Predictive ability of the two-minute step test for functional fitness in hypertensive older individuals

The running title: Two-minute step test determine functional fitness.

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Abstract

Background: The 2-Minute Step Test (2MST) is a simple and inexpensive functional test that measures an individual's ability to perform continuous stepping up and down on a step platform for two minutes. This study evaluated the 2MST as a tool for assessing functional fitness in older individuals with hypertension and determined the correlation between the 2MST and physical fitness tests.

Methods: A total of 91 older individuals with hypertension performed physical fitness tests, including the 2MST, 6-minute walk test (6MWT), five-times sit-to-stand test (FTSST), grip strength and leg strength assessments, and Timed Up and Go test (TUG) to collectively assess their physical fitness.

Results: A cutoff score of ≤60 steps in the 2MST had 87.50% sensitivity and 70.59% specificity in predicting functional exercise performance in older individuals with hypertension. Additionally, the number of steps in the 2MST was positively correlated with the distance covered in the 6MWT, isometric grip strength, and isometric leg strength and negatively correlated with the duration of the FTSST and TUG.

Conclusions: A cutoff score of ≤60 steps in the 2MST predicted functional exercise performance in older individuals with hypertension with 87.50% sensitivity and 70.59% specificity and was correlated with other physical fitness tests, suggesting that the 2MST is a useful tool for assessing functional exercise performance.

Keywords
Hypertension, older adults, 2-minute step test, physical fitness tests, cutoff score

Introduction

The world’s aging population is increasing, and the elderly population is projected to constitute approximately 30% of the global population by 2050. Aging is a significant risk factor for chronic diseases and can trigger the onset of geriatric syndromes and illnesses owing to changes in physiological systems. Hypertension is a prevalent condition in older adults, affecting >70% of the population. This condition is associated with increased risks of cardiovascular disease, cognitive decline, and physical disability. Moreover, hypertension can accelerate decline in physical fitness related to sarcopenia, which is the age-related loss of muscle mass and strength.

Functional stress, which is the ability to perform daily tasks safely and independently without exhaustion or discomfort, is a critical component of healthy aging. It enables individuals to maintain their independence and quality of life. The increase in the number of functionally limited individuals with hypertension highlights the need for early detection and interventions to alleviate the burden of hypertension-aging-disability. Therefore, the accurate identification of functional impairment can assist in tailoring interventions to improve fitness, set achievable goals, and educate individuals about the importance of physical fitness for daily tasks and overall health.

Aerobic capacity, a key aspect of physical fitness, is commonly assessed in healthy and diseased populations. The 6-minute walk test (6MWT) is a common method used to evaluate the submaximal functional aerobic capacity in older adults but its administration requires a 30 m hallway and can be time-consuming for routine outpatient consultations. Simple and quick office-based field exercise tests, such as the 2-Minute
Step Test (2MST)\textsuperscript{12,13} may be valuable options as first screening tools before a detailed assessment of functional status and subsequent treatment. The 2MST is highly correlated with the 6 MWT\textsuperscript{14-16} indicating its potential as a measure of functional aerobic capacity. Its correlation with the Timed Up and Go test (TUG)\textsuperscript{16}, five-times sit-to-stand test (FTSST), and leg strength\textsuperscript{15} highlights the close relationship between cardiovascular endurance, muscle strength, and functional mobility.\textsuperscript{17}

Evaluating functional fitness using the available tools can be difficult because of variations in body composition, physical capacity, and perceptions of physical functioning among different populations and research settings.\textsuperscript{12,18} The assessment of functional capacity is particularly critical in estimating the functional consequences and disability among patients with hypertension. Owing to the limitations of studies evaluating the tests to assess the functional capacity evaluation test specifically in individuals with hypertension, the present study investigated the predictive ability of the 2MST to identify functional impairment in hypertensive older adults and its correlation with other functional measures, including the 6MWT, FTSST, TUG, grip strength, and leg strength.

