Research Paper

Hong Kong Physiotherapy Journal
Vol. 42, No. 2 (2022) 125–136
DOI: 10.1142/S1013702522500123

Hong Kong Physiotherapy Journal
https://www.worldscientific.com/worldscinet/hkpj

Validity and feasibility of using a seated push-up test among community-dwelling older adults

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Received 12 February 2022; Accepted 23 May 2022; Published 22 July 2022

Background: Older individuals face a high risk of mobility and body composition decline, which can affect their independence. In light of a current uncertain healthcare situation created by the coronavirus (COVID-19) pandemic, healthcare paradigm has been shifted with increased demand for a practical measure to promote standard home healthcare services for all individuals, including older adults.
Objective: This study explored the feasibility and validity of seated push-up tests (SPUTs) as clinical measures to reflect the body composition, muscle strength, and mobility among community-dwelling older individuals, aged ≥ 65 years ($n = 82$).

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Methods: Participants were cross-sectionally assessed using SPUTs with various demanding forms, including the 1-time SPUT (1SPUT) along with its upper limb loading SPUT (ULL-SPUT), 5-time SPUT (5SPUT), 10-time SPUT (10SPUT), and 1-min SPUT (1minSPUT) and standard measures.
Results: Participants who passed and failed a 1SPUT showed significant differences in the outcomes of all standard measures ($p < 0.05$). The ULL-SPUT significantly correlated to all body composition, muscle strength, and mobility ($r = 0.247$–0.785; $p < 0.05$). Outcomes of 1minSPUT significantly correlated with muscle strength and mobility outcomes ($r = 0.306$–0.526; $p < 0.05$). Participants reported no adverse effects following the SPUTs.
Conclusion: The findings suggest the use of the 1SPUT, ULL-SPUT, and 1minSPUT as practical measures to reflect the body composition, muscle strength, and mobility of older individuals, according to their functional levels. The tests may especially clinically benefit those with lower limb limitations and those in settings with limited space and equipment.

Keywords: Body composition; clinical measure; endurance; mobility; muscle strength.

Introduction

The physiological decline accompanying aging occurs throughout the body's systems and results in a deterioration of physical function, particularly in the lower extremities. Consequently, approximately one-quarter of older people experience basic mobility limitations such as difficulties with walking, stair climbing, and rising from a chair, affecting their independence.[1–3] The lower limb impairments also distort the use of existing mobility measures that commonly involve lower limb functions such as the 10-m walk test, 6-min walk test, and sit-to-stand test. As a result, considerable effort has been directed towards understanding and attenuating age-related functional decline of the lower extremities. However, clinical measures involving upper limb functions, which might be applied instead among these individuals, have received relatively less attention.[4,5]

Existing evidence reports the use of an upper limb measure—namely, the handgrip test (HG)—to reflect total body strength, total skeletal muscle mass (SMM; $r = 0.49$; $p < 0.01$), and many other crucial aspects for older adults, such as health status and functional decline (odds ratio [OR] = 0.88).[6–8] However, the HG requires a specialised machine to assess the distal muscles of the tested arm in an open-kinetic chain manner. Such characteristics may affect the sensitivity of the outcomes in detecting problems among older individuals, as well as the clinical applications of the measurement in various community- and home-based settings. The present researchers hypothesised that the application of a practical measure involving several upper limb muscles working in a closed-kinetic chain manner may offer another clinical measure to detect common problems among older individuals. Such a test may be particularly beneficial for those with lower limb impairments and in settings with limited space or in which a specialised HG dynamometer is not available, especially in a current healthcare-paradigm shift with the need for standard home healthcare services due to coronavirus (COVID-19) pandemic.

A seated push-up test (SPUT) is a practical measure that can be executed on a chair or bed using push-up boards or wooden boxes. However, the task is very demanding and challenging for the upper limb and upper trunk muscles, as they must be able to exert enough muscle force and joint torque to lift the body upward by both arms and maintain body balance at the shoulder joints.[9,10] Wiyanad *et al.*[11] recently reported the ability of the upper limb loading during a seated push-up test (ULL-SPUT) to reflect body composition among individuals with a spinal cord injury. Our preliminary study also found an association between ULL-SPUT and the SMM of older individuals, particularly when the test is performed in a ring sitting position.[12] However, this preliminary study[12] investigated only the simplest form of SPUT—namely, the 1-time SPUT (1SPUT) along with its ULL-SPUT—in 40 well-functioning older adults. In addition, body composition was assessed only in terms of the SMM, using bioelectrical impedance analysis; the outcomes obtained might contain errors due to many factors, including electrode placement, environmental factors, and participant preparation.[13]

