Physical Therapy and Rehabilitation
ISSN 2055-2386 | Volume 7 | Article 5

HOAJ
Herbert Open Access Journals

Original Research Open Access

Effect of course length on 400 m Walk Test outcomes

Sabrina F. Stocker[1†], Monique A. Samrani[1†], Colton Rapp[1†], Nathan W. Saunders[2] and Megan D. Salvatore[3*]

*Correspondence: salvatmd@mountunion.edu

[†]These authors contributed equally to this work.
[1]Department of Human Performance and Sport Business student, University of Mount Union, USA.
[2]Doctor of Physical Therapy Program, Baylor University, USA.
[3]Department of Physical Therapy faculty, University of Mount Union, USA.

Abstract

Background: The time taken to complete the 400 m Walk Test has been shown to be significantly correlated with mortality rate and overall health. However, the test may be difficult to administer using a standardized course length, and it is known that changing the course length influences the total time to complete the test. GO_{PT}, a mobile phone application, allows for assessment of steady-state cadence, steady-state gait speed, and turn duration during a 400 m Walk Test, but it is presently unknown whether those outcomes are influenced by course length. It was hypothesized that steady-state gait characteristics and average turn duration would be unaffected by course length.

Methods: Twenty-one apparently healthy adults were recruited for this study (eight females: 43 to 79 years, and 13 males: 40 to 85 years). The testing took place on an indoor track with a hard surface made out of synthetic rubber. The subjects completed a 400 m Walk Test three times on a linear course with approximately 10 minutes of rest in between each trial. The three lengths used for the trials were 16, 20, and 25 m. Steady-state cadence, steady-state gait speed, turn duration, and total time were assessed using the GO_{PT} mobile phone application. Repeated measures ANOVA was used to test for a main effect of the three course lengths on 400 m Walk Test outcomes.

Results: Steady-state cadence was shown to be unaffected by course length (132.3 +/- 12.4, 132.9 +/- 13.0, and 132.6 +/- 13.1 steps/min for the 16, 20, and 25 m courses, respectively). Course length did not significantly influence steady-state gait speed either (1.65 +/- 0.26, 1.67 +/- 0.27, and 1.67 +/- 0.26 m/s for the 16, 20, and 25 m courses, respectively). However, turn duration did significantly decrease with increasing course length (4.3 +/- 0.9, 4.2 +/- 0.9, and 4.1 +/- 0.8 s for the 16, 20, and 25 m courses, respectively). As expected, the total time of completion significantly decreased with increasing course length (281.7 +/- 51.6, 272.1 +/- 53.6, and 265.3 +/- 50.5 s for the 16, 20, and 25 m courses, respectively).

Conclusions: Course length was shown to be inversely related to 400 m Walk Test completion time. On the other hand, course lengths between 16 and 25 m appear to have no important effect on steady-state gait cadence, steady-state gait speed, or turn duration. Except for total time, a technician may use the 16, 20, and 25 m course lengths interchangeably when utilizing the GO_{PT} app.

Keywords: Six Minute Walk Test, gait speed, cadence, turn duration

Introduction

The time taken to complete the 400 m Walk Test has been shown to be significantly correlated with future mobility disability/limitation [1], cardiorespiratory fitness [2], ability to walk [3], mortality rate [4], ability to complete daily living tasks [5], and leg strength [6]. Furthermore, gait speed has been suggested to be the 6th vital sign and an appropriate evaluation of general health [7].

While a fairly feasible field assessment, the 400 m Walk Test as traditionally conducted has a few limitations. First, the 400 m Walk Test may be difficult to administer in a standardized manner because of limited physical space. Second, unless there

doi: 10.7243/2055-2386-7-5

is a 400 m straight line path available, the course is likely to include one or more 90° (rectangular course) or 180° (linear course) turns. Introducing turns into a walking test prevents the attainment of a valid stead-state gait speed by simply dividing total distance by total time [8]. Finally, not all individuals are capable of walking 400 m, and there is no outcome of interest for a partially completed test.

We previously validated GO_{PT}, a mobile phone application which assesses steady-state cadence, steady-state gait speed, and turn duration during a 400 m Walk Test performed on a 20 m linear course [9]. In addition to providing those outcomes for a partially completed test, the application accommodates space limitations by allowing the technician to choose between a 16, 20, or 25 m course length. While a potentially nice feature, it is presently unknown to what extent the course length influences test outcomes. The shorter the course length the more repetitions of that length are required to achieve 400 m, and that results in an inverse relationship between course length and number of turns.

