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One-minute seated push-up test: an alternative physical strength and endurance test in community-dwelling older individuals

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ABSTRACT

The available strength and endurance measures commonly involve lower limb functions, whilst the impairments in older people mainly occur in the lower limbs. Therefore, the existing measures may limit clinical application in these individuals. Based on the effects of global physiological changes throughout the body, the researchers hypothesized that the upper limb function can be used as an alternative clinical measure to reflect functional strength and endurance of older people. This cross-sectional study assessed the correlation between the outcome of 1-minute seated push-up test (1minSPUT) and standard measures to reflect functional strength and endurance, including the five times sit-to-stand test (FTSST) and the two-minute step test (2MST), among 67 community-dwelling older adults. Participants with an average age of 75 years were interviewed and assessed for their demographics and the ability to perform the 1minSPUT, FTSST, and 2MST. The findings indicated significant correlation between the 1minSPUT and the FTSST (r_s = -0.492 to -0.537, p-value < 0.05), and the 2MST (r_s = 0.388 to 0.441, p-value < 0.05) for total and separately for male and female participants. The findings suggest the use of 1minSPUT, a practical measure that can be done in a limited area, as an alternative measure to reflect functional strength and endurance in older individuals.

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Introduction

Maximal physiological components, i.e., muscle strength and endurance, are necessary for the continuation of independence in older adults[1,2]. Therefore, the ability to assess, promote and monitor muscular strength and endurance in various clinical and home-based settings is crucial to maximize independence of these individuals who are the fastest growing segment of the country and the world[3]. This issue is also especially important in a current era of healthcare paradigm-shift toward an increased demand for effective standard home healthcare and community-based rehabilitation services[4].

However, the existing simple and practical mobility measures for muscle strength and endurance are commonly involved lower limb functions, such as the five times sit-to-stand test (FTSST)[5], the two-minute step test (2MST)[6,7], and 6-minute walk test[8]. Such measures limit clinical application of the tests for many older individuals because age-related physiological decline is occurred predominantly in the lower body[9,10]. Evidence suggested that many older individuals suffer from lower limb pain and mobility limitation (57% to 95%)[11]. Based on the effects of global physiological changes throughout the body[12,13], the researchers believed that the exploration for a practical measure involving upper limb functions may offer an alternative measure that can be used to screen and monitor functional alteration over time for these individuals.

Previously, the maximum number of push-up repetitions in one minute, as the so-called a 1-minute seated push-up test (1minSPUT), has been applied to measure upper body strength and endurance in young adults[14]. This ability requires the upper limb and trunk muscles to increase muscle force and joint toque to lift the body up from the floor against the body weight[15,16]. The ability of continuous working within a minute also needs muscular and functional endurance to complete the test. With the effects of global physiological changes throughout the body, therefore, the researchers hypothesized that the 1minSPUT can be used as an alternative clinical measure to reflect functional strength and endurance in older people. Nonetheless, the gender-based differences in anatomy and physiology can affect the rate and magnitude of strength and endurance that develop in the muscle and central nervous system for male and female individuals[17,18]. Therefore, this study assessed the correlation between the outcome of 1minSPUT and standard mobility measures to reflect functional strength and endurance, namely FTSST and 2MST, among community-dwelling older adults. The data were analyzed for total participants and separately for male and female participants.

Materials and methods

Study design and participants

This cross-sectional study involved community-dwelling individuals, aged 65 years and older. The inclusion criteria were a body mass index between 18.5 and 29.9 kg/m^2, and the ability of understanding the command used in this study. The exclusion criteria were any signs and symptoms that might affect participation in the study, including no be able to independently perform the test without walking device, uncontrolled medical conditions (e.g., hypertension or heart disease), pain in the musculoskeletal system that might affect outcomes of the study such as rotator cuff injury, history of shoulder and upper limb problems, or pain in the lower limbs that limited ability to perform a 1minSPUT and standard mobility measures with a pain score of more than 5 out of 10 on a visual analog scale. All participants signed written informed consent forms that were approved by the Institutional Ethics Committee for Human Research (HE611600). The estimated minimum number of sample size was 67 participants when sets R_0 = 0.0 and R_1 from a pilot study of 0.335 with 90% power of test and an alpha value of 0.05[19].