Based on the concept of global physiological change throughout the body systems and the closed-association of the musculoskeletal system, the present researchers hypothesised that various forms of SPUTs could be applied in older individuals with different functional levels and that their outcomes would reflect many aspects necessary for the independence of these individuals, depending upon the particular characteristics of the tests. Therefore, this study assessed the discriminative and concurrent validity, as well as the feasibility, of various types of SPUTs—including the 1SPUT along with its ULL-SPUT, 5-time SPUT (5SPUT), 10-time SPUT (10SPUT), and 1-min SPUT (1minSPUT)—as compared to the results of standard measures for body composition, muscle strength, and mobility among community-dwelling older adults.

Methods

Participants

This observational study was conducted among community-dwelling individuals aged 65 years and older with a body mass index (BMI) of between 18.5 kg/m^2 and 29.9 kg/m^2. The eligible participants needed to have the ability to stand up independently, walk with or without a walking device, and understand the instructions for the tests in this study. Individuals were excluded from the study if they had any signs or symptoms that might affect their participation in the study, such as uncontrolled medical conditions (e.g., hypertension or heart disease); pain in the musculoskeletal system that might affect outcomes of the study, such as a rotator cuff injury; and a history of shoulder or upper limb problems that limits their ability to perform SPUTs (i.e., 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 (HE 611600). The estimated minimum sample size for this study was 82 participants, when $R_0 = 0.0$ and the lowest R_1 from a pilot study of 0.31 ($n = 40$), with 90% power and an alpha value of 0.05.[14]

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 (if any). Then, the participants were assessed for their ability to perform SPUTs, and standard measures for the body composition, muscle strength, and mobility of the older individuals. Details of the tests are explained below.

Seated push-up tests: Many forms of SPUTs are clinically available, including untimed and timed SPUTs.[9,10] With the aim to report the feasibility of using SPUTs among older individuals, this study applied simple SPUTs in increasingly demanding forms, including the 1SPUT along with its ULL-SPUT, 5SPUT, 10SPUT, and 1minSPUT, according to the participant's ability to complete the tests (with no pressure to complete all SPUTs if they were unable). Before and after the tests, the participants engaged in a warm-up and stretching session to reduce the risk of musculoskeletal injury, which can occur after completing such demanding measures. The various SPUTs were completed as follows.

The 1SPUT was executed using push-up loading devices at the size of standard clinical push-up boards (18 cm in height) to quantify the ULL-SPUT. The devices were developed from digital load cells (Model L6E3-C, 50 kg-3G, with the standard calibration method based on UKAS LAB 14: 2006; mini-patent application number 2103001612).[11,12] After calibration, the tools were accurate up to < 0.1 kg, with a measurement uncertainty of $\pm$ 0.1 kg. Participants were in a ring sitting position and placed their hands on the push-up loading devices slightly anterior to their hips (Fig. 1). Then, they pushed both hands against the devices, lifted the body from the floor while slightly bending the trunk forward and depressing both scapulars, and gradually bent the elbows to sit down on the floor.[9,11,12] The test was repeated over three trials, with a sufficient rest period between the trials. Outcomes of the test were recorded in terms as either *pass* or *fail*; a *pass* was defined as the ability to lift the body from the floor successfully in at least two of the three trials; if not, the outcome was regarded as a *fail*.[12] In addition, the average data of the maximum ULL-SPUT over the three trials, which was automatically generated by the push-up loading devices, was recorded.[11,12]

Participants who failed a 1SPUT terminated the SPUTs, and were assessed using standard measures. Participants who passed continued the timed-based SPUTs, including the 5SPUT,

