaron 107 candidatos a cirugía bariátrica. Los factores antropométricos fueron: sexo, peso, altura, índice de masa corporal (IMC) e índices cintura-cadera y altura-cintura. Además de la distancia recorrida durante la PM6, se registraron los factores fisiológicos como la sensación subjetiva de esfuerzo (SSE) y el porcentaje de frecuencia cardíaca de reserva utilizada (% FCR). De los 107 pacientes (edad media: 39,6 años), 83 voluntarios aceptaron realizar la PM6. No se encontraron diferencias por sexo respecto de la distancia recorrida, % FCR y ESS durante la PM6. Además, el IMC y el % FCR explicaron el 21% de la distancia recorrida en la PM6. Y los individuos con un IMC ≤41,5 kg/m2 caminaron ~50 metros más que sus pares por encima de este nivel (p=0,05). Resultó interesante que el incremento de la frecuencia cardíaca durante la PM6 fue más bajo que los reportados en poblaciones sanas. El IMC y % FCR fueron los factores que explicaron parte de la variabilidad en el desempeño de la PM6 en candidatos a cirugía bariátrica.
Palabras clave | Cirugía Bariátrica; Prueba de Esfuerzo; Obesidad; Actividad Motora; Frecuencia Cardíaca.

## INTRODUCTION

Obesity is a global health problem. This condition is defined as a chronic disease influenced by genetic, environmental, and sociodemographic factors. It is characterized by an excessive increase in adipose tissue depots throughout the body and is caused by a positive energy balance persistent in time and/or an energy expenditure deficit[1]. In adults, obesity classification depends on the body mass index, which is estimated by dividing the body weight by height[2]. Therefore, values above 30 kg/m$^2$ are associated with obesity[2]. This condition is related to the development of noncommunicable chronic and degenerative diseases during adulthood, such as type 2 diabetes, cancer, hypertension, cardiovascular disease, depression, and psychological disorders; altogether raising the mortality risk[3]. Obesity is considered a worldwide pandemic, given that 39% of adults are classified as obese[2]. Especially in Latin America, by 2025, 18% of men and 21% of women will be classified as obese[4]. Moreover, Chile is among the 10 countries with the highest obesity prevalence worldwide[5], where national surveys show that three out of four people (74.2%) are overweight or obese[6].

Previous research has indicated the inverse association between obesity and physical fitness[7], where submaximal exercise stress tests have been used to estimate exercise tolerance in obese patients. The six-minute walk test (6MWT) has been used in diverse populations, including overweight and obese subjects[8]. Among the functions of this test the measurement of the functional capacity[9] and the detection of eventual motor and cardiorespiratory limitations[10] have been previously described. Given that, this task involves a submaximal effort it can provide the clinician a closer appreciation of the patients' functional level, particularly during daily living activities[11]. Furthermore, it is a simple, reproducible, and inexpensive alternative in a clinical setting. However, the performance in this test depends on several demographic and anthropometric factors, such as age, height, and weight[12-15]. Moreover, performance-related parameters, such as percentage of heart rate reserve used during the test, rating of perceived exertion, and dyspnea scores, are also useful parameters that complement the screening of the functional capacity through this test[12].

Interestingly, the influence of these factors and performance-related parameters varies depending on the population where this test is applied[12-14] along with test-related parameters, such as the protocol applied, length of the corridor, and the presence/absence of verbal encouragement[16]. Considering the high applicability of the 6MWT, it has been used previously in bariatric surgery candidates. For example, in 2009, Souza et al. compared the physical fitness through the 6MWT in obese subjects before and after undergoing bariatric surgery, finding that this test was sensible enough to

detect improvements in this outcome following the expected weight loss after surgery, considering the average increase in distance covered by ~80 m. We highlight that they used a test protocol that included a 30 m corridor, and standardized verbal stimulation every 30 seconds[11]. Moreover, behind this increase in performance, steep decreases in BMI were observed (51 vs 29 kg/m$^2$). These findings make us question the existence of BMI cut-off points that could be associated with significant changes in performance in the 6MWT.

However, candidates for bariatric surgery present specific characteristics regarding demographic and anthropometric factors (e.g., weight, waist, and hip circumferences) along with physiological/performance-related (e.g., heart rate changes and rating perceived exertion) parameters. Therefore, the impact of the latter on the 6MWT performance within this population is unknown. Thus, this study aimed to investigate the influence of demographic (age), anthropometric, and physiological/performance-related parameters in the 6MWT distance covered in bariatric surgery candidates and the influence of gender across these parameters.