Research protocols

The eligible participants were interviewed and assessed for their demographics, including age, gender, height, bodyweight, vital signs, underlying diseases, and walking device used as needed. Then the participants were assessed for the outcomes of the study, including 1minSPUT, FTSST, and 2MST, by an experience assessor in a random order. During the tests, participants could take a period of rest between the tests and the trials as required (or at least 30s) in order to minimize learning effects and fatigue that might occur due to sequences of the tests. Participants were fastened with a lightweight safety belt around their waist in order for the assessor to provide efficient assistance as needed. Details of the tests were as follows.

1minSPUT: The test was executed using standard clinical push-up boards while participant were in a ring sitting position, and placing their hands on the push-up boards at slightly anterior toward their hips (Figure 1A). Then participants performed maximal seated push-up repetitions in a minute. In each repetition, participants pushed both hands against the devices, lifted the body from the floor with slightly bending the trunk forward while depressed both scapulars (Figure 1B), and then bended the elbows to sit down on the floor. Participants were also informed to minimize the use of lower limbs in the test[20]. Before and after the tests, the participants were given a session of warm-up and stretching to reduce the risk of musculoskeletal injury that may occur after completing the test. During the test, the participants could take a period of rest as needed without stopping time, and continued the test as soon as they could or terminated the test if they were unable to do further.

(A) (B)

Figure 1 Position while assessing a 1-minute seated push-up test
(A) Starting position with clinical push-up broads.
(B) Position while lifting the body up from the floor during the test.

2MST: The test is an excellent test-retest reliability (intraclass correlation coefficients [ICC] = 0.90) with good concurrent validity with the one-mile walking time (r = 0.73)[7]. Thus it is recommended as a tool for measuring physical endurance in a small area. The participants raised their knee to a mid-thigh level, i.e., the mid distance between the iliac crest and patella of the participants, marking on the wall. The total number of stepping in place, i.e., the number of the right knee reached the target level, in two minute over one trial was recorded[6].

FTSST: The FTSST is a good test-retest reliability (ICC = 0.81) to reflect functional lower extremity muscle strength and dynamic balance control while changing from a sitting to standing positions[21]. Participants were timed the five chair-rise cycles in the fastest and safest possible manner without using the arms. The average time required over the three trials was recorded[22].

Statistical analysis

Descriptive statistics were used to describe the participants' characteristics and findings of the study. The continuous data between male and female participants were compared using the independent samples t-test for normal distribution variables and Mann-Whitney U test for the non-normal distribution variables. In addition, Chi-squared test was utilized to determine the significant differences of the categorical variables. The Spearman's rank correlation (r_s) was used to analyze the correlation between outcomes of 1minSPUT and standard measures (the FTSST and 2MST). A correlation level was interpreted as very low or negligible (0.00 to 0.30), low (0.30 to 0.50), moderate (0.50 to 0.70), high or strong (0.70 to 0.90), and excellent (0.90 to 1.00)[23]. The closer the correlation coefficient approach to 1, regardless of direction, the stronger is the existing association indicating a linear relationship between the data of SPUTs and standard measures[24]. A level of statistical significance was set at *p*-value < 0.05.

Results

Sixty-seven individuals (31 females) with the average age of approximately 75 years completed the study. Most participants were well-functioning with normal body mass index, and able to perform daily activities independently without mobility devices (*n* = 63, 94%, Table 1). Approximately half of the participants had controlled underlying diseases (ranged 1 to 3 types/participant), including hypertension, diabetes mellitus, hyperlipidemia, and/or gouty arthritis (Table 1). There were no significant differences in demographics between male and female participants (*p*-value > 0.05, Table 1). However, male participants had the number of 2MST significantly greater than that of female individuals (*p*-value < 0.05, Table 1).

