JRSR 8 (2021) 12-18

Journal of Rehabilitation Sciences and Research

Journal Home Page: jrsr.sums.ac.ir

Original Article

Comparative Effects of Six-minute Treadmill Walk and Six-minute Treadmill Walk-talk Test on the Cardiopulmonary Parameters of Healthy Individuals

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ARTICLE INFO

Article History:
Received: 02/05/2020
Revised: 03/03/2021
Accepted: 09/03/2021

Keywords:
Effect
six-minute walk test
Walk-talk test
Cardiopulmonary parameters
Healthy individual

Please cite this article as: Mbada CE, Adeagbo OJ, Mohammed J, Kaka B, Shittu A, Sumaila FG, Oyewole AI, Makinde MO. Comparative Effects of Six-minute Treadmill Walk and Six-minute Treadmill Walk-talk Test on the Cardiopulmonary Parameters of Healthy Individuals. JRSR. 2021;8(1):12-18.

ABSTRACT

Background: To compare the effect of Six-Minute Treadmill Walk Test (6MTWT) and Six-Minute Treadmill Walk-Talk Test (6MTWTT) on cardiopulmonary parameters.

Methods: A total of 35 Nigerian undergraduate students with stable cardiopulmonary parameters at baseline were recruited into this pre-test – post-test experimental study using convenient sampling. The participants performed a 6MTWT and 6MTWTT (after two hours interval between tests) on a powered treadmill using standard protocol. Systolic and diastolic blood pressures (SBP and DBP), heart rate (HR), rate pressure product (RPP), metabolic equivalents (METs), saturated partial pressure of oxygen (SPO_2) and the rate of perceived exertion (RPE) were measured.

Results: The results showed that both the 6MTWT and 6MTWTT lead to significant increases in the values of SBP, HR, METs, RPE and RPP ($P<0.05$), except for DBP where the change was not significant ($P>0.05$). Comparatively, post walk tests results revealed there was significantly higher RPE and SPO_2 scores with 6MTWT compared to 6MTWTT ($P<0.05$), while other parameters were comparable ($P<0.05$). Furthermore, SBP, PR and RPP of both tests correlated moderately with each other ($P<0.05$).

Conclusion: 6MTWT and 6MTWTT, similarly evoke cardiopulmonary changes among apparently healthy young individuals. However, 6MTWTT led to less oxygen consumption and myocardial oxygen demand compared with 6MTWT. This finding may be potentially beneficial for future cardiopulmonary exercise testing using 6MWT.

Introduction

Several modalities have been utilized to objectively assess functional exercise capacity [1, 2]. While some of these modalities provide a complete assessment of all systems involved in exercise performance, others only provide basic information and are easier to perform [3]. Popular clinical exercise tests include stair climbing, 6-Minute Walk Test (6MWT), shuttle-walk tests, cardiovascular stress test and cardiopulmonary exercise test [1, 2, 4, 5]. These tests have shaped the approach to exercise training intervention in both healthy and diseased populations over the years.

Although assessment of functional exercise capacity has been traditionally done using subjective means,

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such as merely asking patients the following questions: "How many flights of stairs can you climb or how many blocks can you walk?" [6], however, there has been a progression to from these subjective methods to more objective but simpler tests [7]. The use and preference for the walk tests have been largely based on the fact that they are more closely related to everyday activities, in addition to other benefits that they may have over other forms of exercise testing methods [8].

Walk tests, as clinical methods for evaluating functional exercise capacity are simple and it generally consist of walking on a level surface or, alternatively, going up steps. These tests impose either a constant or incremental load as a function of the type and time chosen. The most common of these tests for determining functional exercise capacity with wide clinical applicability is the 6MWT and its variants. [9-11]. Recently, some experts now use self-powered treadmill for the 6MWT, in order to overcome the problem of corridor walk and other related challenges with performing the test [9].

Presently, there is a paucity of studies on exercise testing parameters such as ventilatory threshold (Tvent), which is the point whereby respiration increases significantly due to the accumulation and expiration of metabolic by-products. Tvent is also physiologically referred to as the VO_2 at which the ventilatory equivalent for oxygen increased without a marked rise in the ventilatory equivalent for carbon dioxide [12]. Tvent also remains an important parameter for optimal prescription of exercise training (intensity) levels. Consequently, Talk Test (TT) became one of the ways to assess Tvent [13]. The TT is based on the principle that comfortable speech is likely possible when exercise intensity is below the Tvent or lactate threshold, and not likely possible when exercise intensity exceeds these thresholds [13]. In addition, the TT has been confirmed to be valid, reliable, practical and inexpensive tool for prescribing and monitoring exercise intensity [13-15].