## METHODOLOGY

### Study design and subjects

This was an observational, analytic, and cross-sectional study, exploring anthropometric and physiological factors that could influence the 6MWT performance in bariatric surgery candidates.

Our sample included 107 participants (80 women) above 15 years of age, which were admitted to the rehabilitation/preparation program for bariatric surgery candidates of Clinica Alemana de Valdivia, between March 2017 and March 2019. Patients with medical contraindications to perform physical exercise were excluded. Figure 1 shows a detailed flowchart regarding the study's sample.

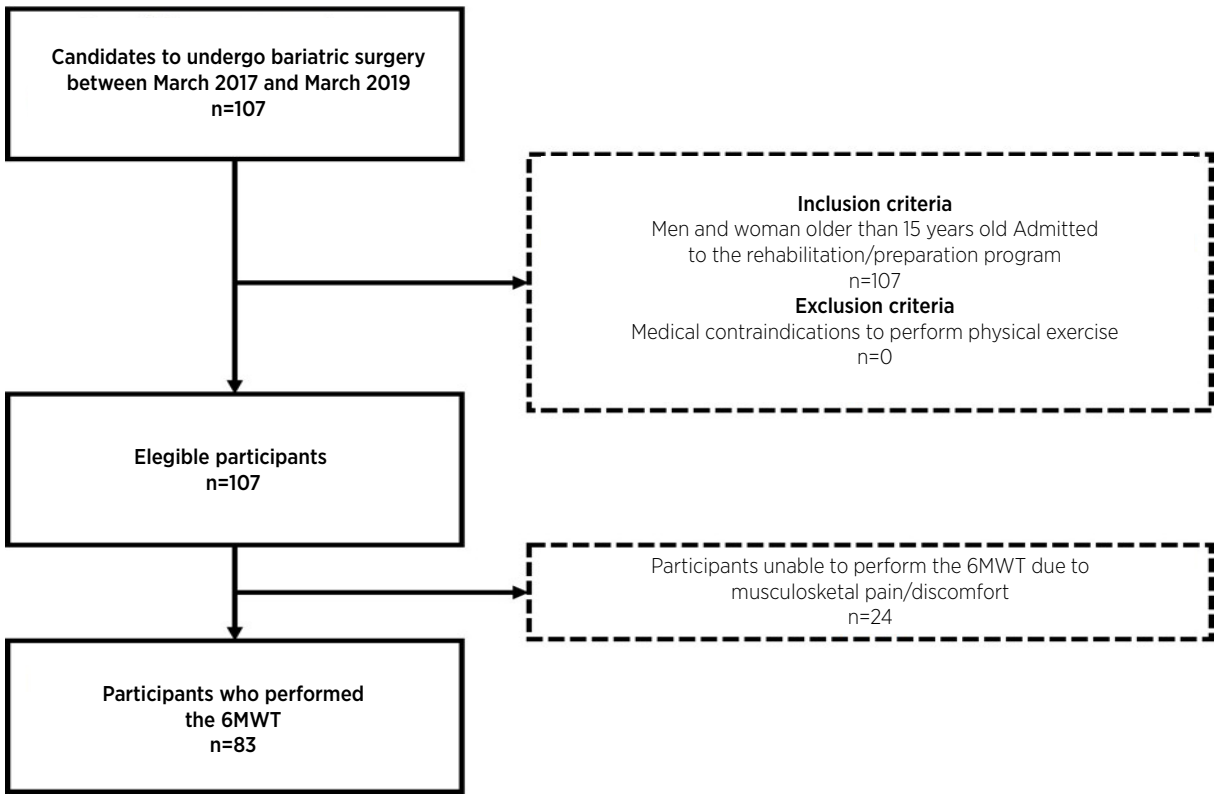


Figure 1. Participants flow diagram. 6MWT: six-minute walk test

Considering that the data analyzed herein were produced as part of routine clinical work, the Ethics Committee did not require informed consent/assent form from the participants.

