Six-minute Walk Test versus Three-minute Step Test for Measuring Functional Endurance (Alternative Measures of Functional Endurance)

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Abstract

The purpose of this study was to compare 2 practical measures of functional endurance. Specifically, the Six-minute Walk Test (SMWT) and Three-minute Step Test (TMST) were compared to determine their appropriateness for use as field tests and inclusion in the NIH Toolbox for Assessment of Neurological and Behavioral Function. Individuals between 14 and 85 years performed both the SMWT and TMST in random order. We documented completion rates, criterion performance, heart rate responses, and subjective exertion associated with the 2 tests. All 189 participants completed the SMWT, but only 73.0% completed the TMST. Those completing the TMST were more likely to be male, report better health, and have a younger age and lower body mass index. The SMWT distance was greater for those who did, versus those who did not, complete the TMST. For those completing both tests, the average distance walked in 6 minutes was 595.9 meters; the average cumulative heart beats during the minute after the TMST was 107.4. Distance walked and cumulative heart beats were correlated weakly. Average heart rate and perceived exertion were significantly higher after the TMST than the SMWT. Post test heart rate and perceived exertion for the 2 tests correlated significantly but not strongly. We conclude that the SMWT is more likely to be completed and is usually less stressful physiologically than the TMST and therefore may be a better option for field testing functional endurance and inclusion in the NIH Toolbox.

Keywords

measurement; function; endurance; fitness; exercise test; NIH Toolbox

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INTRODUCTION

Cardiorespiratory endurance is a fundamental component of physical fitness. While maximal oxygen uptake is the gold standard for quantifying cardiorespiratory endurance (12), its determination is physically demanding and requires instrumentation not widely available or easily transportable. Notable alternatives to the measurement of maximal oxygen uptake during maximal treadmill or ergometer testing are submaximal functional tests. Two such functional tests that are practicable in many settings are the Six-minute Walk Test (SMWT) advocated by the American Thoracic Society (1) and the YMCA Three-Minute Step Test (TMST) (9) included in the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription (12). The reliability, validity, and responsiveness of the SMWT are well established (13,16,17,19,20). The reliability and validity of step tests has also been demonstrated (5,14,15,24). Nevertheless, the comparability of individuals' physiological responses to the SMWT and TMST is not clear. The only study we found making such a comparison involved patients with cystic fibrosis. It showed that breathlessness and pulse rate increased more with the TMST than with the SMWT (2). More information than this is required if judicious decisions are to be made regarding the selection of field tests. We, therefore, undertook this study to compare responses of individuals across a wide age-span to the SMWT and TMST and thereby determine their appropriateness for use as field tests and inclusion in the NIH Toolbox for Assessment of Neurological and Behavioral Function (7). Specifically, we intended to compare the completion rates, criterion performance, heart rate responses, and subjective exertion associated with the 2 tests.

METHODS

Experimental Approach to the Problem

This investigation was a component of the validation phase of the NIH Toolbox Assessment for Neurological and Behavioral Function study, which sought to identify a brief but comprehensive battery of portable, low-cost and lay-administerable measures of cognitive, motor, sensory, and emotional health and function appropriate for use in large cohort studies (7). During a single test session, participants performed the SMWT and TMST in random order with at least 60 minutes between the tests. The number of participants completing the tests as well as their performance on the tests were described. The criterion measure for each test (distance walked for SMWT and cumulative 1 minute post-exercise heart rate for TMST) and immediate post-exercise heart rate and perceived exertion were compared.

Participants

The present investigation used motor domain data gathered by trained testers at 2 participating sites (University of Connecticut and Rehabilitation Institute of Chicago). The investigation was approved by the institutional review boards at both sites. After receiving an explanation of the study purpose and procedures participants (or parents) provided written informed consent. Inclusion required that participants were fluent in English, were able to walk without an assistive device, were between 14 and 85 years of age, and had no

cardiopulmonary, vascular, or musculoskeletal problems that precluded their walking, standing from a chair, or climbing steps.

Assessments

Basic demographic (race, age, gender) were obtained by self-report. Height was obtained using a wall-mounted measuring tape. Weight was obtained using calibrated digital scales. Body mass index (BMI) was calculated using the height and weight values. Participants rated their health on an ordinal scale as: excellent (1), very good (2), good (3), fair (4), or poor (5). Thereafter, the SMWT and TMST were performed in random order with a hiatus between the tests of at least an hour. If a participant was unable to complete either test, the time at failure and reason were documented.

The SMWT required that participants traverse a 50 foot course (out and back) walking (not running) as far as possible over 6 minutes. Standing rests were allowed if needed with the request that participants resume walking as soon as possible so they could cover as much ground as able over the 6 minutes. At one-minute intervals the participants were told “you are doing well” or “keep up the good work” and were informed of the time remaining (1). Immediately after completion of the test the participants’ pulse rate was obtained with a pulse oximeter. At completion they rated their perceived exertion using the Borg (6 to 20) perceived exertion scale (16). The distance they walked in 6 minutes was then documented.

