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Predictive Ability of the Three-Time Stand and Walk Test to Determine Frailty and its Associations with Fear of Falling and Cognitive Function in Community-Dwelling Older Adults

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Background: The three-time stand and walk test (TTSW) is a complex functional task used to determine muscle strength, balance, and fall risk in older individuals. This study hypothesized that TTSW is an appropriate tool for detecting frailty related to falls and the cognition of community-dwelling older adults. The study objectives were to assess the ability of the TTSW to determine frailty by exploring the optimal cut-off score, and to investigate the correlations between TTSW outcomes with falls and cognitive function in 118 community-dwelling older adults. **Methods:** The demographic data of eligible participants were assessed, and the participants were diagnosed with frailty based on the frailty phenotype. The participants then completed the Frail Non-Disabled (FiND) questionnaire, TTSW, Falls Efficacy Scale-International (FES-I), and Mini-Mental State Examination Thai version (MMSE-Thai 2002). **Results:** The results demonstrated that the TTSW outcomes were significantly correlated with FiND, FES-I, and MMSE-Thai 2002 (rho=0.705, r=0.482, and r=−0.510, respectively; p<0.001). Moreover, a TTSW time of 18 s or longer had a good ability to indicate frailty in older individuals (sensitivity=88.41%, specificity=83.67%, area under the receiver operating characteristic curve [AUC]=0.926). **Conclusions:** Implementing this tool in a community setting may be useful for the initial screening, monitoring, and referral of data by healthcare professionals. A cut-off TTSW time of 18 seconds or longer was the optimal criterion to indicate frailty in community-dwelling older people.

Key Words: Aging, Postural balance, Falls, Cognition, Muscle weakness

INTRODUCTION

Increased age is associated with gradual molecular and cellular damage, impaired bodily functions; decreased muscle mass and strength; reduced bone density; multimorbidity; and hearing, vision, and recognition decline or loss, leading to the development of frailty in older individuals.[1] Frailty is an age-associated biological syndrome that precedes disability and negatively affects multiple functional domains, including gait and mobility, balance, muscle strength, aerobic endurance, and motor processing.[2,3] Such conditions in older adults are often associated with an increased risk of falls, hospitalization, and morbidity, subsequently causing negative effects on their ability to conduct daily activities.[4,5] Moreover, functional limitations and frailty are associated with low cognitive performance.[6,7] Although methods exist for preventing frailty, such as exercise or the development of guidelines on primary prevention,[8,9] early risk screening can enhance the effectiveness of these prevention methods. Therefore, screening and monitoring tools for early detection and periodic follow-up are important for effective disease prevention and treatment.

The most common methods of diagnosing frailty are based on phenotypic and deficit accumulation approaches.[10] The frailty

phenotype approach, or Fried's frailty phenotype, classifies an individual as frail if they present three or more of the five frailty items—slow walking speed, impaired grip strength, declining physical activity levels, exhaustion, and unintended weight loss. The presence of one or two of the five items is defined as pre-frailty, while individuals with none of these items are considered healthy or robust.[11] In addition, many screening tools are available to assess the risk of frailty. However, most of these are in the form of questionnaires[11,13] for qualitative assessment, including the Frail Non-Disabled (FiND) questionnaire, Clinical Frailty Scale, and simple frailty questionnaire (FRAIL).[14,15] These are commonly applied through interviews and observations; thus, the outcomes are subjective and highly dependent on the experience of the assessors.[16] In addition, decisions about clinically relevant changes can be difficult to make when the time intervals between visits are long or when assessors change.[17] By contrast, functional assessments are objective and roughly indicate the functioning levels of individuals; moreover, the outcomes may suggest further assessments for systems with disorders.[18-20] Therefore, functional assessments, as assessed by Fried's frailty phenotype, may be more useful and are commonly used as screening and monitoring tools over time.[20] However, this standard method of assessment is based on a combination of multiple tests, which can be time-consuming and may be inconvenient for use in communities with large populations. Therefore, the exploration of a simple functional test reflecting the overall functional ability that contributes to frailty is crucial and may promote the effectiveness of prevention and management strategies for older individuals.