### Outcomes

In admittance to the program, age in years and gender of patients were registered. Anthropometric

factors, such as weight in kilograms and height in meters, were recorded using a weight and height scale (Seca®) respectively. Then, the body mass index (BMI; kilograms/meters$^2$) was obtained. For the waist-to-hip and waist-to-height ratios, the waist circumference was measured using the umbilicus as reference point[17], whereas the hip circumference was measured at the higher prominence level. The presence/absence of cardiovascular risk factors were measured using the criteria proposed by the American College of Sports Medicine[18]: age (for men >45 years; for women >55 years); premature age of a family member with a first-degree cardiovascular disease (for men <55 years; for women <65 years); the presence of: smoking, sedentarism, obesity, hypertension, dyslipidemia, and prediabetes.

The 6MWT was applied following the protocol established by the Chilean Society of Respiratory Diseases[19]. Briefly, in the Physical Therapy and Rehabilitation Service of Clinica Alemana de Valdivia, a 30-meter plain straight hallway was delimited by two cones at its extremes. Before starting the test, participants stayed in a sitting position for 10 minutes, a period where resting heart rate and the rating of perceived exertion (RPE; by the modified Borg's scale) were measured[20]. Afterward, the participants were instructed to walk as fast as they could through the hallway, back and forth, for six minutes. At the end of the test, performance-related parameters, such as the distance covered in meters, heart rate, and RPE, were registered. The percentage of heart rate reserve used (%HRR) was estimated using Karvonen's equation[21].

### Statistical analysis

For all analyses, the SPSS (version 20) and GraphPad (version 7) software for Windows were used. Quantitative parameters were expressed in means and standard deviations, or median and interquartile range when necessary. Qualitative parameters were described in absolute frequencies. Comparisons between women and men were carried out to investigate the effect of gender in the outcomes of interest, using the Student's t, Mann-Whitney's, and chi-squared tests. To study possible correlations between outcomes, Spearman's index was used[22]. Depending on the outcomes that exhibited significant correlations with the 6MWT performance, multiple linear regression models were obtained in order to estimate the amount of variability of the 6MWT performance that could be explained by those variables. Finally, a classification tree by a CHI-squared automatic interaction detector (CHAID) was calculated to explore the possibility of classifying performance in the 6MWT by outcomes of interest. A p-value ≤0.05 was considered significant.

## RESULTS

As shown in Table 1, when comparing the age and waist-to-height ratio between men and women, no significant differences were found. In contrast, body weight, height, waist-to-hip ratio, and BMI were significantly higher in men. From the 107 initial participants, 83 volunteers were accepted to perform the 6MWT (58 women). In total, 24 volunteers were not able to perform the 6MWT due to musculoskeletal pain (e.g., osteoarthritis). Regarding 6MWT performance and associated factors, a slight but significant difference was found in resting heart rate, being higher in women, whereas the distance covered, %HRR, and RPE pre and post-6MWT were similar between genders. Complementarily, after comparing the cardiovascular risk factors distribution between men and women, no differences were observed (Table 2). We highlight that the records of only 105 patients were available for this analysis.

Table 1. Patients' characteristics

| Outcome | Men (n=27) | Women (n=80) | All (n=107) |
|---|---|---|---|
| Age (years) | 40.7±12.7 | 39.2±12.4 | 39.6±12.5 |
| Weight (kg) | 117.1±20.4 | 93.3±15.5* | 99.3±19.7 |
| Height (m) | 1.72±0.07 | 1.62±0.06* | 1.65±0.08 |
| BMI (kg/m$^2$) | 39.6±7.7 | 35.4±5.8* | 36.5±6.6 |
| Waist-to-hip ratio | 0.97±0.10 | 0.90±0.08* | 0.92±0.09 |
| Waist-to-height ratio | 0.69±0.08 | 0.67±0.09 | 0.68±0.09 |
| 6MWT distance (m)# | 576±87 | 560±49 | 565±63 |
| Resting HR (beats/min) # | 74±12 | 80±11* | 78±12 |
| HRR post-6MWT (%)# | 35.2±16.5 | 43.1±17.8 | 40.7±17.7 |
| Pain pre-6MWT (points) | 0 [0-0] | 0 [0-0] | 0 [0-0] |
| Pre-6MWT RPE (points) # | 0 [0-0] | 0 [0-0] | 0 [0-0] |
| Post-6MWT RPE (points) # | 4 [4-5] | 4 [3-5] | 4 [3-5] |

BMI: body mass index; HR: heart rate; HRR: heart rate reserve; 6MWT: six-minute walk test; RPE: rating of perceived exertion.
Values are expressed in terms of mean ± standard deviation and median [interquartile range]
*: indicates significant differences between men and women (p<0,05)
#: All six-minute walk test-related parameters were obtained from the 83 participants (58 women) that accepted to perform it.