In accordance with the YMCA TMST protocol (9) the participants stepped on and off a 30.5 cm (12 inch) step 24 times per minute for 3 minutes. They were aided in this endeavor by an electronic metronome set at 96 beats per minute which they were to match with 96 steps (24 ascent-descent cycles) per minute. At one-minute intervals participants were told “you are doing well” and the time remaining was indicated. Immediately after completion of the test the participants’ pulse rate was obtained with a pulse oximeter. They rated their perceived exertion using the Borg (6 to 20) perceived exertion scale (18). Their cumulative heart beats were determined by auscultation with a stethoscope during the first minute after test completion.

Statistical Analysis

Analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 15.0. Standard descriptive statistics were calculated separately for participants who were able and participants who were unable to complete both tests. Characteristics of participants who completed or did not complete both tests were compared using chi-square (gender, health rating) and independent sample t-tests (age, height, weight, BMI, SMWT distance). For participants completing both tests, criterion measures for the 2 tests (distance walked over 6 minutes in the SMWT and the cumulative pulse over the minute after completing the TMST) were compared using Pearson correlations. The post test pulse rates and perceived exertion for the SMWT and TMST were compared using paired t-tests and Pearson correlations. The significance level for all inferential tests was set at 0.05.

RESULTS

For 189 individuals participating in this component of the NIH Toolbox study, there were no adverse events. All participants completed the SMWT (2 with a brief standing rest). Fifty-one (27.0%) did not complete the TMST; all stopping within 2 minutes of starting. Reasons for stopping the TMST included fatigue, task difficulty, inability to maintain cadence, balance problems, joint or muscle discomfort, and failure to stand up completely on the step. Table 1 summarizes measures obtained from the 138 participants who did and the 51 participants who did not complete both tests. Those who completed the TMST were more likely to be men and healthier by self-report. Participants completing the TMST were significantly younger than those who did not complete the TMST. Of those who failed to complete the TMST, all but 4 were greater than 50 years old. Participants completing the TMST were also significantly taller and leaner (had lower BMIs) than participants not completing the test. Those completing the TMST also walked significantly further on the SMWT.

For participants completing both tests, a descriptive summary of the criterion variables for the 2 tests, as well as the post-test heart rate and relative perceived exertion for the tests, are presented in Table 2. The criterion measures of the 2 tests, distance walked in 6 minutes (SMWT) and cumulative heart rate (TMST), were correlated significantly but weakly (Table 3) with a common variance of only 3.1%. Both post test heart rate and Borg perceived exertion ratings were significantly higher for the TMST than for the SMWT. Though as Figure 1 illustrates, the physiologic demand was greater for the SMWT than for the TMWT for some individuals. The post test heart rates and perceived exertion associated with the SMWT and TMST were significantly correlated (Table 3). However, the post test heart rates were only moderately correlated and the post test perceived exertion ratings were just weakly correlated.

DISCUSSION

In keeping with the aims of the NIH Toolbox study we compared 2 relatively brief, portable, low cost tests of functional endurance with the potential for broad field application. Although the SMWT is well established and highly recommended (1), many settings may lack an unobstructed corridor of adequate length even when the course is shortened to 50 feet as in this study. We therefore chose to compare the SMWT to the TMST which requires far less space.

One factor important to test selection is its completion rate. While some information is available on the completion rate of the SMWT (4,8), we were unable to find information on the completion rates of step tests. In our study the completion rates of SMWT and TMST were considerably different. All participants completed the SMWT, but many individuals, particularly those who were older, of shorter stature, or overweight or obese were unable to complete the TMST. The importance of weight is not surprising as the vertical work associated with negotiating a 12 inch step is influenced by a participant's mass. Specifically, work is the product of force and distance while force is the product of mass and acceleration. Distance in the TMST is fixed at 12 inches. Acceleration in the TMST is essentially fixed by

set cadence. That leaves mass as the chief determinant of work. Use of a lower step and/or cadence would have reduced the work and potentially increased the completion rate but would have also rendered the test less challenging for more able individuals.

The criterion measures used for the SMWT (distance walked) and TMST (cumulative heart beats) are different. Consequently, a comparison of the measures was limited to correlational analysis. The weak correlation found between the variables suggests a lack of convergent validity between them. Thus, they do not appear to be measuring the same underlying construct and cannot be used in lieu of one another.

Heart rate and perceived exertion were both measured at the conclusion of the SMWT and TMST. Higher post test heart rates and Borg perceived exertion ratings show that the TMST was usually more demanding overall than the SMWT. One participant greater than 80 years even surpassed his age predicted maximum heart rate (220-age) by the end of the TMST. Consequently, caution should be exercised if contemplating use of the TMST with people who are older or have cardiopulmonary issues. That said, the finding of a greater demand during the TMST did not apply to all individuals. Some young and fit individuals were not particularly challenged physiologically by the fixed work of the TMST, but they pushed themselves so that they achieved higher heart rates and perceived exertion during the SMWT. So, for example, a young collegiate cross-country runner who had a post SMWT heart rate of 174 had a far smaller post TMST heart rate of 114. Whether or not the SMWT and TMST are comparably demanding, the post test heart rates and perceived exertion associated with them should correlate if convergent validity is to be claimed. While correlations between the variables were significant, neither correlation was of sufficient magnitude to conclude that the SMWT and TMST were capturing the same underlying construct, that is, functional endurance. In spite of both tests requiring continuous performance of a functional activity, we believe the lack of strong correlations relates to fundamental differences in tests themselves. The SMWT involves little work against gravity and performance is determined by the self-selected effort expended. As running is not permitted in the SMWT, even prolonged walking at a maximum speed is far from maximal in fit individuals. The TMST, on the other hand, involves greater work against gravity and a fixed degree of effort. As indicated before, it is therefore more affected by body mass and stature.