It is reasonable to assume that more turns would result in a greater total time to complete the 400 m Walk Test, even if steady-state gait speed was the same (due to more decelerations and accelerations associated with turning). This has two important implications. First, a person may need to be tested using the same course design for repeated tests to be directly comparable. Second, results may only be comparable to normative data when using the same course design that was used to create the normative data. The purpose of the present study was to investigate the effect of course length on the GO_{PT} outcomes for the 400 m Walk Test. It was hypothesized that, while the total time to complete the test would increase as the course length decreases, steady-state gait characteristics and average turn duration would be unaffected by course length.

Methods

Study design

The testing took place on an indoor track with a hard surface made out of synthetic rubber. The subjects completed a 400 m Walk Test three times on a linear course with approximately 10 minutes of rest in between each trial. The three lengths used for the trials were 16, 20, and 25 m. Steady-state cadence, steady-state gait speed, turn duration, and total time were assessed using the GO_{PT} mobile phone application.

Subjects

A review of medical history and a demographic questionnaire were completed to confirm subject eligibility. Twenty-one apparently healthy adults over the age of 40 were recruited for this study using convenience sampling from a university fitness center. Inclusion criteria were age 40 or older and ability to walk unassisted. Subjects with known balance, orthopedic, or neurological impairments were excluded. Eight females (Age Range: 43 to 79 years) and 13 males (Age Range: 40 to 85 years) completed the study. The age distribution of the subjects is shown in **Table 1**. This study was approved by the University of Mount Union Institutional Review Board, and all subjects signed an informed consent prior to participation.

Table 1. Distribution of subjects by age.

Age (years)	Number of Subjects
40-49	7
50-59	2
60-69	6
70-79	4
80-89	2

Protocols and procedures

Figure 1 (adapted from Salvatore et al., 2018 [9]) shows the three course designs for the 400 m Walk Test. The yellow zones (always 2.5 m, regardless of course length) represent areas where the subject decelerates, turns 180 degrees (alternating directions throughout), and accelerates. The green zone represents a presumed steady-state cadence and gait speed, and it is this zone that was altered to create the different course lengths. Subjects completed one trial on each course in random order.

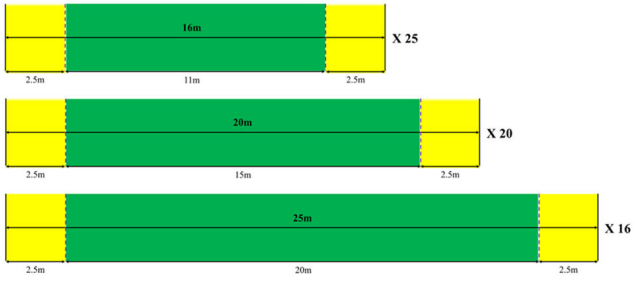

Figure 1. Course set-ups for the 400 m Walk Test. The yellow regions represent areas where the subject accelerates and decelerates. The green regions represent areas where gait speed and cadence are expected to be relatively stable. The numbers to the right of the course schemes represents the number of lengths that would need to be completed to equal 400 m.

The following script was read to the subject prior to each trial to minimize random error: "*This is one of the trials of the 400 m Walk Test. I want you to complete this as fast as possible without running. There are arrows at both ends of the course. One arrow points to the left and the other points to the right. The direction of the arrow indicates which way to turn at each end. This will result in a figure 8 pattern. This trial will be completed on a (insert 16/20/25) m course, so you will walk (insert) 25/20/16 lengths. You do not have to count as I will be keeping track, but you may count as well.*" Subjects performed one practice lap before each trial.

doi: 10.7243/2055-2386-7-5

Pulse rate and oxygen saturation (Santamedical Generation 2 SM-165) were assessed before each trial with the subject standing in their starting position. These measurements were taken to 1) determine that exercise was safe, and 2) determine the potential effect of course length on pulse rate and oxygen saturation. The technician stood in the middle of the course with the subject to their left. The test began with a countdown, "3...2...1...GO" and the subject was instructed to start on the word "GO." As explained in previously published work (Salvatore et al., 2018 [9]), the technician used GO_{PT} to timestamp zone transitions and strides within the steady-state zone. No verbal encouragement was offered, but subjects were notified when they had three lengths remaining. Pulse rate and oxygen saturation were again assessed at the conclusion of the test with the subject still standing at the finish line (most results obtained within 15 s of the completion of the trial). Subjects were then asked to rest for 10 minutes in a seated position before starting the subsequent trial. Once all three trials had been completed the results were casually discussed, which included the consistency of their performance between trials and how their performance compared with age and gender-based norms.