Table 2. Distribution of cardiovascular risk factors by gender

| Risk factor* | Men | Women | p-value |
|---|---|---|---|
| Age | | | |
| Absence | 21 | 64 | 0.626 |
| Presence | 6 | 14 | |
| Family history | | | |
| Absence | 23 | 66 | 0.943 |
| Presence | 4 | 12 | |
| Smoking | | | |
| Absence | 20 | 56 | 0.819 |
| Presence | 7 | 22 | |
| Sedentarism | | | |
| Absence | 4 | 9 | 0.656 |
| Presence | 23 | 69 | |
| Obesity | | | |
| Absence | 2 | 12 | 0.293 |
| Presence | 25 | 66 | |
| Hypertension | | | |
| Absence | 23 | 70 | 0.521 |
| Presence | 4 | 8 | |
| Dyslipidaemia | | | |
| Absence | 22 | 57 | 0.383 |
| Presence | 5 | 21 | |
| Prediabetes | | | |
| Absence | 21 | 52 | 0.280 |
| Presence | 6 | 26 | |

*For this table only 105 patients are included given that for two patients the records were not available.

Regarding correlations between 6MWT performance and the anthropometric and physiological outcomes measured, height, BMI, waist-to-height ratio, and %HRR were associated with the 6MWT performance (Table 3). Interestingly, BMI was correlated with the waist-to-height ratio, but not with the waist-to-hip ratio. Moreover, it is possible that the waist-to-hip ratio could be influenced by height in our sample, given the significant correlation found between these two parameters.

We calculated multiple regression models in order to investigate which of the parameters could partially explain the 6MWT performance in our sample. Then, BMI along with %HRR explained a variability of 21% in 6MWT distance covered (Table 4). Moreover, by a CHAID classification analysis, we found that participants with a BMI higher than 41.5 kg/m$^2$ walked almost 50 m less than their counterparts below this level, a difference that was statistically significant (Figure 2).

Table 3. Correlations

| Outcome | 6MWT distance | Age | Height | BMI | Waist-to-hip ratio | Waist-to-height ratio | Resting HR | %HRR | Post-6MWT RPE |
|---|---|---|---|---|---|---|---|---|---|
| 6MWT distance | X | −0.014 | **0.228*** | **−0.300**** | 0.122 | **−0.277*** | −0.044 | **0.253*** | 0.121 |
| Age | | X | −0.088 | −0.189 | −0.072 | −0.101 | **−0.256*** | -0,204 | 0,016 |
| Height | | | X | −0.032 | **0.330*** | −0.157 | −0.139 | -0,128 | -0,078 |
| BMI | | | | X | 0.036 | **0.604**** | 0.054 | 0,208 | 0,077 |
| Waist-to-hip ratio | | | | | X | **0.396**** | 0.033 | 0,056 | -0,016 |
| Waist-to-height ratio | | | | | | X | 0.009 | 0,043 | 0,118 |

BMI: body mass index; 6MWT: six-minute walk test; HR: heart rate; RPE: rating of perceived exertion.
*: p<0.05; **: p<0.01

Table 4. Multiple linear regression model

| Model | Beta Coefficient | Standard error | t | p-value |
|---|---|---|---|---|
| Constant | 644.886 | 38.914 | 16.572 | <0.001 |
| %HRR | 1.280 | 0.372 | 3.441 | 0.001 |
| BMI | −3.512 | 1.017 | −3.454 | 0.001 |
| $R^2$=0.21 (F=10.116) | | | | <0.001 |

Dependent outcome: 6MWT distance covered.
BMI: body mass index; %HRR: percentage of heart rate reserve used during the six-minute walk test.