**Materials and Methods**

**Participants**

This cross-sectional study included on 91 older individuals with hypertension in Phayao Province, Thailand, who were undergoing routine antihypertensive medication therapy. We identified and recruited eligible participants during their routine
appointments at a primary healthcare center, and informed consent was obtained from all individuals before their participation. The study included participants who met specific criteria, including a diagnosis of hypertension, age >60 years, body mass index (BMI) <30 kg/m², and absence of any physical limitations that would impact their ability to walk or perform stepping movements. Participants with respiratory diseases or clinical conditions such as cognitive impairment, uncontrolled hypertension, unstable angina, and infectious diseases were excluded from the study. This study was approved by the Human Research Ethics Committee of the University of Phayao (No.1.2/056/65). The minimum estimated sample size required was 62 participants for a diagnostic study, with a 90% power, 0.05 P-value, and 80% sensitivity based on a previous study.19)

Procedure

The experimental protocol was divided into two visits. On the first visit, we assessed the participants’ general information using a self-reported questionnaire, and collected sociodemographic (age and sex), anthropometric (height and weight to compute body mass index), and general clinical data (duration of hypertension, medical conditions, and physical activity) using the Physical Activity Questionnaire for Elderly Japanese20). Subsequently, a physical fitness test, handgrip strength measurement, leg strength measurement, TUG, FTSST, and 2MST were performed for each participant with a 30-min rest between tests. During the second visit on the following week, the participants performed the 6MWT.

Hand grip strength was measured with a Jamar Hand Dynamometer. After a practice test, participants were instructed to stand with their arms extended, and squeeze the dynamometer twice as hard as possible for 3 seconds with the dominant arm. The
participants were allowed to rest between measurements. Three trials were performed and the average values were recorded, regardless of hand dominance.\textsuperscript{21)}

In the 6MWT protocol, the participants were asked to sit on a chair for 5 min to record their vital signs, dyspnea, and leg fatigue. They were then instructed to walk as fast as possible for 6 min without running and to continue at the same pace without stopping. The distance covered by each participant was recorded.\textsuperscript{9)} One minute after the test, the participants’ vital signs, dyspnea, and leg fatigue were recorded.

In the 2MST protocol, the participants were instructed to stand against a wall, and marks were made on the wall at the level of the anterior superior iliac crest and patella. Half of the distance between the two marks was marked using a piece of tape. The participants were asked to lift their knees to the height marked by the tape while treading in place as quickly as possible for 2 min. The number of steps taken on the right side to reach the criterion height was counted for each participant and recorded.\textsuperscript{22)}

In the FTSST protocol, the participants were asked to stand up and sit down as fast as possible five times with their arms folded across their chests. Two trials were conducted with a rest period of 1 min between trials. The average time of two trials was recorded as the test result.\textsuperscript{23)}

In the leg strength protocol, the participants were instructed to stand with their feet shoulder-width apart on the dynamometer base and hold onto a bar with their hands. The chain was adjusted such that the knees were flexed at 110°. The participants were then asked to pull as hard as possible on the chain while trying to straighten their legs and
keep their upper limbs straight without flexing their backs. Each subject performed two trials and the maximum performance was recorded.\textsuperscript{24)

The TUG protocol involved measuring the time required for the participants to rise from a chair with an approximate seat height of 46 cm, walk 3 m to a line on the floor, turn, walk back to the chair, and sit down again. The participants had one practice walk-through before being timed for three attempts with one-minute rest intervals and verbal encouragement. The shortest time was recorded for analysis.\textsuperscript{25, 26, 27)

\textit{Statistical analysis}

We computed the descriptive statistics, including means, standard deviations, and percentages, for the participant characteristics and study outcomes. Receiver operating characteristic (ROC) curve analysis was used to identify the accuracy of the 2MST in differentiating older adults with hypertension with and without functional impairment. We used a 6MWT cut-off of 320 m,\textsuperscript{14} which is associated with low exercise endurance in older adults. Based on these cutoffs, we identified the threshold for the 2MST to identify functional impairments. The area under the curve (AUC), best cutoff point, sensitivity, and specificity were identified. We compared older adults with hypertension below or above the cut-off point in the 2MST using the independent samples \textit{t}-test or Mann–Whitney U test, as appropriate. Physiological responses (blood pressure [BP], heart rate [HR], and oxygen saturation [O\textsubscript{2} sat]) and differences between the 2MST and 6MWT were evaluated using dependent samples \textit{t}-test or signed-rank test. Leg fatigue and dyspnea scores were measured using the signed-rank test. Pearson correlation coefficient was used to verify the correlation between the 2MST and 6MWT, handgrip
strength, leg strength, TUG, FTSST, and 6MWT. Data were analyzed using Stata 14.0 (StataCorp LLC, College Station, TX, USA), with a significance level of 5%.