While there is substantial literature on 6MWT being a low-risk protocol/intervention [16, 17], however, a report by Singh et al [18] indicates that it is negatively associated with risk of disease exacerbation and mortality. Also, Robert et al [19] raised concerns about risks of substantial oxygen desaturation in patients with moderate to severe COPD where adverse events such as dizziness, chest pain, chest tightness and palpitations have led to non-adherence to the standardised ATS guideline for the 6MWT. As a precautionary measure, the ATS and the European Respiratory Society for patients with COPD recommended continuous recording of oxygen saturation during testing [16]. This is because the test may be very fatiguing for some patients, especially in severe COPD [20]. Consequently, some researchers have recommended modifications or alternatives to the test [21-24]. As a result, walk tests of shorter durations have evolved and are still being validated [25]. Other than altering duration of the 6MWT only, it is unclear to what degree, incorporating TT into 6MWT could prove valuable and reduce the chance of test-related events. The use of TT is adduced to be capable of ensuring that 6MWT is not conducted faster than the patient or client can talk.

Therefore, the objective of this study was to compare the effects of six-minute treadmill walk test (6MTWT) and six-minute treadmill walk-talk test (6MTWTT) on cardiopulmonary parameters in apparently healthy individuals.

Methods

Participants

This pre-test - post-test quasi experimental study was conducted among male and female undergraduates of Obafemi Awolowo University Ile-Ife, Nigeria. The participants were 18 years and older, and had stable cardiopulmonary parameters at baseline (or rest). Individuals with a positive history of extreme chest discomfort, a positive history or any obvious musculoskeletal problem and those who used stimulants on the day of experiment were all excluded.

The sample size for this study was estimated from previous study by Xu [26] using the following formulae: $n = Z^2 S^2 / d^2$

where: n, is the size of sample; Z, is the z-statistics for the desired level of confidence; usually set at 1.96 or occasionally at 2.58; S, is the population standard deviation; usually set at 30 or 40; d, is the half width of the desired interval, usually set at 10 or occasionally at 5. Thereafter, the sample size was calculated to be a minimum of 35 subjects.

Procedure

Ethical approval for this study was obtained from the ethics and research committee 0f Obafemi Awolowo University Teaching Hospital Complex (OAUTHC). Consent of the participants were obtained. Thereafter, screening was done to ensure eligible for the study.

For the 6MTWT, the participants began walking on a level motor driven treadmill (Enrafnonius Treadmill; Bonte Technology BV, The Netherlands; Serial NR: ETB 04-4313) at a speed of about 2.0 mph for the 6MTWT. The treadmill grade begins at 0 and is increased by 2% at every 2 minute interval [10]. The participants who were unable to walk at least 2.0 mph were set at a walking speed of about 0.5mph. Thereafter, the speed was gradually increased until such a participant reaches a speed of 2.0 mph. After the participants reaches 2.0 mph, the treadmill grade was then increased by 2% every 2 minutes until maximal exertion [10]. After two hours, the participants were then recalled to perform the 6MTWTT using the same protocol described above. Two hours was considered sufficient to allow for the cardiovascular parameters to return to baseline (cardiovascular recovery) [27, 28].

The difference between the 6MTWT and 6MTWTT was that the participants recited the "Nigerian national pledge", (a 33 word paragraph) during the last 33 seconds. All tests were stopped if there was evidence of shortness of breath, chest pain, light headedness, or at the end of the 6 minutes duration.

Outcomes

All the participants were required to identify the rate of perceived exertion (RPE) by pointing at a modified Borg scale, which was recorded. A pulse oximeter (EC-500A; M/s. Swayam Thermometers Industries, New Delhi, India) was fixed to the index finger of the participants to assess the Heart Rate (HR) or pulse rate (PR) and Oxygen Saturation Pressure (SPO_2). A digital blood pressure (BP) monitor (Omron, MX2 HEM-742-E2; The Netherlands) was used to assess their Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) in comfortable sitting. All interventions and assessments were carried out between 8:00 a.m. and 11:00 a.m. each time.

The maximal oxygen consumption (VO_{2max}), metabolic equivalents (METs) and Rate Pressure Products (RPP) were calculated from the measured cardiopulmonary parameters. RPP was calculated as the product of the SBP and HR. Speed on the treadmill range between 0.5mph-2.0 mph, which corresponds to a brisk walking pace [30]. The VO_{2max} was calculated using the following formula from the American college of sports medicines (ACSM) guidelines for exercise testing and prescription, 2006) [31]:

VO_{2max} *(ml/kg/min) = (Mph×2.68) + (1.8×26.82×grade/100)+3.5*

Furthermore, METS was calculated as a function of VO_{2max} (ml/kg/min) divided by 3.5 [32].