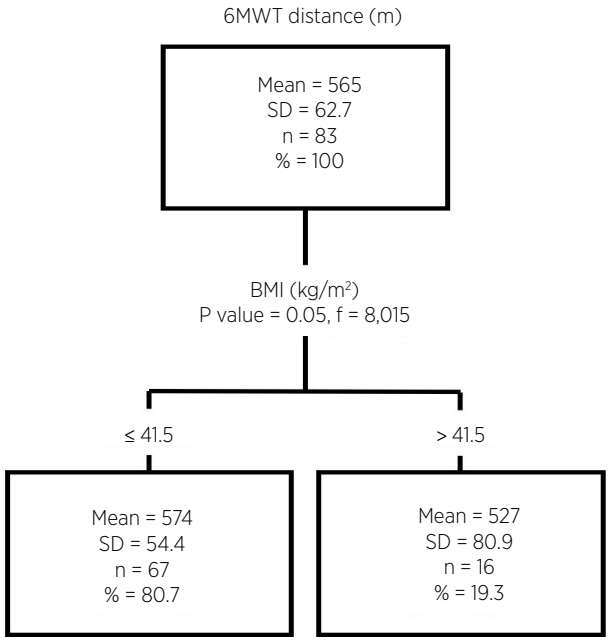


Figure 2. Classification of the six-minute walk test (6MWT) performance by body mass index (BMI).
SD: standard deviation; n: number of subjects in each group.

## DISCUSSION

This study aimed to investigate the influence of demographic/anthropometric factors and performance-related parameters in the 6MWT performance in candidates for bariatric surgery. In our sample, height, BMI, and waist-to-height ratio indicate a low but significant association with the distance covered during this test. Furthermore, only two variables (BMI and %HRR) explained some of the variability on this submaximal test (21%).

Regarding distance covered – when analyzing the performance of our sample – our results are similar to what others have reported previously. In this context, Terra et al. observed that a group of patients, before undergoing bariatric surgery, walked around 500 meters during the 6MWT[23]. These results are interesting considering that the ages of those subjects were similar to the age of our sample, which indicates the high reproducibility of this test, as previously described in obese individuals[8]. Furthermore, we highlight that the distance covered by our patients was similar to what has been described for healthy populations (~500 meters)[24] with similar ages[14]. These findings question the influence of body weight on the ability to perform submaximal efforts. Previous studies failed to detect significant differences in terms of 6MWT distance covered after comparing subjects with BMI levels between 25 and 35 kg/m$^2$ with peers above this level[25].

Based on the participants that performed the test, we concluded that BMI has a mild but significant association with the 6MWT distance covered. The main influence of the test was observed in subjects with BMI levels above 40 kg/m$^2$, since patients with BMI higher than 41.5 kg/m$^2$ showed lower performance in this test, a difference that has been previously described as clinically significant (~50 meters)[26]. Thus, BMI seems to affect the aerobic capacity in people with obesity, however, this effect would only be visible at certain levels. For example, Angoorani et al. conducted the 6MWT with candidates for bariatric surgery who had a similar mean age compared to our group (40 years). Interestingly, they walked 150 meters less than our patients, nevertheless, the mean participants' BMI of that study was ~44 kg/m$^2$ [27], higher than in our sample (~35 kg/m$^2$). Therefore, body mass could affect the submaximal performance in candidates for bariatric surgery, however, this effect could only be seen in patients with high degrees of obesity. One aspect that was not investigated was the influence of musculoskeletal pain, which hampered 24 of our participants to perform the 6MWT. Considering its relevance, future studies should explore the influence of this factor in the 6MWT performance, particularly in candidates for bariatric surgery.

An interesting point to be considered when comparing 6MWT results from different studies is the variability of protocols used, where parameters such as length of the corridor, verbal encouragement, and instructions given to patients are significant[16]. In our study, we had a 30 m corridor with a standardized verbal encouragement every minute, where the instructions were given at the beginning of the test[19]. Coincidentally, Angoorani et al., which studied a similar population, used a protocol where the corridor was 100-ft long (30.5 m) and the verbal encouragement was standardized and given every minute[27]. Therefore, our results can be compared with this study with a certain level of certainty. However, Souza et al. gave verbal encouragement every 30 s[11], a fact that hinders direct comparisons with their results, therefore, a close analysis of the protocol used should be done before comparing results from different studies in the field.

To understand why the submaximal capacity seems to be preserved in people with lower levels of obesity, previous studies have described that people with obesity incur higher physical workloads when performing submaximal activities[28]. Considering this, one explanation could be that this higher

workload sustained during daily living activities, such as walking, would preserve their capacity to make submaximal efforts. In that regard, previous studies have described the relevance of workload for physical function preservation, even in obesity conditions[29]. However, this hypothesis requires further investigation in order to be tested.