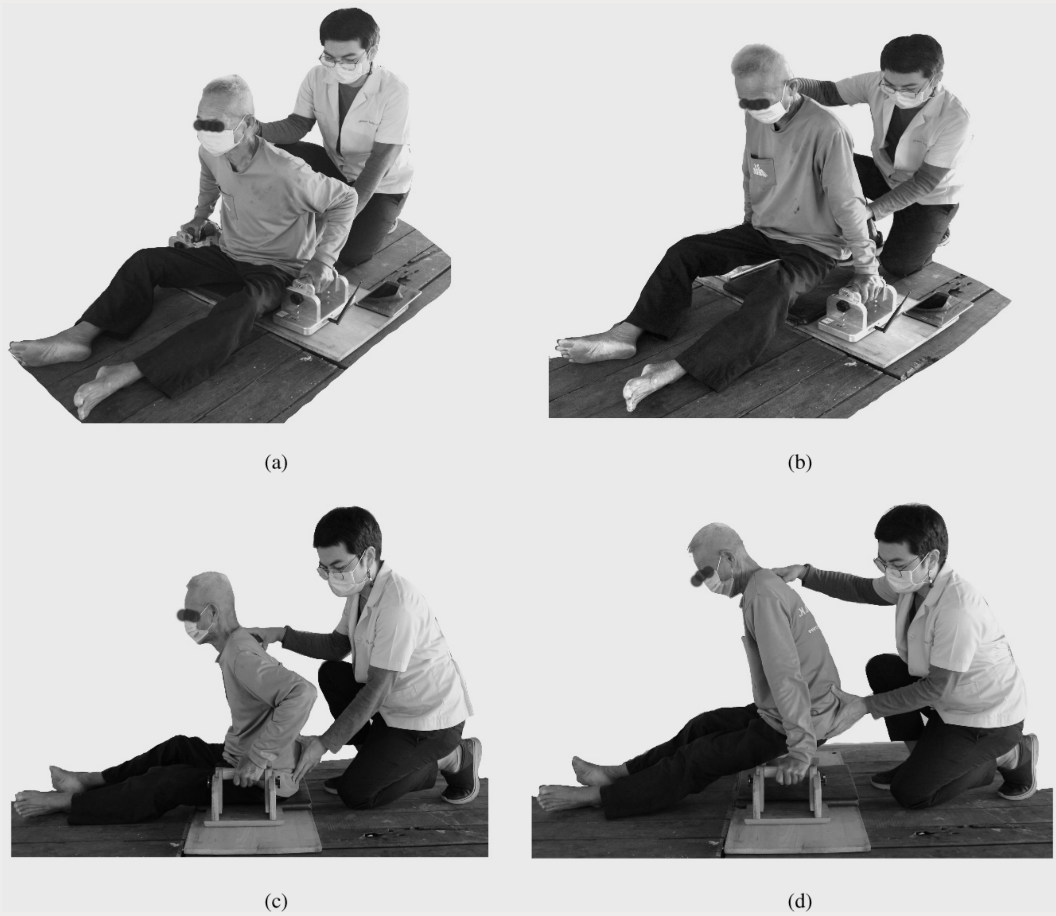
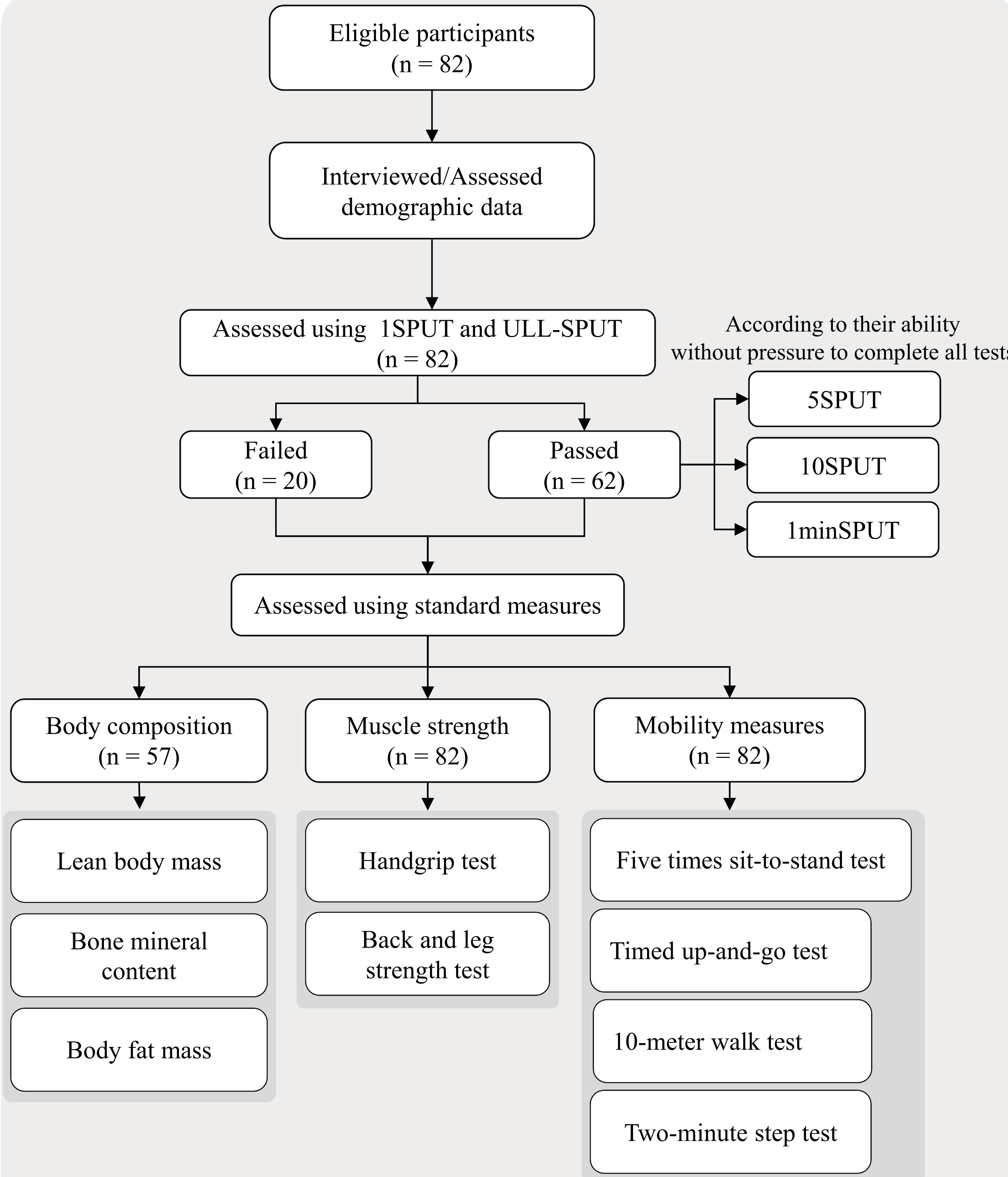