Statistical analyses

All statistical analyses were performed using SPSS version 24. Repeated measures ANOVA was used to test for a main effect of the three course lengths on 400 m Walk Test outcomes (pulse rate, oxygen saturation, steady-state cadence, steady-state gait speed, turn duration, and total time). Additionally, several analyses were conducted specifically comparing the shortest (16 m) to the longest (25 m) course. Coefficient of Variation (CV) was calculated as 100 times the standard deviation of the two measures divided by the mean of the two measures. Systematic bias between the two measures was calculated as the mean difference between the two measures and was tested for statistical significance using a paired t-test. Finally, the 95% Limits of Agreement (LOA) were calculated as +/-1.96 times the standard deviation of the two measures [10].

Results

All subjects completed the 3 trials of the 400 m Walk Test without error or modification. The pre-exercise pulse of each subject increased progressively from the first to the third trial (regardless of testing order). However, the average starting pulse was statistically the same for all 3 course lengths, an indication that the testing order randomization was effective (**Table 2**). Likewise, the average post-exercise pulse was statistically similar for all 3 course lengths, suggesting that the oxygen demand of the activity was the same for all course lengths. Oxygen saturation was normal at rest and at the completion of exercise.

A repeated measures ANOVA was used to test for a main effect of course length on 400 m Walk Test outcomes (**Figures 2A-2D**). Steady-state cadence was shown to be unaffected by course length (132.3 +/- 12.4, 132.9 +/- 13.0, and 132.6 +/- 13.1 steps/min for the 16, 20, and 25 m courses, respectively). Course length did not significantly influence steady-state gait speed either (1.65 +/- 0.26, 1.67 +/- 0.27, and 1.67 +/- 0.26 m/s for the 16, 20, and 25 m courses, respectively). However, turn duration did significantly decrease with increasing course length (4.3 +/- 0.9, 4.2 +/- 0.9, and 4.1 +/- 0.8 s for the 16, 20, and 25 m courses, respectively). As expected, the total time of completion significantly decreased with increasing course length (281.7 +/- 51.6, 272.1 +/- 53.6, and 265.3 +/- 50.5 s for the 16, 20, and 25 m courses, respectively).

It was reasoned that if course length was to have an effect on performance outcomes that it would be most noticeable when comparing the 16 m and 25 m (shortest vs. longest) course outcomes (**Table 3**). CV, a measure of relative agreement, was less than 5% for all outcomes and less than 2% for steady-state gait speed and cadence. Of note, even the CV for total time and turn duration were marginal at 4.2% and 4.3%, respectively. Bias, the absolute difference, was both small and non-significant for steady-state gait speed and cadence. Paired t-tests revealed a significant difference between the 25 m and 16 m course lengths with respect to total time (-16.3 s) and turn duration (-0.2 s).

Table 2. Pre and post-exercise pulse and oxygen saturation.

Outcome	Course Length (m)					
	16		20		25	
	Mean	SD	Mean	SD	Mean	SD
Pre-Exercise Pulse (bpm)	84.1	18.4	87	20.5	87.4	17.9
Post-Exercise Pulse (bpm)	119.2	23.4	120.8	23.6	118.5	26.4
Pre-Exercise SpO2 (%)	97.8	1	97.5	0.7	97.5	0.7
Post-Exercise SpO2 (%)	97	1	97.1	1.2	97	1.5