According to our findings, physiological factors seem to play a role in the submaximal capacity of bariatric surgery candidates. In this context, in our study, we observed that during the 6MWT, participants used a ~40% of their HRR, lower levels compared to healthy populations where HRR usage in this test has been described to be above 60%[13,14]. One possible explanation is the development of chronotropic incompetence, which is defined as the inability of the heart to raise its rate when physical workload increases in are imposed[30]. In this regard, previous studies have described impaired chronotropic responses in progressive tests to exhaustion in subjects with obesity, that is, these subjects presented lower maximal heart rates compared to lean counterparts[31]. This condition is associated with autonomic dysfunctions, which are also related to higher mortality risk[32] and exercise intolerance in other populations[33]. Moreover, we found positive correlations between the 6MWT distance covered and %HRR, which could indicate that the chronotropic response might play a role in obese patients. However, no studies regarding the presence of chronotropic incompetence in candidates for bariatric surgery are known, therefore, future studies within the field should focus on this outcome. Complementarily, the possibility that our participants did not execute the 6MWT properly is not plausible, given that the reported RPE levels by our sample are similar to what was reported previously for healthy individuals[13,14] and populations with cardio ventilatory dysfunctions[12].

In our study, no major gender effects were found regarding the 6MWT performance-related parameters, even when previous studies have indicated clear differences in regarding distance covered during the 6MWT between women and men[14]. This finding could be explained by the differences observed in some of the anthropometric factors, given that men had higher weight and BMI levels than women, factors that are negatively associated with the 6MWT distance covered[14,25]. Moreover, the fact that the average age of both genders was similar, highlight the relevance of anthropometric factors in this population. However, other physiological and anthropometric factors that were not measured may be playing a role when comparing genders in an obesity context, such as muscle mass and muscle strength and quality[34], along with cardiorespiratory fitness[35]. Therefore, future studies should consider the measurement of these outcomes to have a more comprehensive analysis of the factors and parameters that influence the 6MWT performance during obesity.

As limitation of this study, our participants were selected by a non-probabilistic sampling, therefore, future reports should have a multicenter approach in order to obtain representative results for the population of bariatric surgery candidates. On top of this, the distribution between males and females in our sample was not balanced, which could incur bias considering the over-representation of women in the analysis. Moreover, no osteoarticular pain measurements were included, a factor that was described as significant regarding the limitation in daily living activities and quality of life of this population, regardless of cardiovascular function[36]. Also, outcomes regarding the physiologic response before and during (minute by minute)[37] the 6MWT, such as blood pressure, oxygen saturation, and breathing rate, were not assessed. These factors are known to be affected by inflammatory states such as obesity[38]. Furthermore, the absence of a gold standard measurement for the body composition measurement hinders the possibility to establish eventual associations with, for example, visceral adipose tissue levels. Nevertheless, the use of simple and easy-to-measure anthropometric outcomes increases the replicability and applicability of this study results.

## CONCLUSION

Among the anthropometric and physiological factors considered in this study, BMI and %HRR were associated with the 6MWT performance in bariatric surgery candidates. Moreover, we found that even when the participants walked a distance closer to what has been described for healthy populations, lower heart rate increases were reported during the 6MWT in this group, a finding that could suggest the presence of cardiac dysfunctions during submaximal efforts, which requires further exploration in the future.