Data Analysis

Data was analysed using both descriptive (mean and standard deviation) and inferential statistics. Paired t-test and Independent t-test were used to compare the within-and-between group differences on effects between 6MTWT and 6MTWTT on cardiopulmonary parameters. Influence of gender and anthropometric parameters were explored using correlation analysis. Alpha level was set at $P<0.05$. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp. IBM Corp. was used for data analysis.

Results

Physical Characteristics of the Participants

The physical characteristics of the participants according to gender are presented in Table 1. Here, it can be seen that the male subjects were significantly older, taller and had more weight ($P<0.05$). Nevertheless, both male and female participants had a comparable BMI that can be classified as normal weight ($P>0.05$).

Comparison of Cardiopulmonary Parameters at Baseline and After Both Walk Tests

Paired t-test comparison of cardiopulmonary parameters at baseline and after the 6MTWT is presented in Table 2. From the results, there were significant increases differences in values of the SBP, PR, METs, and RPP following both walk tests. On the other hand, SPO_2 and RPE were significantly decreased ($P<0.05$). In all, there were no significant differences in the DBP (and RPE) following both tests in Tables 2 and 3.

Comparison of Cardiopulmonary Responses of the Two Walk Tests (6MTWT and 6MTWTT)

Table 4 shows the comparison of mean difference (post-test – pre-test values) and not the absolute values. The results indicate that the changes were significantly higher in RPE and SPO_2 values during the 6MTWT compared with 6MTWTT. ($P<0.05$). The other parameters revealed no differences following both the 6MTWT and 6MTWTT with respect the PR, RPE, SBP and DBP values ($P>0.05$).

Correlations of the Selected Cardiopulmonary Parameters between the 6MTWT and 6MTWTT

The results of the Pearson's product moment correlation between 6MTWT and 6MTWTT on their cardiopulmonary parameters. The results indicated that there was a significant correlation in the values of the SBP ($r=0.503$; $P=0.002$), PR ($r=0.498$; $P=0.002$) and RPP ($r=0.536$; $P=0.001$) of the two walk tests (6MTWT and 6MTWTT). Again, the only exception was the DBP ($r=0.255$; $P=0.140$), which did not reveal a significant correlation among of the two walk tests. These results are illustrated in Figure 1.

Table 1: Physical Characteristics of the Participants

Variable	Male (21) Mean±SD	Female (14) Mean±SD	t	P	All participants
Age	23.7±1.35	22.5±1.65	2.386	0.023*	23.2±1.57
Weight	64.3±8.60	54.21±8.60	3.461	0.002*	60.3±9.75
Height	1.73±0.53	1.61±0.06	6.313	0.001*	1.68±0.08
BMI	21.6±2.92	21.0±2.73	0.649	0.521	21.3±2.82

*Indicate significant difference

Table 2: Paired t-test comparison of cardiopulmonary response and other outcomes to Six-Minute Treadmill Walk Test

Variable	Pre-test Mean±SD	Post-test Mean±SD	t	P
SBP	110.6±7.72	117.9±10.8	-5.473	0.001*
DBP	68.5±7.24	69.2±5.79	-0.650	0.520
PR	75.7±8.82	84.7±2.21	-7.486	0.001*
RPP	8371.4±1136.03	9996.4±1862.53	-8.352	0.001*
SPO_2	96.86±0.94	95.34±1.14	7.333	0.001*
METS	34.4±0.01	37.8±0.01	1422.322	0.001*
VO_2 Max	9.83±0.01	10.8±0.01	405.780	0.001*
RPE	2.09±0.82	1.11±0.72	-5.313	0.001*

*Indicates significant difference. SBP= Systolic Blood Pressure (mmHg); DBP= Diastolic Blood Pressure (mmHg); PR= Pulse rate; SPO_2= oxygen saturation pressure; RPP= Rate Pressure Product (RPP) and RPE=Rate of Perceived Exertion VO_2Max= Maximum Oxygen Consumption; MET_s= Metabolic Equivalents of Tasks and RPE=Rate of Perceived Exertion.