Frailty is often determined by important physical abilities, including strength, gait ability, and balance. Therefore, we previously developed a three-time stand and walk test (TTSW) to assess muscle strength, gait, and balance ability in community-dwelling older individuals.[21] The test requires individuals to perform sit-to-stand movements on a chair three times, walk around a traffic cone placed 3 m from the front edge of the chair, and return to sit down on the chair at the fastest safe speed.[21] The test has excellent reliability (intraclass correlation coefficient [ICC] = 0.991; 95% confidence interval [CI], 0.984–0.996) and good correlation with standard tests, including the five-time sit-to-stand (FTSST) ($r = 0.648$, $p < 0.001$) and Timed Up and Go test (TUGT) ($r = 0.673$, $p < 0.100$).[22] Moreover, the outcome of TTSW was used to indicate the risk of falling in older individuals.[21] Therefore, the present study hypothesized that the TTSW is an appropriate method for detecting frailty related to falls and cognition in community-dwelling older adults. The objectives of this study were to assess the predictive validity (primary objective) by exploring the optimal cut-off score of the TTSW and to determine frailty and concurrent validity (secondary objective) by investigating the correlation between TTSW outcomes with falls and cognitive function in community-dwelling older adults.

MATERIALS AND METHODS

The cross-sectional study involved 118 Thai community-dwelling older people aged 60 years and above and a body mass index (BMI) between 18.5 and 29.9 kg/m^2. For eligibility, the participants were required to be able to stand up independently, walk with or without a walking device, and understand the commands used in this study. The exclusion criteria were any signs and symptoms that might affect study participation, such as uncontrolled or unstable hypertension, heart disease, and pain in the musculoskeletal system with a visual analog scale score of more than 5 out of 10. The research protocols were approved by the Ethics Committee of the Institute for Human Research (No. 2/064/61), University of Phayao, Thailand. The participants provided written informed consent before their participation in the study.

This study complied the ethical guidelines for authorship and publishing in the *Annals of Geriatric Medicine and Research*.[23]

Procedures

The eligible participants were assessed to collect demographic data, including age, sex, height, weight, vital signs, underlying diseases, requirement for a walking device, and fall history over the past 6 months. The participants were diagnosed with frailty based on the frailty phenotype criteria.[11] The participants were then assessed for the study outcomes (Fig. 1), including the following.

FiND questionnaire

This study used the FiND questionnaire as a standard screening tool to determine frailty. The FiND questionnaire consists of five questions. Two questions are specifically aimed at identifying individuals with mobility disabilities (an early stage of the disabling process). For the present analysis, we defined the presence of mobility disability as "a lot of difficulties" or "inability" to perform at least one of these two terms. The remaining three questions are aimed at assessing the following signs, symptoms, or conditions that are commonly considered components of frailty syndrome: weight loss, exhaustion, and sedentary behavior. In the present analyses, we considered participants meeting one or more frailty criteria in the absence of mobility disability to be "frail." Notably, the weight loss and exhaustion criteria included in the FiND questionnaire were the same as those originally proposed for the frailty phenotype. Participants reporting no mobility disability and no frailty criteria were considered robust in the FiND questionnaire.[11,14,24]

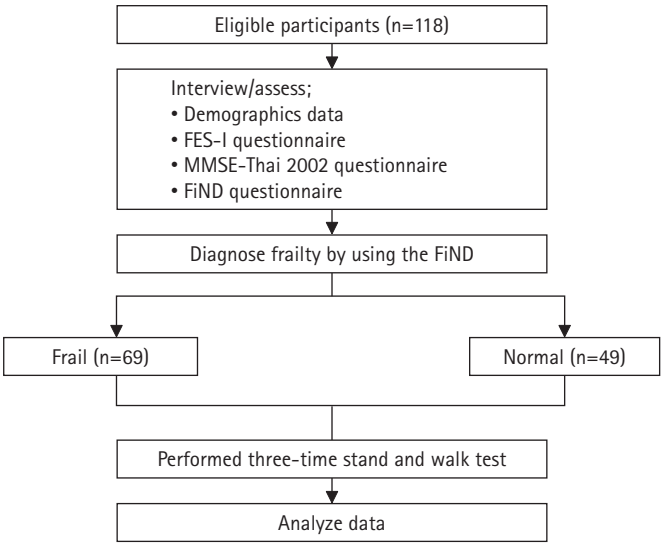

Fig. 1. Participation flowchart. FES-I, Falls Efficacy Scale-International; MMSE-Thai 2002, Mini-Mental State Examination Thai version 2002; FiND, Frail Non-Disabled.

TTSW

The participants were required to sit on a standard armless chair with their backs upright, a hip flexion of 90°, feet placed flat on the floor approximately 10 cm behind the knees, and arms at their sides. The participants were then instructed to stand with their hips and knees in full extension and then sit down three times, walk around a traffic cone placed 3 m from the front edge of the chair, and return to sit down on the chair at the fastest safe speed.[21] The average time to complete the three trials was used in the data analyses. During the tests, the participants wore a lightweight safety belt around their waist, with a physiotherapist walking alongside them to ensure the safety of the participants and improve the accuracy of the outcomes.