Table 1 Personal data and outcomes of the study of total, male and female participants

Variable	Total (n = 67)	Male (n=36)	Female (n=31)	*p*-value
Age[a]: years[*]	75.0 ± 6.6 (73.4 – 76.6)	75.8 ± 6.4 (73.6 – 77.8)	74.3 ± 6.9 (71.7 – 76.1)	0.348
Body mass index[b]: kg/m^2[*]	23.0 ± 3.0 (22.3 – 23.7)	22.5 ± 3.3 (21.4 – 23.7)	23.5 ± 2.6 (22.8 – 24.6)	0.105
Underlying disease[ⴕc]: n (%)	32 (47.8)	18 (50.0)	14 (45.2)	0.196
Daily walking device[c]: Cane [n (%)]	4 (6.0)	1 (2.8)	3 (9.7)	0.235
2MST[b]: times[*]	55.7 ± 14.7 (52.1 – 59.3)	59.9 ± 12.7 (55.9 – 64.0)	50.7 ± 15.6 (44.6 – 56.4)	0.012
FTSST[a]: s[*]	12.6 ± 2.9 (12.2 – 13.5)	12.6 ± 2.9 (11.7 – 13.6)	13.2 ± 2.9 (12.3 – 14.3)	0.249
1minSPUT[b]: times[*]	29.3 ± 1.1 (27.6 – 31.1)	30.9 ± 6.6 (28.7 – 33.1)	27.5 ± 7.4 (25.2 – 30.5)	0.075

Note: [*]The data are presented by mean (SD) and (95% confidence interval), and the data between male and female participants were compared [a]using the independent samples *t* test for normal dis tribution variables, [b]using the Mann-Whitney U test non normal distribution variables, and [c]the data are presented using number (%), and comparison between male and female participants using the *Chi* square test.

ⴕ Underlying disease, including hypertension, diabetes mellitus, hyperlipidemia, gout, heart failure, chronic kidney disease, asthma, and osteoarthritis.

Abbreviation: FTSST, five times sit-to-stand test; 2MST, two-minute step test.

Figure 2 illustrates the correlation between outcomes of the 1minSPUT, and FTSST and 2MST when analysed for total participants and separately for male and female participants. The outcomes of the 1minSPUT showed negative low-to-moderate correlation with the FTSST (r_s = -0.492 to -0.590, *p*-value < 0.01, Figure 2A), and positive correlation with the 2MST (r_s = 0.412 to 0.469, *p*-value < 0.05, Figure 2B).