Table 3: Paired t-test comparison of cardiopulmonary response and other outcomes to Six-Minute Treadmill Walk Test

Variable	Pre-test Mean±SD	Post-test Mean±SD	t	P
SBP	109.68±8.00	114±11.3	-4.597	0.001*
DBP	70.00±5.80	69.6±5.22	0.448	0.664
PR	75.86±9.33	81.3±10.09	-4.529	0.001*
RPP	8321.5±1221.86	9379.7±1468.13	-6.074	0.001*
SPO_2	96.49±1.34	95.60±1.54	3.426	0.002*
METS	34.4±0.01	37.8±0.01	3.426	0.002*
VO_2 Max	9.83±0.01	10.8±0.01	3.426	0.002*
RPE	2.09±0.82	1.97±0.75	-0.639	0.525

NOTES: *Indicates significant difference, SBP= Systolic Blood Pressure (mmHg); DBP= Diastolic Blood Pressure (mmHg); PR= Pulse rate; SPO_2= oxygen saturation pressure; RPP= Rate Pressure Product (RPP) and RPE=Rate of Perceived Exertion VO_2Max= Maximum Oxygen Consumption; MET_S= Metabolic Equivalents of Tasks and RPE=Rate of Perceived Exertion

Table 4: Independent t-test comparison of cardiovascular and cardiopulmonary responses following the Six-Minute Treadmill Walk Test and Six-Minute Treadmill Walk-Talk Test

Variable	6MTWT Mean±SD	6MTWTT Mean±SD	t	P
SBP	7.29±7.80	5.29±6.80	1.056	0.289
DBP	0.74±6.76	0.37±5.02	0.756	0.455
PR	9.03±7.14	5.77±7.54	1.870	0.070
RPP	1625.00±115.99	1058.26±1030.70	2.315	0.027*
SPO_2	1.51±1.22	0.89±1.53	7.037	0.001*
RPE	2.09±0.82	1.97±0.75	-0.639	0.525

NOTES: *Indicates significant difference, SBP= Systolic Blood Pressure (mmHg); DBP= Diastolic Blood Pressure (mmHg); PR= Pulse rate; SPO_2= oxygen saturation pressure; RPP= Rate Pressure Product (RPP) and RPE=Rate of Perceived Exertion RPE=Rate of Perceived Exertion

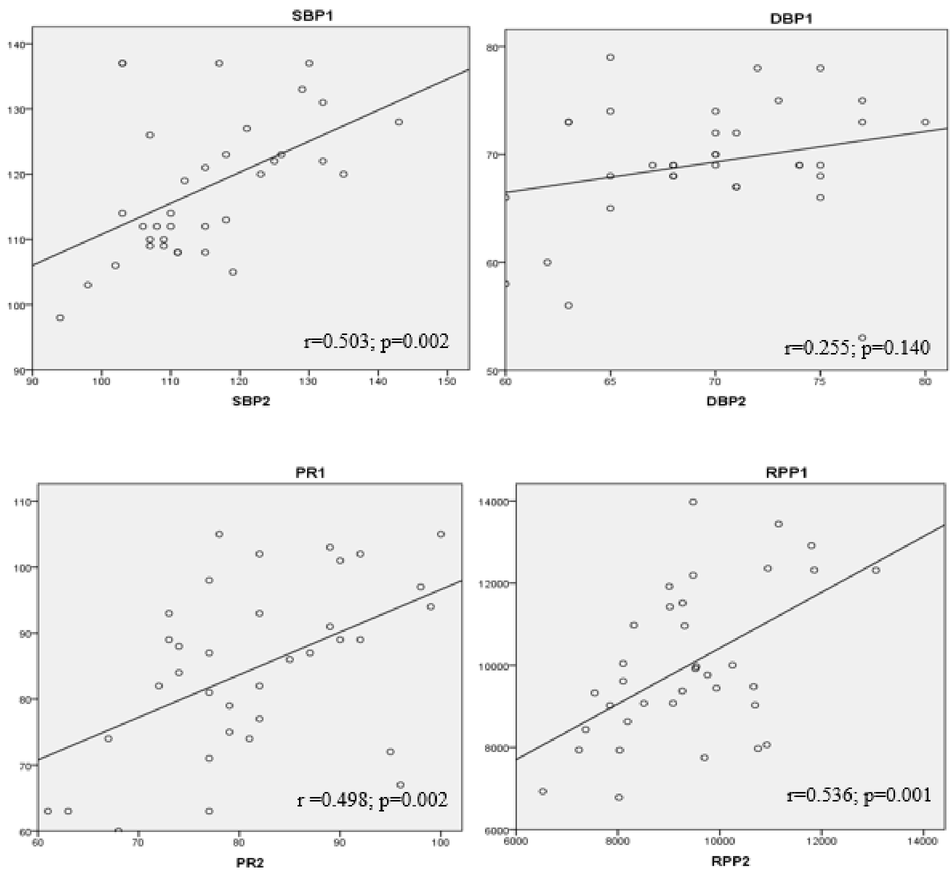

Figure 1: Scattered plots of the relationships outcomes between Six-Minute Treadmill Walk Test and Six-Minute Treadmill Walk-Talk Test

Discussion

This study compared the effects of 6MTWT and 6MTWTT on the selected cardiopulmonary parameters. The participants in this study were apparently healthy young individuals (23 years), with a narrow standard deviation. Thus, eliminating the possible moderating effect of variability in age to cardiovascular response to exercise. It is already widely known the age has considerable influence on cardiovascular response to exercise [33, 34].