doi: 10.7243/2055-2386-7-5

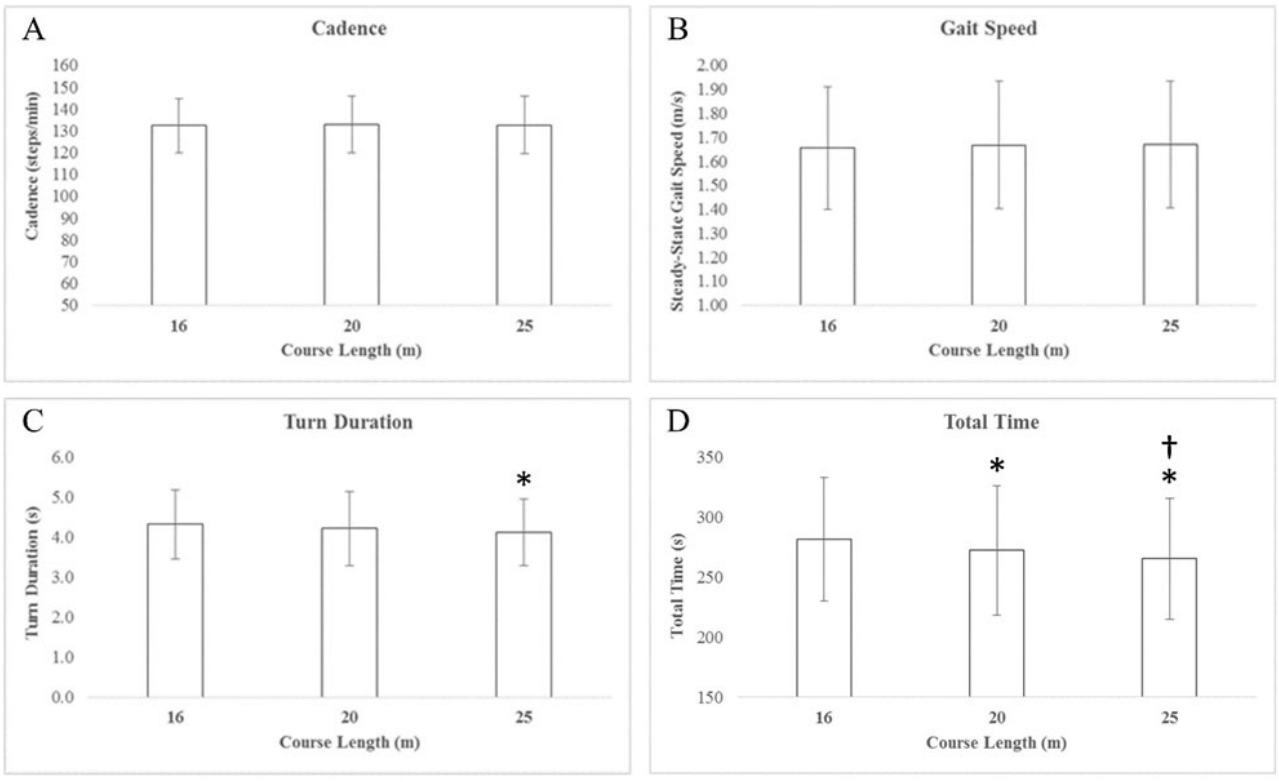

Figure 2. 400 m Walk Test Outcomes by course length. Error bars represent ± one standard deviation from the mean. * = statistically different from the 16 m course. † = statistically different from the 20 m course.

Table 3. Comparison between 400 m Walk Test outcomes completed on 16 and 25 m courses.

Outcome	25 m		16 m		CV (%)	Bias (25 m - 16 m)	Limits of Agreement (95%)	
	Mean	SD	Mean	SD			Lower Limit	Upper Limit
Total Time (s)	265.3	50.5	281.7	51.6	4.2	-16.3	-39.0	6.3
Steady-State Gait Speed (m/s)	1.67	0.26	1.65	0.26	1.73	0.02	-0.04	0.07
Steady-State Cadence (steps/min)	132.6	13.1	132.3	12.4	0.9	0.3	-2.1	2.7
Turn Duration (s)	4.1	0.8	4.3	0.9	4.3	-0.2	-0.6	0.1

Note. CV = Coefficient of Variation. Bias = the absolute difference. SD = one standard deviation from the mean.