**Results**

This study enrolled 91 older individuals with hypertension, with a mean age of $70.29 \pm 4.95$ years and an almost equal distribution of men (49.45%) and women (50.55%). The participants had a mean body weight of $58.59 \pm 0.71$ kg, a mean height of $160.94 \pm 12.02$ cm, and a mean BMI of $22.59 \pm 3.85$ kg/m$^2$. The average duration of hypertension since diagnosis was $8.87 \pm 3.54$ years, and most participants had comorbidities including diabetes (48.4%), dyslipidemia (38.46%), and orthopedic problems (9.89%). A small proportion of participants had cardiovascular disease (8.79%). The participants' level of physical activity was $8.77 \pm 5.23$ metabolic equivalents (METs) hr/wk, indicating moderate physical activity levels. Table 1 summarizes the participants’ characteristics.

As shown in Table 2, the 2MST had an optimal cut-off score of $\leq 60$ steps, with a sensitivity of 87.50% and a specificity of 70.59%. The AUC was 0.91 (95%CI: 0.84–0.97).

Compared to the group of participants that completed the 2MST with $\geq 60$ steps, those that completed the test with $<60$ steps had significantly lower handgrip strength, leg strength, TUG, FTSST, and 6MWT distances ($P<0.001$), as well as significantly lower systolic blood pressure (SBP) and diastolic blood pressure (DBP) ($P<0.001$ and $P=0.036$, respectively). The HR, HR as a percentage of the predicted maximum, $O_2$ sat, and dyspnea grade did not differ significantly between the groups (Table 3).
Table 4 shows the results of the comparison of physiological responses, dyspnea, and leg fatigue between the 2MST and 6MWT in older adults with hypertension. The HR in beats per minute (bpm) during the 2MST was significantly increased when compared to the 6MWT (86.91 ± 14.10 bpm vs. 83.02 ± 15.36 bpm, P<0.001), as well as the HR in percentage of predicted maximum HR (57.10 ± 2.56% vs. 54.69 ± 2.20%, P<0.001). SBP during the 2MST was also significantly higher than that during the 6MWT (154.33 ± 21.61 mmHg vs. 144.42 ± 18.71 mmHg, P<0.001). The DBP and O₂ sat levels did not differ significantly between the two tests (P=0.452 and P=0.050, respectively).

Regarding the subjective responses, the dyspnea and leg fatigue levels were significantly higher during the 2MST than those during the 6MWT (11.48 ± 2.73 vs. 10.54 ± 2.92, P=0.004 and 2.12 ± 1.67 vs. 1.45 ± 1.33, P<0.001, respectively). These results suggested that the 2MST may be more challenging in terms of cardiovascular and subjective responses than the 6MWT in older adults with hypertension (Table 4).

Table 5 presents the associations between the number of steps taken in the 2MST and various demographic and physical factors in older adults with hypertension. The results demonstrated a negative correlation between 2MST and age (r=-0.294, P=0.005), a positive correlation with height (r=0.332, P=0.001), and no significant correlation with body weight (r=0.144, P=0.172).

The results of several physical fitness tests in the same population, including the 6MWT distance, grip strength, leg strength, TUG duration, and FTSST duration showed that the number of steps in the 2MST was positively associated with the distance of the 6MWT (r=0.747, p<0.0001), isometric grip strength (r=0.567, P<0.0001), and isometric leg strength (r=0.472, P<0.0001). In contrast, the number of steps in the 2MST was
negatively associated with FTSST ($r=-0.491$, $P<0.0001$) and TUG ($r=-0.632$, $P<0.0001$) duration (Table 5).