From the result of this study, 6MTWT and 6MTWTT led to significant increase in SBP, PR and RPP, respectively. However, DBP response to 6MTWT and 6MTWTT were not significantly different. Similar to the findings in this study, some studies have reported decrease in SBP during 6MTWT [35, 36]. However, some other studies have reported significant increase in SBP [37, 38]. Literature seems to be divided in the direction of cardiovascular response to 6MTWT. This may be due to environmental influence, active muscle mass involved and intensity of the exercise. What is clear to us is that the subjects in this study were young and can be considered to be physically active. Some authors opined that the decrease in DBP after endurance testing could be explained by reactive hyperaemia following large build-up of metabolites in the muscles [39-41]. It is also conceivable that constant stressful lifestyle may reduce the DBP significantly in healthy individuals. From this study, DBP did not significantly change following 6MTWT. Change in DBP during exercise is indicative of unstable form of hypertension related to coronary artery diseases (CADs) other heart-related problems or body position during exercise and type of exercise [42, 43]. Both 6MTWT and 6MTWTT are sub-maximal exercise that may not adequately evoke significant change in DBP.

The comparison of cardiovascular response to 6MTWT and 6MTWTT indicate that both tests were comparable in their blood pressure responses (SBP, DBP and PR). Both test were significantly different in their saturated pressure of oxygen (SPO_2) and RPP responses. As such, 6MTWTT led to significant lower SPO_2 and RPP responses. SPO_2 is a measure of the amount of the oxygen carried in the haemoglobin. Thus, 6MTWTT seems to be a task that evoke a lesser demand on oxygen or led to re-oxygenation of oxygen combusted. Literature show that a higher oxygen demand is dependent on intensity and may be longer than six minutes duration of exercise under many circumstances [15]. In line with ATS [16] guideline on 6MWT, Gupta et al [44] submit that although 6MWT is not intended to document oxygen desaturation during exertion but is often used predict exercise-induced desaturation during a 6MWT. Following, studies that have validated measuring SpO2 during a 6MWT [45, 46], the European Respiratory Society and ATS in an updated statement as recommended using 6MWT as a standard O2 desaturation test with the use of a pulse oximeter for SpO2 and heart rate [16, 18].

At the same time, RPP is a predictor of oxygen consumption of the heart in healthy individuals. 6MTWTT led to a smaller effect on RPP which implies that the pattern of this increase is a trend reported for general exercise. It is adducible that the significant lower oxygen change in pre and post 6MTWTT was due to possible increase in supply of oxygen through the talk in the walk. Talking is a ventilating process states that talk improve relative cardiovascular fitness and exercise capacity [47]. Other studies by Porth [48] and Felker [49] also corroborated the above submission. On the other hand, non-talking during a test can lead to Valsalva manoeuvre. Valsalva manoeuvre is entails vocal fold closure at the end of a deep inspiration followed by physical exertion that is often associated with tasks or activities such as playing wind instrument, lifting a heavy weight etc. [50]. Valsalva manoeuvre during 6MTWT has been reported in previous studies on 6MWT [51]. Baas et al. [52] has associated Valsalva manoeuvre with BP and HR fluctuations which is as a result of blood flow changes and blood vessels constriction and re-expansion. Consequently, the body's blood oxygen need is also altered during exercise or task related activities when more oxygen is required [53]. Valsalva manoeuvre increases the risk of raising carbon dioxide and thus depleting oxygen reserve in the body during a task [48, 54].

The study showed significant gender related differences in SBP and DBP during both 6MTWT and 6MTWTT. The significant gender related difference in cardiovascular responses to 6MTWT was believed to be due to the differences in sympathetic-parasympathetic or adrenal interactions at the cardiac level [55]. This study found significantly higher SBP response to both 6MTWT and 6MTWTT among male subjects, while significantly higher DBP response to the 6MTWTT was also observed among male subjects. The significant gender related difference in cardiovascular response to both 6MTWT and 6MTWTT obtained in this study could be due to the significant differences observed in the anthropometric variables between the male and the female subjects. It has been reported that the substantial anatomical, physiological, and morphological differences that exist between men and women could influence the magnitude of their response to exercise and also influence exercise capacity [56].

Some potential limitations of this study include its sample size. A cohort of larger sample size is needed to strengthen the external validity of the study. Also, this study was conducted among apparently healthy young adults, extrapolation of findings to adults or patients' populations should be treated with caution. Thus, inviting for similar studies in health and disease. Furthermore, this current study was not aimed to evaluate safety of the 6MWT. Future studies should investigate the cardio-respiratory responses of 6MTWTT and as it relates to other populations for clinical purposes.