Discussion

While the 400 m Walk Test is widely utilized, the course length may vary as a result of physical space limitations. Given that the test outcomes are often compared for the same subject over time, or compared against normative data at a single point in time, it was important to identify the extent to which course length may influence these outcomes. The present study investigated the effect of three linear course lengths on 400 m Walk Test outcomes. Consistent with our hypothesis, steady-state cadence and gait speed were unaffected by course length. The hypothesis of a significant inverse relationship between course length and total time to complete the 400 m Walk Test was also supported. Contrary to our hypothesis, turn duration was marginally but significantly influenced by course length, with turn duration being the greatest on the shortest course with the most turns. The following discussion will provide an interpretation of the meaningfulness of these differences relative to test-retest reproducibility and clinically important differences.

doi: 10.7243/2055-2386-7-5

Total time

It was anticipated that the total time to complete the 400 m Walk Test would increase progressively with the number of turns. The American Thoracic Society reported a similar relationship between course length and Six-Minute Walk Test performance, with shorter courses resulting in less distance walked in six minutes [11]. It has also been shown that subjects completing the Six-Minute Walk Test on a continuous course (circular or oval) walked 28.1 m farther than they did when completing the same test on a linear course [12]. This would equate to a 31 s decrease in 400 m Walk Test time. In the present study, there was only a 16 s difference in the time of completion between the shortest and longest course. To put that value into perspective, it was previously determined in a longitudinal study that a slight improvement in function was associated with a 22 s improvement in 400 m Walk Test performance [13]. While the difference resulting from course design here is less than the reported meaningful difference (16 vs. 22 s), it does represent a source of error that should be considered and possibly controlled when the total time to complete the test is the main outcome.

Steady-State gait outcomes

We suggested that changing the length of the course should not affect steady-state cadence or gait speed, and that is what the present statistical analyses supported. Perhaps more important than a statistical approach is a direct comparison between test-retest performance on the same course vs. test-retest performance on different courses. In a previous study, subjects completed two Six-Minute Walk Tests on a 25 m linear course with a 1-hour rest between tests [8]. The minimum detectable changes in steady-state cadence and gait speed for repeated tests on the same course were calculated to be 7.0 steps/min and 0.12 m/s, respectively. In comparison, the absolute difference in steady-state cadence and gait speed between the 25 and 16 m courses presented here were substantially less (0.3 steps/min and 0.02 m/s, respectively). In further support of the present statistical outcomes, this finding suggests that course length is irrelevant when assessing steady-state cadence and gait speed. This also leads to a recommendation that these steady-state gait characteristics are preferred primary outcomes from the 400 m and Six-Minute Walk Test, as they are less influenced by course design than total time and total distance.

Turn duration

Turn duration was measured as the time taken to decelerate, turn, and accelerate. The total turn distance remained constant for all courses (**Figure 1**), and therefore course length was not expected to influence turn duration. However, turn duration was on average 0.2 seconds longer for the 16 m course, compared with the 25 m course. It is possible that the greater number of turns associated with the 16 m course resulted in slight turning fatigue, but it may also be a result of random error. While statistically significant, it is still less than the previously reported minimum detectable change of 0.3 seconds for repeated tests on the same course [8]. Turn duration is not an outcome generally assessed during the 400 m Walk Test, so we narrowly speculate here based on the present findings that course length has little important impact on turn duration.

Limitations

There were four primary limitations. First, while the results presented here would likely hold for subjects instructed to walk at their usual gait speed, it is important to reiterate that these findings represent subjects walking as fast as they could without running. Second, the repeatability of these findings may be influenced by walking surface and environmental conditions. Third, the pulse oximeter utilized here did not have published validity or reliability data. As such, the pulse rate and oxygen saturation data presented here should be interpreted cautiously. Finally, only apparently healthy subjects participated in this study. Though unlikely, course length may significantly influence 400 m Walk Test outcomes in individuals with various health conditions.

Conclusions

Course length does impact the total time to complete the 400 m Walk Test. Therefore, if the total time is the only outcome of interest it is important to use a consistent course length, or estimate a correction based on the results presented here. On the other hand, course lengths between 16 and 25 m appear to have no important effect on steady-state gait cadence, steady-state gait speed, or turn duration. This has two main implications. First, it may be prudent to focus on those outcomes, rather than the total time, as they are less likely to be influenced by variations in course design. Second, a technician may use the 16, 20, and 25 m course lengths interchangeably when utilizing the GO_{PT} app.

Competing interests

NS has a financial interest in Mobile Assessment Technologies, LLC, the company that created the mobile phone application utilized in the present study. No other authors have competing interests.