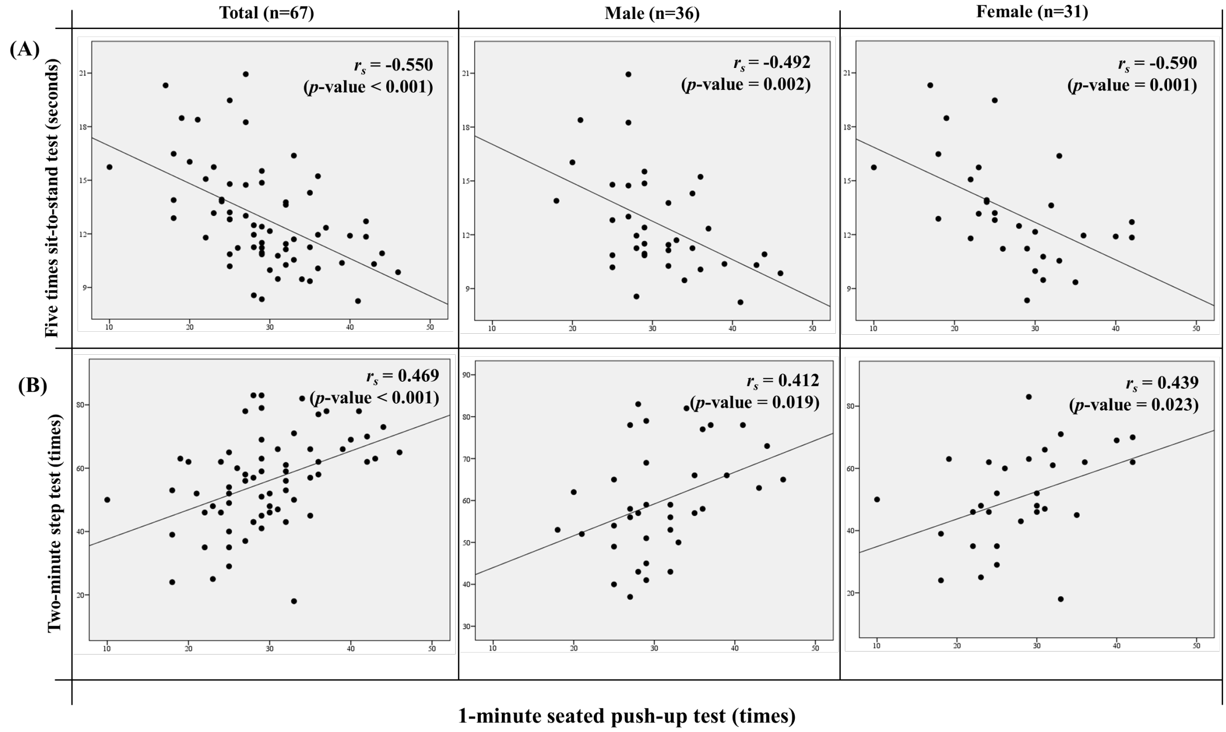

Figure 2 The correlation between a 1-minute seated push up tests and standard measures, including
(A) Five times sit-to-stand test
(B) Two-minute step test

Discussion

With the impairments occurring predominantly in the lower body, this study assessed the ability of the upper limb mobility measure, namely a 1minSPUT, to be used as an alternative measure to reflect functional strength and endurance of community-dwelling older individuals. The findings indicated significant correlation between outcomes of 1minSPUT, and the FTSST and 2MST (r_s = 0.412 to -0.590, *p*-value < 0.05, Figure 2) among community-dwelling older adults in both males and females.

The findings reflect characteristics of a 1minSPUT and global physiological change of the human body systems[13,25]. The ability of continuous lifting the body up from the floor by both hands in a minute requires significant muscle force and joint toque of the upper limb and upper trunk muscles[25]. In each attempt, participants needed muscle mass and muscle strength to adequately generate upper limb loading greater than 80% of the body weight[26]. The involvement of the small muscles in the upper extremities also increased cardiovascular stress that required oxygen uptake and respiratory control greater than the tasks involving large muscle groups of the lower extremities at any given absolute power output[27,28]. Moreover, the upper extremity muscles also have relatively small blood vessels, resulting in less capillary supply and limited oxidative capacity that facilitates cardiovascular stress, autonomic cardiac responses, perceived exertion, and early onset of muscle fatigue as compared to lower extremity muscles[29]. Then the effects of global physiological alteration occurring throughout the human body enabled outcomes of the test involving upper limb muscles to reflect data of the test involving lower limb muscles[13]. Consequently, the ability to continuously lift the body up from the floor in a minute significantly correlated to the FTSST and the 2MST, in both male and female individuals (r_s = 0.412 to -0.590, p-value < 0.05, Figure 2).