Fear of falls (FOF) assessment

We tested the participants' FOF using a yes/no question evaluation scale combined with the Falls Efficacy Scale-International (FES-I).[25] The FES-I was developed and validated for the intensive assessment of FOF, self-efficacy, and balance confidence. The questionnaire comprises 16 items, including basic and instrumental activities of daily living. Each activity was scored from 1 (not at all concerned) to 4 (very concerned), resulting in a total score ranging from 16 (absence of concern) to 64 (extreme concern).

Mini-Mental State Examination (MMSE) Thai 2002

This study used the Thai version of the MMSE (MMSE-Thai 2002). The test was developed and validated using the original English version.[26] The MMSE-Thai 2002 is a screening instrument commonly used as a global cognitive test and is the current clinical mainstay cognitive screening instrument in Thailand. The test was scored in terms of the number of correctly completed items, in which low scores indicated poor performance and significant cognitive impairment. This 30-item questionnaire (the maximum score is 30) is used extensively in clinical, research, and community settings to measure and screen for cognitive impairment.[27,28]

Statistical Analysis

We used descriptive statistics to explain the personal data and study findings. An independent sample t-test was used to indicate the discriminative ability of TTSW for participants with and without frailty. Spearman rank correlation coefficient (rho) and Pearson correlation coefficient (r) were used to quantify the levels of correlation between the outcomes of TTSW and those of FiND, FES-I, and MMSE-Thai 2002 scores. Receiver operating characteristic (ROC) curves were further utilized to verify the diagnostic accuracy of the TTSW to indicate frailty by exploring the optimal cut-off score, sensitivity, specificity, and area under the ROC curve (AUC). The level of statistical significance was set at $p < 0.05$.

RESULTS

The current study recruited a total of 118 eligible participants with an average age of 73 years and a normal BMI. The average age and BMIs differed significantly between frail and normal participants ($p < 0.001$ and $p < 0.05$, respectively) (Table 1). Although most participants could walk independently without assistive walking devices (77.97%), all those who used walking devices (26 participants) were frail. The results showed significant differences in the TTSW, FES-I, and MMSE-Thai 2002 scores between participants with and without frailty ($p < 0.001$) (Table 1).

Fig. 2 is a scatterplot showing the levels of correlation between the outcomes of the TTSW and the FiND, FES-I, and MMSE-Thai 2002. The results revealed that the TTSW scores were significantly correlated with FiND, FES-I, and MMSE-Thai 2002 (rho = 0.705, r = 0.482, and r = –0.510, respectively; $p < 0.001$) (Fig. 2).

Table 2 shows the optimal cut-off scores for the TTSW. The results indicated that a TTSW time ≥ 18 seconds had a good ability to indicate frailty in older individuals, with the best sensitivity, specificity, and accuracy.

DISCUSSION

The results of the present study verified the TTSW as an alternative optimal screening tool to detect frailty in community-dwelling

Table 1. Demographics of the participants

Variable	Total (n = 118)	frailty (n = 69)	normal (n = 49)	p-value
Age (y)	73.03 ± 7.69	74.81 ± 8.68	70.53 ± 5.00	< 0.001
Sex				
Male	39 (33.05)	21 (30.43)	18 (36.73)	
Female	79 (66.95)	48 (69.57)	31 (63.27)	
BMI (kg/m^2)	22.13 ± 3.94	21.48 ± 4.27	23.08 ± 3.22	0.028
Assistive walking devices				
None	92 (77.97)	43 (62.32)	49 (100)	
Cane	24 (20.34)	24 (34.78)	0 (0)	
Walker	2 (1.69)	2 (2.70)	0 (0)	
FES-I score	35.95 ± 13.73	40.87 ± 13.50	29.02 ± 10.84	< 0.001
MMSE-Thai 2002 score	24.53 ± 3.71	23.15 ± 3.68	26.55 ± 2.70	< 0.001
FiND score				
0	49 (41.53)	-	-	
1	49 (41.53)	-	-	
2	17 (14.40)	-	-	
3	3 (2.54)	-	-	

Values are presented as mean±standard deviation or number (%).
BMI, body mass index; FES-I, Falls Efficacy Scale-International; MMSE-Thai 2002, Mini-Mental State Examination Thai version 2002; FiND, Frail Non-Disabled; TTSW, three-time stand and walk test.