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## REFERENCES


1. Gadde KM, Martin CK, Berthoud HR, Heymsfield SB. Obesity: pathophysiology and management. J Am Coll Cardiol. 2018;71(1):69-84. doi: 10.1016/j.jacc.2017.11.011.
2. World Health Organization. Obesity and overweight [Internet]. Geneva: WHO; 2021 Jun. 9 [cited 2021 Sep 23]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
3. Pedersen BK. The diseasome of physical inactivity--and the role of myokines in muscle--fat cross talk. J Physiol. 2009;587(Pt 23):5559-68. doi: 10.1113/jphysiol.2009.179515.
4. Ruilope LM, Nunes Filho ACB, Nadruz W Jr, Rodriguez Rosales FF, Verdejo-Paris J. Obesity and hypertension in Latin America: current perspectives. Hipertens Riesgo Vasc. 2018;35(2):70-6. doi: 10.1016/j.hipert.2017.12.004.
5. Atalah E. Epidemiología de la obesidad en Chile. Rev Med Clin Condes. 2012;23(2):117-23. doi: 10.1016/s0716-8640(12)70287-0.
6. Chile. Ministerio de Salud. Encuesta Nacional de Salud 2016-2017 [Internet]. Santiago: Ministerio de Salud; 2017 [cited 2021 Sep. 24]. Available from: https://bit.ly/3i4rO5n.
7. Chin SH, Kahathuduwa CN, Binks M. Physical activity and obesity: what we know and what we need to know. Obes Rev. 2016;17(12):1226-44. doi: 10.1111/obr.12460.
8. Beriault K, Carpentier AC, Gagnon C, Ménard J, Baillargeon JP, Ardilouze JL, et al. Reproducibility of the 6-minute walk test in obese adults. Int J Sports Med. 2009;30(10):725-7. doi: 10.1055/s-0029-1231043.
9. Holland A, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. Eur Respir J. 2014;44(6):1428-46. doi: 10.1183/09031936.00150314.
10. Donini LM, Poggiogalle E, Mosca V, Pinto A, Brunani A, Capodaglio P. Disability affects the 6-minute walking distance in obese subjects (BMI>40 kg/m(2)). PLoS One. 2013;8(10):e75491. doi: 10.1371/journal.pone.0075491.
11. Souza SAF, Faintuch J, Fabris SM, Nampo FK, Luz C, Fabio TL, et al. Six-minute walk test: functional capacity of severely obese before and after bariatric surgery. Surg Obes Relat Dis. 2009;5(5):540-3. doi: 10.1016/j.soard.2009.05.003.
12. Baeza-Barría VC, Martín-Correa MAS, Rojas-Rojas GA, Martínez-Huenchullán SF. Respuesta fisiológica en el test de marcha en 6 minutos en pacientes con enfermedad pulmonar obstructiva crónica. Fisioterapia. 2014;36(4):160-6. doi: 10.1016/j.ft.2013.08.002.
13. Muñoz R, Medina P, Escobar M. Prueba de caminata en seis minutos: ¿es relevante explorar la longitud de la pista? Revista de Estudiosos en Movimiento [Internet]. 2015 May [cited 2021 Sep. 24];2(1):25-31. Available from: https://bit.ly/3zGSiQd.
14. Osses AR, Yáñez JV, Barría PP, Palacios SM, Dreyse JD, Díaz OP, et al. Prueba de caminata en seis minutos en sujetos chilenos sanos de 20 a 80 años. Rev méd Chile. 2010;138(9):1124-30. doi:10.4067/s0034-98872010000900006.
15. Saibene F, Minetti AE. Biomechanical and physiological aspects of legged locomotion in humans. Eur J Appl Physiol. 2003;88(4-5):297-316. doi: 10.1007/s00421-002-0654-9.
16. Tramontini MR, Mayer AF, Cardoso F, Jardim JR. Variability in walk test conditions at pulmonary rehabilitation programs in Latin America and on the Iberian Peninsula. Arch Bronconeumol. 2005;41(12):667-78. doi: 10.1016/s1579-2129(06)60334-0.
17. Palacio A, Vargas P, Ghiardo D, Rios MJ, Vera G, Vergara S, et al. Primer consenso chileno de nutricionistas en cirugía bariátrica. Rev Chil Nutr. 2019;46(1):61-72. doi: 10.4067/s0717-75182019000100061.
18. American College of Sports Medicine. ACSM's Guidelines for exercise testing and prescription. 10th ed. Philadelphia: Lippincott Williams & Wilkins; 2017.
19. Gutiérrez-Clavería M, Beroíza TW, Cartagena CS, Caviedes IS, Céspedes JG, Gutiérrez-Navas M, et al. Prueba de caminata de seis minutos. Rev Chil Enferm Respir. 2009;25(1):15-24. doi: 10.4067/S0717-73482009000100003.
20. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377-81. doi:
21. Carvalho VO, Guimaraes GV, Bocchi EA. The relationship between heart rate reserve and oxygen uptake reserve in heart failure patients on optimized and non-optimized beta-blocker therapy. Clinics. 2008;63(6):725-30. doi: 10.1590/s1807-59322008000600003.
22. Mukaka MM. Statistics corner: a guide to appropriate use of correlation coefficient in medical research. Malawi Med J [Internet]. 2012 Sep [cited 2021 Sep. 24];24(3):69-71. Available from: https://bit.ly/3AFqc9n.
23. Terra CMO, Simões CF, Mendes AA, Oliveira RP, Dada RP, Mendes VHS. The relation among the physical activity level during leisure time, anthropometry, body composition, and physical fitness of women underwent of bariatric surgery and an equivalent group with no surgery. Arq Bras Cir Dig. 2017;30(4):252-5. doi: 10.1590/0102-6720201700040006.
24. Someya F, Mugii N, Oohata S. Cardiac hemodynamic response to the 6-minute walk test in young adults and the elderly. BMC Res Notes. 2015;8:355. doi: 10.1186/s13104-015-1331-5.
25. Pires SR, Oliveira AC, Parreira VF, Britto RR. Teste de caminhada de seis minutos em diferentes faixas etárias e índices de massa corporal. Rev Bras Fisioter. 2007;11(2). doi:10.1590/s1413-35552007000200010.
26. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. J Am Geriatr Soc. 2006;54(5):743-9. doi: 10.1111/j.1532-5415.2006.00701.x.
27. Angoorani H, Mazaherinezhad A, Moezy A, Sartaj E, Safavi M. The effect of Roux-en-y Gastric Bypass surgery on fitness parameters in women with morbid obesity. J Minim Invasive Surg Sci. 2018;7(1):e69491. doi: 10.5812/minsurgery.69491.
28. Larsson UE, Reynisdottir S. The six-minute walk test in outpatients with obesity: reproducibility and known group validity. Physiother Res Int. 2008;13(2):84-93. doi: 10.1002/pri.398.
29. Gaesser GA, Tucker WJ, Jarrett CL, Angadi SS. Fitness versus fatness: which influences health and mortality risk the most? Curr Sports Med Rep. 2015;14(4):327-32. doi: 10.1249/JSR.0000000000000170.
30. Brubaker PH, Kitzman DW. Chronotropic incompetence: causes, consequences, and management. Circulation. 2011;123(9):1010-20. doi: 10.1161/CIRCULATIONAHA.110.940577.