However, the inversed directions of the correlation found with standard measures reflect characteristics of the tests. The longer the duration used to complete the FTSST reflects individuals with impaired lower limb muscle strength[21,30]. On the contrary, the higher the number of stepping in place and push up repetitions infers to those with good ability in the 2MST and 1minSPUT[31]. As a result, the outcomes of 1minSPUT showed negative correlation with those of the FTSST (Figure 2A), but positive correlation with 2MST (Figure 2B). However, the low-to-moderate correlation found between the 1minSPUT and both standard measures may reflect distinct characteristics of the test involving upper limbs that performed in sitting (1minSPUT) and the tests involving lower limbs that executed in standing (FTSST and 2MST). In addition, the study found that male participants had the number of 2MST significantly greater than that of female individuals (p-value < 0.05, Table 1). The results of this study are likely based on the fundamental characteristics of male participants who have comparatively greater physical ability, strength and endurance than female[32].

The findings suggest the use of 1minSPUT as an alternative measure to screen and monitor muscle strength and endurance of older individuals, particularly those with lower limb impairments. Nonetheless, there are some noteworthy limitations of the study. Without existing evidence using a 1minSPUTs in older individuals, this study was conducted cross-sectionally in well-functioning older individuals with a body mass index of less than 30 kg/m^2 (average data of 23.0 kg/m^2) using a fixed size of standard clinical push up boards. The findings may limit generalizability in older individuals with frailty and obesity. In addition, when considering characteristics of a 1minSPUT, outcomes of the test may be able to reflect other aspects crucially for older individuals. Therefore, a further study may be conducted in frailty individuals, and explore additional issues relating to SPUTs and older individuals, such as participant's height, elbow flexion angle, body compositions, balance ability and independence.

Conclusion

The present findings suggest the use of a 1minSPUT as an alternative measure to reflect functional strength and endurance of community-dwelling older individuals. Such practical measure may be useful in those with lower limb deficits, and/or having area and equipment limitation. The findings may help to promote the standard and effective community-based rehabilitation and home healthcare services, particularly in this era of limited hospital access.

Take home messages

A 1minSPUT may be applied as an alternative measure to reflect functional strength and endurance in older individuals, particularly in those with lower limb limitation.

Conflict of interest

The authors declare no conflict of interest.

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References

1. Suominen H. Ageing and maximal physical performance. Eur Rev Aging Phys Act 2011; 8(1): 37-42.
2. Izquierdo M, Häkkinen K, Antón A, Garrues M, Ibañez J, Ruesta M, et al. Maximal strength and power, endurance performance, and serum hormones in middle-aged and elderly men. Med Sci Sports Exerc 2001; 33(9): 1577-87.
3. Worapanwisit T, Prabpai S, Rosenberg E. Correlates of falls among community-dwelling elderly in Thailand. J Aging Res 2018; 2018: 8546085.
4. Rawlinson G, Connell L. Out-patient physiotherapy service delivery post COVID-19: opportunity for a re-set and a new normal? Physiotherapy 2021; 111: 1-3.
5. Bohannon RW. Measurement of sit-to-stand among older adults. Top Geriatr Rehabi 2012; 28(1): 11-6.
6. Rikli RE, Jones CJ. Functional fitness normative scores for community-residing older adults, ages 60-94. J Aging Phys Act 1999; 7(2): 162-81.
7. Rikli RE, Jones CJ. Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Act 1999; 7(2): 129-61.
8. Bautmans I, Lambert M, Mets T. The six-minute walk test in community dwelling elderly: influence of health status. BMC Geriatr 2004; 4: 6.
9. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol (1985) 2000; 89(1): 81-8.
10. Frontera WR, Hughes VA, Fielding RA, Fiatarone MA, Evans WJ, Roubenoff R. Aging of skeletal muscle: a 12-yr longitudinal study. J Appl Physiol (1985) 2000; 88(4): 1321-6.
11. Dell'Isola A, Turkiewicz A, Jönsson T, Rolfson O, Dahlberg L, Englund M. The role of pain and walking difficulties in shaping willingness to undergo joint surgery for osteoarthritis: Data from the Swedish BOA register. Osteoarthr Cartil 2021; 3(2): 100157.
12. Amarya S, Singh K, Sabharwal M. Changes during aging and their association with malnutrition. J Clin Gerontol Geriatr 2015; 6(3): 78-84.
13. Colon-Emeric CS, Whitson HE, Pavon J, Hoenig H. Functional decline in older adults. Am Fam Physician 2013; 88(6): 388-94.
14. Jackson, Fromme, Plitt, Mercer. Reliability and validity of a 1 minute push-up test for young adults. Res Q Exerc Sport 1994; 65(sup1): A57.
15. Short FX, Winnick JP. Test items and standards related to muscle strength and endurance on the brockport physical fitness test. Adapt Phys Activ Q 2005; 22(4): 371-400.
16. Yoshimura Y, ISE M. Analysis of the push-up movement base on action potentials of upper extremity muscles and ground reaction force between the palms and a force plate. Kawasaki J Med Welf 2005; 11(1): 7.
17. Hunter SK. The relevance of sex differences in performance fatigability. Med Sci Sports Exerc 2016; 48(11): 2247-56.
18. Skrzek A, Ignasiak Z, Kozieł S, Sławińska T, Rożek K. Differences in muscle strength depend on age, gender and muscle functions. Isokinet Exerc Sci 2012; 20: 229-35.
19. Mohamad AB, Nurakmal B. Sample size guideline for correlation analysis. World J Soc Sci Res 2016; 3(1): 37-46.
20. Wiyanad A, Amatachaya P, Sooknuan T, Somboonporn C, Thaweewannakij T, Saengsuwan J, et al. The use of simple muscle strength tests to reflect body compositions among individuals with spinal cord injury. Spinal Cord 2021. doi: 10.1038/s41393-021-00650-4. Epub ahead of print.
21. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther 2005; 85(10): 1034-45.