Conclusion

Both the 6MTWT and the 6MTWTT had comparable influence on the cardiopulmonary parameters in apparently healthy young adults. However, the 6MTWTT evoked a lesser oxygen consumption and myocardial oxygen demand than 6MTWT. This finding may be potentially beneficial for future cardiopulmonary exercise testing using 6MWT.

Conflict of Interests: None declared.

References

1. American Thoracic Society (ATS) Committee on Proficiency Standards for Clinical. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, ATS Statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002; 166: 111–11.
2. Palange P, Ward S, Carlsen K, Casaburi R, Gallagher C, Gosselink R, et al. Recommendations on the use of exercise testing in clinical

practice. European Respiratory Journal. 2007;29(1):185-209.
3. Vilaró J, Resqueti V, Fregonezi G. Clinical assessment of exercise capacity in patients with chronic obstructive pulmonary disease. Brazilian Journal of Physical Therapy. 2008;12(4):249-59.
4. Wise RA, Brown CD. Minimal clinically important differences in the six-minute walk test and the incremental shuttle walking test. COPD: Journal of Chronic Obstructive Pulmonary Disease. 2005;2(1):125-9.
5. Brunelli A, Refai M, Xiumé F, Salati M, Sciarra V, Socci L, et al. Performance at symptom-limited stair-climbing test is associated with increased cardiopulmonary complications, mortality, and costs after major lung resection. The Annals of thoracic surgery. 2008;86(1):240-8.
6. Rachakonda Ramakrishna NB. Relevance of six minute walk test in clinical practice. Journal of Evolution of Research in Pulmonary Medicine. 2016;2(1):6-10.
7. Chiaranda G, Bernardi E, Codecà L, Conconi F, Myers J, Terranova F, et al. Treadmill walking speed and survival prediction in men with cardiovascular disease: a 10-year follow-up study. BMJ open. 2013;3(10):e003446.
8. Mazzeo RS, Tanaka H. Exercise prescription for the elderly. Sports medicine. 2001;31(11):809-18.
9. Adedoyin RA, Adeyanju SA, Balogun MO, Akintomide AO, Adebayo RA, Akinwusi PO, et al. Assessment of exercise capacity in African patients with chronic heart failure using six minutes walk test. International journal of general medicine. 2010;3:109.
10. Laskin, J. J., Bundy, S., Marron, H., Moore, H., Swanson, M., Blair, M., & Humphrey, R. (2007). Using a treadmill for the 6-minute walk test: reliability and validity. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *27*(6), 407-410.
11. Weiglein L, Herrick J, Kirk S, Kirk EP. The 1-Mile Walk Test is a Valid Predictor of VO 2max and is a Reliable Alternative Fitness Test to the 1.5-Mile Run in US Air Force Males. Military Medicine. 2011;176(6).
12. Gaskill, S. E., Walker, A. J., Serfass, R. A., Bouchard, C., Gagnon, J., Rao, D. C., ... & Leon, A. S. (2001). Changes in ventilatory threshold with exercise training in a sedentary population: the HERITAGE Family Study. *International journal of sports medicine*, *22*(08), 586-592.
13. Reed JL, Pipe AL. The talk test: a useful tool for prescribing and monitoring exercise intensity. Current Opinion in Cardiology. 2014;29(5):475-80.
14. Persinger R, Foster C, Gibson M, Fater DC, Porcari JP. Consistency of the talk test for exercise prescription. Medicine & Science in Sports & Exercise. 2004;36(9):1632-6.
15. Foster C, Porcari JP, Anderson J, Paulson M, Smaczny D, Webber H, et al. The talk test as a marker of exercise training intensity. Journal of cardiopulmonary rehabilitation and prevention. 2008;28(1):24-30.
16. Holland, A.E.; Spruit, M.A.; Troosters, T.; Puhan, M.A.; Pepin, V.; Saey, D.; McCormack, M.C.; Carlin, B.W.; Sciurba, F.C.; Pitta, F.; et al. An official European Respiratory Society/American Thoracic Society technical standard: Field walking tests in chronic respiratory disease. Eur. Respir. J. 2014, 44, 1428–1446.
17. Kubo H, Nozoe M, Yamamoto M, Kamo A, Noguchi M, Kanai M, Mase K, Shimada S. Safety and Feasibility of the 6-Minute Walk Test in Patients with Acute Stroke. J Stroke Cerebrovasc Dis. 2018 Jun;27(6):1632-1638. doi: 10.1016/j.jstrokecerebrovasdis.2018.01.017. Epub 2018 Feb 21. PMID: 29429885.
18. Singh, S.J.; Puhan, M.A.; Andrianopoulos, V.; Hernandes, N.A.; Mitchell, K.E.; Hill, C.J.; Lee, A.L.; Camillo, C.A.; Troosters, T.; Spruit, M.A.; et al. An official systematic review of the European Respiratory Society/American Thoracic Society: Measurement properties of field walking tests in chronic respiratory disease. Eur. Respir. J. 2014, 44, 1447–1478.
19. Mary M Roberts 1 , Jin-Gun Cho, Jacqueline S Sandoz, John R Wheatley. Oxygen desaturation and adverse events during 6-min walk testing in patients with COPD. Respirology. 2015 Apr;20(3):419-25. doi: 10.1111/resp.12471. Epub 2015 Jan 20.
20. Gloeckl R, Teschler S, Jarosch I, Christle JW, Hitzl W, Kenn K. Comparison of two-and six-minute walk tests in detecting oxygen desaturation in patients with severe chronic obstructive pulmonary disease—A randomized crossover trial. Chronic respiratory disease. 2016 Aug;13(3):256-63.