Authors' contributions

Authors' contributions	SFS	MAS	CR	NWS	MDS
Research concept and design	✓	✓	✓	✓	✓
Collection and/or assembly of data	✓	✓	✓	✓	--
Data analysis and interpretation	✓	✓	✓	✓	✓
Writing the article	✓	✓	✓	✓	✓
Critical revision of the article	✓	✓	✓	✓	✓
Final approval of article	✓	✓	✓	✓	✓
Statistical analysis	--	--	--	✓	--

Publication history

Editor: Gordon John Alderink, Grand Valley State University, USA.
Received: 10-Apr-2020 Final Revised: 22-May-2020
Accepted: 29-May-2020 Published: 10-Jun-2020

References

1. Deshpande N, Metter EJ, Guralnik J, Bandinelli S and Ferrucci L. **Predicting 3-year incident mobility disability in middle-aged and older adults using physical performance tests**. *Arch Phys Med Rehabil*. 2013; **94**:994-7. | Article | PubMed Abstract | PubMed FullText
2. Simonsick EM, Fan E and Fleg JL. **Estimating cardiorespiratory fitness in well-functioning older adults: treadmill validation of the long distance corridor walk**. *J Am Geriatr Soc*. 2006; **54**:127-32. | Article | PubMed
3. Chang M, Cohen-Mansfield J, Ferrucci L, Leveille S, Volpato S, de Rekeneire N and Guralnik JM. **Incidence of loss of ability to walk 400 meters in a functionally limited older population**. *J Am Geriatr Soc*. 2004; **52**:2094-8. | Article | PubMed
4. Vestergaard S, Patel KV, Bandinelli S, Ferrucci L and Guralnik JM. **Characteristics of 400-meter walk test performance and subsequent mortality in older adults**. *Rejuvenation Res*. 2009; **12**:177-84. | Article | PubMed Abstract | PubMed FullText
5. Gurses HN, Zeren M, Denizoglu Kulli H and Durgut E. **The relationship of sit-to-stand tests with 6-minute walk test in healthy young adults**. *Medicine (Baltimore)*. 2018; **97**:e9489. | Article | PubMed Abstract | PubMed FullText
6. Brach JS, Simonsick EM, Kritchevsky S, Yaffe K and Newman AB. **The association between physical function and lifestyle activity and exercise in the health, aging and body composition study**. *J Am Geriatr Soc*. 2004; **52**:502-9. | Article | PubMed
7. Middleton A, Fritz SL and Lusardi M. **Walking speed: the functional vital sign**. *J Aging Phys Act*. 2015; **23**:314-22. | Article | PubMed Abstract | PubMed FullText
8. Salvatore MD, Colacino AM, Hess ME, Todd SW and Saunders NW. **Concurrent validity and minimum detectable change of Senior Fitness Test components: instrumented vs. manual assessment**. *Phys Ther Rehabil*. 2017; **4**:13. | Article
9. Salvatore MD, Miller KM, Green NL, Gassman BJ, Ghazinour K, Shirima E and Saunders NW. **Validity and feasibility of a cell phone application for the assessment of gait and other functional fitness outcomes**. *Phys Ther Rehabil.* 2018; **5**:19. | Article
10. Bland JM and Altman DG. **Measuring agreement in method comparison studies**. *Stat Methods Med Res*. 1999; **8**:135-60. | Article | PubMed
11. **ATS statement: guidelines for the six-minute walk test**. *Am J Respir Crit Care Med*. 2002; **166**:111-7. | Article | PubMed
12. Andrianopoulos V, Holland AE, Singh SJ, Franssen FM, Pennings HJ, Michels AJ, Smeenk FW, Vogiatzis I, Wouters EF and Spruit MA. **Six-minute walk distance in patients with chronic obstructive pulmonary disease: Which reference equations should we use?** *Chron Respir Dis*. 2015; **12**:111-9. | Article | PubMed
13. Kwon S, Perera S, Pahor M, Katula JA, King AC, Groessl EJ and Studenski SA. **What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P study)**. *J Nutr Health Aging*. 2009; **13**:538-44. | Article | PubMed Abstract | PubMed FullText

Citation:
Stocker SF, Samrani MA, Rapp C, Saunders NW and Salvatore MD. **Effect of course length on 400 m Walk Test outcomes**. *Phys Ther Rehabil*. 2020; **7**:5.
http://dx.doi.org/10.7243/2055-2386-7-5