22. Thaweewannakij T, Wilaichit S, Chuchot R, Yuenyong Y, Saengsuwan J, Siritaratiwat W, et al. Reference values of physical performance in Thai elderly people who are functioning well and dwelling in the community. Phys Ther 2013; 93(10): 1312-20.
23. Hinkle DE, Wiersma W, Jurs SG. Applied statistics for the behavioral sciences: Houghton Mifflin College Division; 2003.
24. Taylor R. Interpretation of the correlation coefficient: a basic review. J Diagn Med Sonogr 1990; 6(1): 35-9.
25. Contreras B, Schoenfeld B, Mike J, Tiryaki-Sonmez G, Cronin J, Vaino E. The biomechanics of the push-up: implications for resistance training programs. Strength Cond J 2012; 34(5): 41-6.
26. Siriyakul C, Kosura N. Possibility of using a seated push up test to determine skeletal muscle mass in older adults. [term paper of Bachelor of Science (Physical Therapy)]. Khon Kaen: faculty of associated medical sciences, Khon Kaen University. 2019.
27. Volianitis S, Yoshiga CC, Nissen P, Secher NH. Effect of fitness on arm vascular and metabolic responses to upper body exercise. Am J Physiol Heart Circ Physiol 2004; 286(5): H1736-41.
28. Volianitis S, Secher NH. Arm blood flow and metabolism during arm and combined arm and leg exercise in humans. J Physiol 2002; 544(3): 977-84.
29. Theisen D. Cardiovascular determinants of exercise capacity in the Paralympic athlete with spinal cord injury. Exp Physiol 2012 97(3): 319-24.
30. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. J Gerontol A Biol Sci Med Sci 2002; 57(8): M539-43.
31. Haas F, Sweeney G, Pierre A, Plusch T, Whiteson J. Validation of a 2 minute step test for assessing functional improvement. Open J Ther Rehabil 2017; 5: 71-81.
32. Courtright SH, McCormick BW, Postlethwaite BE, Reeves CJ, Mount MK. A meta-analysis of sex differences in physical ability: revised estimates and strategies for reducing differences in selection contexts. J Appl Psychol 2013; 98(4): 623-641.