21. Burioka N, Imada A, Kiyohiro A, Sugitani F, Fujii T, Hosaka A, Nakamoto S, Amisaki T, Shimizu E. Modified six-minute walk test: number of steps per second. Yonago acta medica. 2014 Mar;57(1):61.
22. Dunn A, Marsden DL, Nugent E, Van Vliet P, Spratt NJ, Attia J, Callister R. Protocol variations and six-minute walk test performance in stroke survivors: a systematic review with meta-analysis. Stroke Res Treat. 2015;2015:484813. doi: 10.1155/2015/484813. Epub 2015 Jan 20. PMID: 25685596; PMCID: PMC4320847.
23. Bohannon RW. Normative reference values for the two-minute walk test derived by meta-analysis. Journal of Physical Therapy Science. 2017. 29(12): 2224-2227.
24. Mantha S, Tripuraneni SL, Roizen MF, Fleisher LA. Proposed modifications in the 6-minute walk test for potential application in patients with mild COVID-19: a step to optimize triage guidelines. Anesthesia and analgesia. 2020 May 26.
25. Butland RJ, Pang JA, Gross ER, Woodcock AA, Geddes DM. Two-, six-, and 12-minute walking tests in respiratory disease. British medical journal (Clinical research ed.). 1982 May 29;284(6329):1607.
26. Xu G. Estimating sample size for a descriptive study in quantitative research. Quirk's Marketing Research Review. 1999;1.
27. Carter III R, Watenpaugh DE, Wasmund WL, Wasmund SL & Smith ML (1999). Muscle pump and central command during recovery from exercise in humans. Journal of Applied Physiology, 87: 1463-1469.
28. Javorka M, Zila I, Balharek T, Javorka K. Heart rate recovery after exercise: relations to heart rate variability and complexity. Brazilian Journal of Medical and Biological Research. 2002 Aug;35(8):991-1000.
29. Dimpka U (2009). Post-exercise heart rate recovery: an index of cardiovascular fitness. J Exerc Physiol Online 12:19-22.
30. Rowe D, Welk G, Heil D, Mahar M, Kemble C, Calabro M, et al. Stride rate recommendations for moderate-intensity walking. Medicine and science in sports and exercise. 2011;43(2):312-8.
31. Medicine ACoS, Medicine ACoS. ACSM's guidelines for exercise testing and prescription. 2006. Baltimore: Williams & Wilins.
32. Gunn SM, Brooks AG, Withers RT, Gore CJ, Owen N, Booth ML, et al. Determining energy expenditure during some household and garden tasks. Medicine and science in sports and exercise. 2002;34(5):895-902.
33. Boettger MK, Schulz S, Berger S, Tancer M, Yeragani VK, Voss A, et al. Influence of age on linear and nonlinear measures of autonomic cardiovascular modulation. Annals of Noninvasive Electrocardiology. 2010;15(2):165-74.
34. Tsang TS, Barnes ME, Gersh BJ, Takemoto Y, Rosales AG, Bailey KR, et al. Prediction of risk for first age-related cardiovascular events in an elderly population: the incremental value of echocardiography. Journal of the American College of Cardiology. 2003;42(7):1199-205.
35. Mbada CE, Jaiyeola OA, Johnson OE, Dada OO, Ogundele AO, Awotidebe TO, Akinwande OA. Reference Values for Six Minute Walk Distance in Apparently Healthy Young Nigerian Adults (Age 18-35 Years). Int J Sport Sci. 2015;5:19-26.
36. Mandini S, Conconi F, Mori E, Myers J, Grazzi G, Mazzoni G. Walking and hypertension: greater reductions in subjects with higher baseline systolic blood pressure following six months of guided walking. PeerJ. 2018 Aug 30;6:e5471.
37. Mbada CE, editor Assessment of exercise capacity and health related quality of life of persons living with hiv/aids and apparently healthy controls. 9th WCPT Africa Region Congress; 2012.
38. Pescatello LS, Fargo AE, Leach CN, Scherzer HH. Short-term effect of dynamic exercise on arterial blood pressure. Circulation. 1991;83(5):1557-61.
39. Kniffeki K, Mense S, Schmidt R. Muscle receptors with fine afferent fibers which may evoke circulatory reflexes. Circulation research. 1981;48(6 Pt 2):I25-31.
40. Stebbins CL, Walser B, Jafarzadeh M. Cardiovascular responses to static and dynamic contraction during comparable workloads in humans. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology. 2002;283(3):R568-R75.
41. Hietanen E. Cardiovascular responses to static exercise. Scandinavian journal of work, environment & health. 1984:397-402.
42. Rosendorff C, Lackland D, Allison M, Aronow W, Black H, Blumenthal R, et al. AHA/ACC/ASH scientific statement. Treatment of hypertension in patients with coronary artery disease: a scientific statement from the American Heart Association, American College of Cardiology, and American Society of Hypertension. J Am Coll Cardiol. 2015;65(1998):e2038.
43. Fletcher GF, Mills WC, Taylor WC. Update on exercise stress testing. American family physician. 2006;74(10).
44. Gupta R, Ruppel GL, Espiritu JR. Exercise-induced oxygen desaturation during the 6-minute walk test. Medical Sciences. 2020 Mar;8(1):8.