**Discussion**

This study investigated the usefulness of the 2MST for assessing functional fitness in older individuals with hypertension and its correlation with other physical fitness tests. The results showed that the 2MST was effective in identifying functional limitations in this population, with a cutoff score of ≤60 steps indicating lower functional ability and physiological responses. Furthermore, the 2MST was more challenging than the 6MWT and was significantly correlated with demographic factors, handgrip strength, leg strength, TUG, and FTSST.

The 2MST was originally developed as a component of the Senior Fitness Test (SFT) by Rikli and Jones in 1999. The SFT is a comprehensive set of tests designed to evaluate physical fitness in older adults, with the 2MST specifically assessing aerobic endurance and lower body strength. Various studies have demonstrated the 2MST's usefulness in assessing functional capacity and found it to be a reliable and valid measure of physical fitness in older adults. Our study found that a cutoff of 60 steps in the 2MST accurately distinguished older individuals with hypertension with or without functional impairment. This result is consistent with those of a previous study that identified the 2MST as the best predictor of functional capacity in hypertensive individuals, with an average of 69 repetitions and an AUC of 0.7. Individuals who performed <60 repetitions in the 2MST exhibited longer times on the TUG and FTSST, indicating potential mobility and balance issues. These findings, along with lower handgrip and leg strength and higher leg fatigue, may suggest a decrease in overall physical fitness,
including reduced endurance and physical capacity. Therefore, <60 repetitions in the 2MST may serve as a useful marker for identifying functional impairment, indicating the need for interventions to improve physical fitness and functional capacity in individuals with hypertension.

The 2MST is a good measure of cardiorespiratory fitness when other submaximal fitness tests cannot be undertaken, such as the 6MWT, and involves lifting the knees to the mid-level between the patella and iliac crest; thus, it requires more intensity and a longer duration of single-leg support than the standard step. In our study of older adults with hypertension, the 2MST elicited a higher HR, SBP, dyspnea, and leg fatigue compared to the 6MWT. The biomechanics of the 2MST require greater lower-body strength, physical skills, and longer periods of single-leg support, which explained the higher physiological demand and RPE compared with the 6MWT. The RPE was significantly higher in the 2MST group than in the 6 MWT group.

The 2MST and 6MWT exhibit a strong correlation, indicating that both tests are reliable measures of cardiorespiratory fitness. Our results are consistent with those of previous studies, which suggests that the 2MST can complement the 6MWT in various populations, including those with coronary artery disease, hypertension in older adults, symptomatic peripheral artery disease, and systolic heart failure. Additionally, other studies have reported an association between these tests in both healthy older individuals and those with pathologies suggesting that the 2MST can assess the integrated global response to exercise of all human body systems. We observed correlations between age, height, weight, and 2MST, suggesting that these factors may impact test performance and should be considered.
Our study results revealed significant inverse correlations between the 2MST and two functional mobility tests, the FTSST and TUG, which assess the ability to complete tasks such as standing up from a chair or standing on one leg. These results reinforce the strong relationship between cardiovascular endurance and functional mobility. A negative correlation implies that poor cardiovascular endurance may lead to poor functional mobility, and vice versa. These results are consistent with those of previous studies reporting a correlation between functional capacity and functional mobility in older adults with hypertension\textsuperscript{16,17}. Moreover, we observed a significant positive correlation between 2MST, handgrip strength, and leg strength. This supports prior research indicating a relationship between the 2MST and quadriceps strength in patients with systolic heart failure.\textsuperscript{35} In older adults, maintaining strong handgrip and leg muscles is crucial not only for completing daily tasks but also for reducing the risks of mortality, functional decline, disability, and falls.\textsuperscript{36-38} Moreover, poor aerobic endurance and leg strength contribute significantly to slow gait velocity in community-dwelling patients with stroke.\textsuperscript{39}

In conclusion, the 2MST is a useful tool for assessing functional capacity in older individuals with hypertension, with a cut-off of 60 steps accurately identifying functional impairment. The 2MST was positively correlated with the 6MWT, grip strength, and leg strength and negatively associated with the FTSST and TUG duration.

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