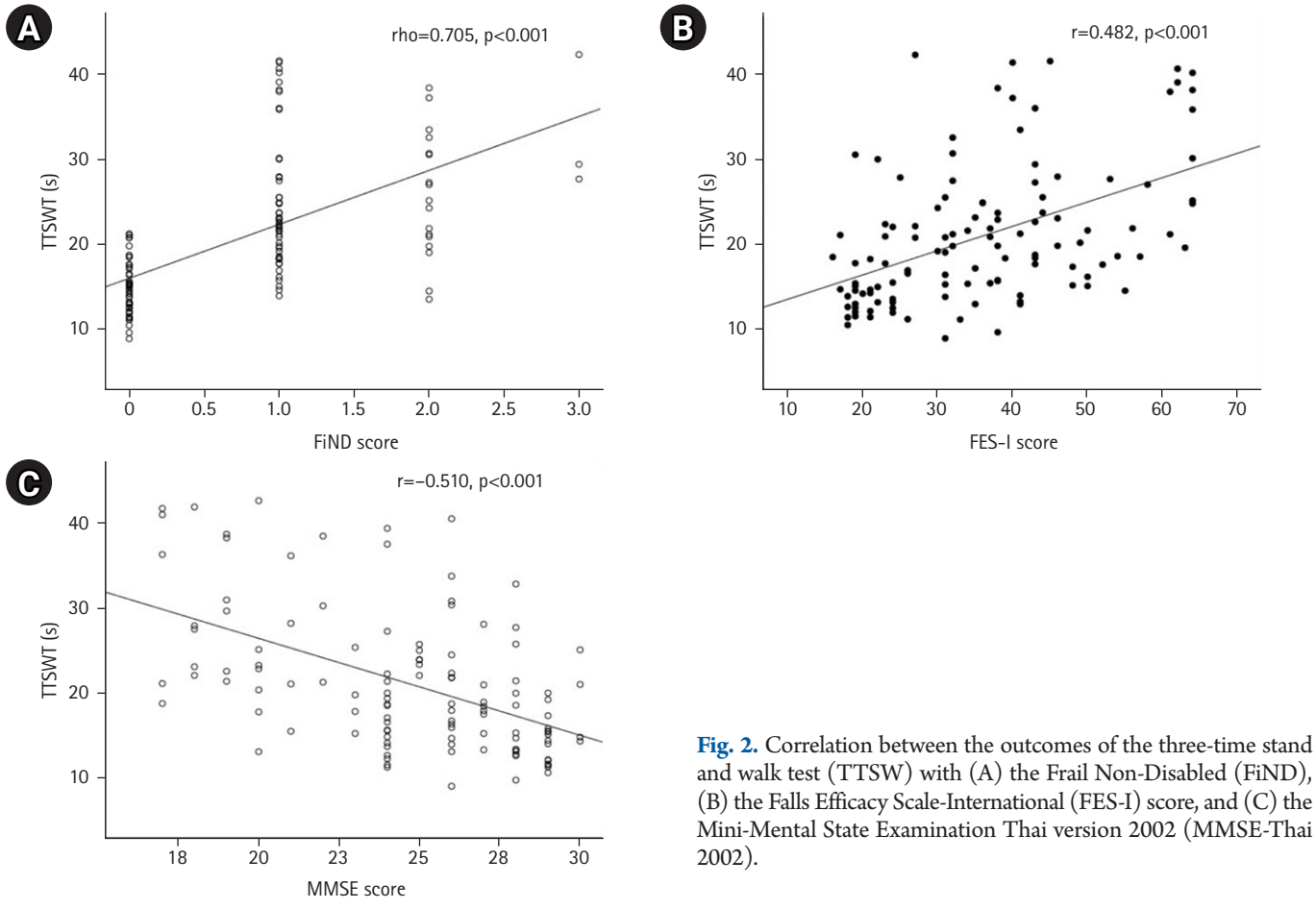

Fig. 2. Correlation between the outcomes of the three-time stand and walk test (TTSW) with (A) the Frail Non-Disabled (FiND), (B) the Falls Efficacy Scale-International (FES-I) score, and (C) the Mini-Mental State Examination Thai version 2002 (MMSE-Thai 2002).