45. Ziegler, B.; Rovedder, P.M.; Oliveira, C.L.; e Silva, F.D.; Dalcin, P.D. Repeatability of the 6-minute walk test in adolescents and adults with cystic fibrosis. Respir. Care 2010, 55, 1020–1025.
46. Wilsher, M.; Good, N.; Hopkins, R.; Young, P.; Milne, D.; Gibson, A.; Suppiah, R.; Ly, J.; Doughty, R.; Dalbeth, N. The six-minute walk test using forehead oximetry is reliable in the assessment of scleroderma lung disease. Respirology 2012, 17, 647–652.
47. Cohen-Solal A, Zannad F, Kayanakis J, Gueret P, Aupetit J, Kolsky H. Multicentre study of the determination of peak oxygen uptake and ventilatory threshold during bicycle exercise in chronic heart failure. Comparison of graphical methods, interobserver variability and influence of the exercise protocol. The VO2 French Study Group. European heart journal. 1991;12(10):1055-63.
48. Porth CJ, Bamrah VS, Tristani FE, Smith JJ. The Valsalva maneuver: mechanisms and clinical implications. Heart Lung. 1984;13(5):507-18.
49. Felker GM, Shaw LK, Stough WG, O'connor CM. Anemia in patients with heart failure and preserved systolic function. American heart journal. 2006;151(2):457-62.
50. Metzger BL, Therrien BA. Effect of position on cardiovascular response during the Valsalva maneuver. Nursing research. 1990 Jul 1;39(4):198-202.
51. Marolini DMD, Tanner R, Davey C, Patel SM, Polkey IM. Significance of Patent Foramen Ovale in patients with gold stage 2 chronic obstructive Pulmonary disease COPD. Journal of COPD foundation. 2014;1(2):185-92.
52. Baas, LS, Meissner, JE, and Coughlin, A. (2002) "Cardiovascular care," in Illustrated Manual of Nursing Practice, 3rd Edn, ed. HN Holmes (Springhouse: Lippincott Williams & Wilkins), 168–323.
53. Gauss A, Röhm H-J, Schäuffelen A, Vogel T, Mohl U, Straehle A, et al. Electrocardiographic exercise stress testing for cardiac risk assessment in patients undergoing noncardiac surgery. Anesthesiology: The Journal of the American Society of Anesthesiologists. 2001;94(1):38-46.
54. Ikeda ER, Borg A, Brown D, Malouf J, Showers KM, Li S. The valsalva maneuver revisited: the influence of voluntary breathing on isometric muscle strength. J Strength Cond Res. 2009;23(1):127-32.
55. Demoulin C SG, Thierry B, Jean-Louis C, Didier M, Cédric L, Jean-Michel C, Marc V. Cardiovascular Responses to Static Assessments of Trunk Muscles. 2009; 17(4): 378-389. Journal of Musculoskeletal Pain. 2009;17(4):378-89.
56. Chapman JHaE, P.W.R. Cardiovascular effects of static and dynamic exercise. European Journal of Applied Physiology and Occupational Physiology 1988;58(1-2):152-7.