31. Gondoni LA, Titon AM, Nibbio F, Augello G, Caetani G, Liuzzi A. Heart rate behavior during an exercise stress test in obese patients. Nutr Metab Cardiovasc Dis. 2009;19(3):170-6. doi: 10.1016/j.numecd.2008.07.001.

32. Lauer MS, Francis GS, Okin PM, Pashkow FJ, Snader CE, Marwick TH. Impaired chronotropic response to exercise stress testing as a predictor of mortality. JAMA. 1999;281(6):524-9. doi: 10.1001/jama.281.6.524.

33. Hulo S, Inamo J, Dehon A, Le Rouzic O, Edme JL, Neviere R. Chronotropic incompetence can limit exercise tolerance in COPD patients with lung hyperinflation. Int J Chron Obstruct Pulmon Dis. 2016;11:2553-61. doi: 10.2147/COPD.S112490.

34. Vilaça KH, Alves NMC, Carneiro JAO, Ferriolli E, Lima NKC, Moriguti JC. Body composition, muscle strength and quality of active elderly women according to the distance covered in the 6-minute walk test. Braz J Phys Ther. 2013;17(3):289-96. doi: 10.1590/s1413-35552012005000093.

35. Zhang Q, Lu H, Pan S, Lin Y, Zhou K, Wang L. 6MWT performance and its correlations with VO(2) and handgrip strength in home-dwelling mid-aged and older chinese. Int J Environ Res Public Health. 2017;14(5):473. doi:10.3390/ijerph14050473.

36. Tamura LS, Cazzo E, Chaim, EA, Piedade SR. Influence of morbid obesity on physical capacity, knee-related symptoms and overall quality of life: a cross-sectional study. Rev Assoc Med Bras (1992). 2017;63(2):142-47. doi: 10.1590/1806-9282.63.02.142.

37. Muñoz-Cofré R, Medina-González P, Escobar-Cabello M. Análisis del comportamiento temporal de variables fisiológicas y de esfuerzo en sujetos instruidos en la prueba de marcha de 6 minutos: complemento a la norma de la Sociedad Americana del Tórax. Fisioterapia. 2016;38(1):20-7. doi: 10.1016/j.ft.2015.01.003.

38. Rodriguez DA, Garcia-Aymerich J, Valera JL, Sauleda J, Togores B, Galdiz JB, et al. Determinants of exercise capacity in obese and non-obese COPD patients. Respir Med. 2014;108(5):745-51. doi: 10.1016/j.rmed.2014.02.004.