This study had several limitations. One is that the procedure of a single walk test, the SMWT, was used. Results may have differed if a shorter duration test (eg, 2 Minute Walk Test) was used. Similarly, only 1 step test, the TMST, was employed. Other steps tests exist (eg, Harvard, Queen's College, Chester) (5,10,14), but they involve different step heights and cadences and thus different work loads. The completion rates for these alternative tests, the demands associated with them, and the correlation of their criterion and common measures with the SMWT is not known. Second, the oxygen consumption associated with the SMWT and TMST was not compared to the oxygen consumption determined using a maximal exercise test. While doing so would address criterion validity, it would add undesirable complexity and cost to the testing. The focus of the NIH Toolbox on simple and affordable tests broadly applicable in the field precludes measuring oxygen consumption, lactate levels, and the like. Third, a convenience sample of apparently healthy adolescents

and adults was used in this report. By intention, participants did not have pathologies resulting in impairments severe enough to preclude independent living in the community. While the presence of pathology, impairments and activity limitations do not necessarily preclude use of the SMWT (3,6,11,16,17,19,20), they can affect step negotiation and therefore completion of the TMST. Indeed, some of our older participants had undisclosed impairments (eg, knee pain) precluded their completion of the TMST. The next stage of the NIH Toolbox project will focus on normative testing and will employ a population-based sample (21). Fourth, we did not divide our study sample into strata based on age, gender, activity levels, or exercise participation. A larger sample so divided would allow for a more focused evaluation and comparison of the SMWT and TMST.

Alternatives to the SMWT and TMST that are also brief, portable and low cost warrant further investigation. One such alternative for quantifying functional endurance is the Two Minute Step Test described by Rikli and Jones (22). The test requires no more space than the TMST and requires only that steps of each lower limb be counted as an individual walks (marches) in place.

In conclusion, though both the SMWT and TMST have been recommended as measures of functional endurance, they are not equally likely to be completed. Providing that adequate floor space is available, the SMWT is more likely to provide performance-based measures for individuals across the age span. Moreover, the SMWT is typically less stressful. These facts may render the SMWT a better choice as a brief, portable, low cost field test for use across a broad age spectrum and settings as envisioned by the NIH Toolbox project.

Practical Applications

Both the SMWT and TMST are practical methods for measuring functional endurance. While the TMST requires less space, it tends to be more physically demanding. Consequently many individuals are unable to complete the TMST. We, therefore, recommend the SMWT over the TMST for characterizing functional endurance and use in the NIH Toolbox project and other field research involving individuals across the age span.

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Figure 1.

Scatterplot illustrating the relationship between heart rates obtained immediately after performance of the Six-minute Walk Test (SMWT) and Three-minute Step Test (TMST)

Table 1

Comparison of participant characteristics and Six- minute Walk Test (SMWT) performance between those who did versus did not complete the Three-minute Step Test (TMST)

Variable	TMST Completed	TMST Not Completed	Comparison Statistic (p)
Gender: female (n)	78/138	42/51	χ^2 (.001)
Health (median)	2	2	χ^2 (.008)
Age: years (mean [SD])	39.9 [19.4]	70.4 [14.2]	t (.001)
Height: meters (mean [SD])	1.70 [.11]	1.64 [.08]	t (.001)
Weight: kg (mean [SD])	72.9 [17.8]	73.1 [12.9]	t (.934)
BMI: kg/m ² (mean [SD])	25.0 [5.0]	27.1 [4.1]	t (.004)
SMWT distance: meters (mean [SD])	595.9 [81.8]	451.0 [71.4]	t (.001)

Table 2

Summary of variables relevant to the Six-minute Walk Test and Three-minute Step Test for participants completing both tests

Variable	Six-minute Walk Test Mean (SD)	Three-minute Step test Mean (SD)	T test (p)
Distance (meters)	595.9 (81.8)	NA	NA
Cumulative beats (n)	NA	107.4 (19.7)	NA
Post test heart rate (beats/min)	127.2 (25.1)	131.8 (20.1)	2.37 (.019)
Borg perceived exertion (6–10)	11.1 (2.9)	12.9 (2.7)	−6.07 (.001)

Table 3

Pearson correlations between performance variables of the Six-minute Walk Test (SMWT) and the Three-minute Step Test (TMST)

Comparison	Pearson (p)
SMWT distance x TMST cumulative beats	-.176 (.039)
SMWT post heart rate x TMST post heart rate	.513 (.001)
SMWT Borg x TMST Borg	.203 (.017)