Table 2. Cut-off score of the TTSW to determine frailty in older adults

Cut-off (s)	Sensitivity (%)	Specificity (%)	Correctly classified (%)	AUC (95% CI)
16	91.30	71.43	83.05	0.926 (0.883–0.970)
17	88.41	75.51	83.05	
18	88.41	83.67	86.44	
19	79.71	87.76	83.90	
20	72.46	91.84	80.57	

TTSW, three-time stand and walk test; AUC, area under ROC curve; CI, confidence interval.

older adults. The key finding of the current study was that the TTSW was significantly correlated with frailty, FOF, and cognitive function, as measured using FiND, FES-I, and MMSE-Thai 2002, respectively. Moreover, the results of the current study showed that the time to complete TTSW was at least 18 seconds, which was the optimal cut-off score to indicate frailty in community-dwelling older individuals.

The TTSW was developed to assess the functional capacity and risk of falls in community-dwelling older individuals.[21] The test is challenging and demanding for muscles in the lower extremities and for assessing balance control and walking ability. This ability requires adequate muscle co-contraction, muscle force, and joint torque in the lower extremities to repeatedly perform sit-to-stand movements. Moreover, the ability to stand from a chair at the fastest safe speed three times can determine the functional capacity and risk of falls in community-dwelling older adults.[29] The ability to perform sit-to-stand movements three times was significantly correlated with FTSST ($r = 0.942$, $p < 0.001$) and was an excellent fall indicator (sensitivity = 88.89%, specificity = 100%, AUC = 0.92, 95% CI 0.81–1.00).[29] In addition, the participants were requested to walk at the fastest and safest speed for 3 m and then return to sit in the testing chair. This ability requires good postural control while walking at the maximum speed and turning. In particular, the ability to walk at a maximum and safe speed requires good neuromuscular function[30] and can be a valuable assessment tool to more rapidly determine functional decline than that based on usual walking speed with advancing age.[31,32] Moreover, the assessment of walking speed has shown validity in predicting frailty.[33,34] Therefore, the results of the test were significantly positively correlated with functional strength and balance in community-dwelling older people ($r = 0.88$, $p < 0.001$ and $r = 0.91$, $p < 0.001$, respectively)[35] and can be a good fall screening tool, with high sensitivity and specificity and a high AUC (sensitivity = 80.00%, specificity = 91.43%, AUC = 0.87, 95% CI 0.79–0.98).[21]

Frailty leads to poor outcomes in older people.[11] In particular, frailty is associated with physical capacity impairments, such as muscular weakness and slow walking speed,[11] and decreases in other physical capacities, including reduced balance, speed, endurance, dexterity, and muscle density.[36,37] Older individuals who experience falls often develop FOF when performing daily activities.[38,39] The results of the present study demonstrated that falls are an independent predictor for developing FOF 20 months later (OR = 1.75; $p < 0.001$), and that FOF at baseline was a predictor of falling at 20 months (OR = 1.79; $p < 0.001$).[39] An intense FOF caused a 1.45-fold higher risk of cognitive decline in older adults compared to that in individuals without FOF.[40] In particular, the participants with and without frailty showed significant differences in executive functions and processing speed domain ($p < 0.01$), as measured by the MMSE.[40]

This study has some limitations. First, many methods were used to screen for frailty in older individuals, which may have affected the identification of the participants in this study compared to other studies and their future use. In particular, the current study was conducted in older Thais; therefore, caution is needed when applying the results to other populations that may have different baseline characteristics. Second, two-thirds of the participants were women, which may have affected the results. However, when the participants were divided into frail and non-frail groups, the proportions of male and female participants were equal. Third, this study utilized the FiND to identify frailty; however, this tool may not be consistent with other international definitions of frailty. Further studies may need to apply gold-standard diagnostic criteria such as the Cardiovascular Health Study (CHS) frailty phenotypes.

In conclusion, the results of the current study support the use of the TTSW to determine frailty in community-dwelling older adults. TTSW showed significant correlations with the outcomes of frailty, FOF, and cognitive function (rho = 0.705, $r = 0.482$ and $r = -0.510$, respectively; $p < 0.001$) (Fig. 2) and had excellent diagnostic accuracy in determining frailty with high sensitivity (88.41%), specificity (83.67%), and AUC (0.926; 95% CI 0.883–0.970) (Table 2). The TTSW is a complex but practical and inexpensive tool with minimum equipment requirements. The implementation of this tool in a community setting may be useful for the initial screening, monitoring, and referral of data by healthcare

professionals. A TTSW cut-off score of 18 seconds was the optimal criterion to indicate frailty in community-dwelling older people.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Conceptualization, PP, SK; Data curation, SK; Funding acquisition, PP, SK; Investigation, SK; Methodology, PP; Project administration, SK; Supervision, PP; Writing–original draft, PP; Writing–review & editing, PP, SK.

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