Fig. 1. Testing protocols of seated push-up tests. (A) Starting position with push-up loading devices. (B) Position while lifting the body from the surface with push-up loading devices. (C) Starting position with push-up boards. (D) Position while lifting the body from the surface with push-up boards.

10SPUT, and 1minSPUT—using standard clinical push-up boards and a starting position similar to that used for the 1SPUT. For the 5SPUT and 10SPUT, the participants were timed on their ability to complete 5 and 10 SPUT repetitions in the fastest and safe manner from the instruction "start" until the participant's buttock touched the floor on the last repetition. The average time over the three trials was recorded. For the 1minSPUT, the participants were assessed for the maximum number of SPUT repetitions they could do in one minute over one trial. During the test, they could take a period of rest as required and continue the test as soon as they could; otherwise, they terminated the test if they were unable to continue.

The SPUTs were assessed on a hard and level surface by an experienced rater (intraclass correlation coefficients [ICCs] = 0.932–1; $p < 0.001$). The participants could take a period of sufficient rest between the trials and the tests as required (at least a minute). The number of participants who could complete each method of SPUT was recorded, along with the adverse events (if any), such as musculoskeletal pain, chest pain, or accidental events, for the consideration on the feasibility of the SPUTs.

Standard measures: The participants were assessed using standard measures to indicate their body composition (i.e., lean body mass [LBM], bone mineral content [BMC], and body fat mass), muscle strength, and mobility (Table 1) by an experienced assessor in a random order. The participants could take a period of rest between the tests and the trials as required (or at least 30 s), in order to minimise the learning effects and fatigue that might occur due to the sequence of the tests. They were fastened with a lightweight safety belt around their waist so that the assessor could provide efficient assistance if needed. Details of the standard measures are described in Table 1.[15–34]



Notes: SPUT = seated push up test, ULL-SPUT = upper limb loading during a seated push up test

Fig. 2. Participation flowchart.

Table 1. Details of the standard measures for body compositions, muscle strength, and mobility.

Outcome measure		Aims of the assessments/ psychometric properties	Details of the measurement
Body compositions	Dual-energy X-ray absorptiometry (DXA)	Body compositions (lean body mass [LBM], bone mass content [BMC], and body fat mass [FM]).[16] Inter- and intra-tester reliability (ICC = 0.97–0.98).[17]	Participants were in a supine position on a DXA table with the arms placed on their sides, the legs extended, and the toes facing upward according to the standard protocols recommended by GE-Healthcare.[18] The data of body compositions, including LBM, BMC, and body fat mass, were automatically generated by the machine in kilograms.
Muscle strength tests	Handgrip test	Upper limb muscle strength, physical frailty, and disability in older individuals. Excellent test-retest reliability (ICC = 0.912–0.954).[19]	Participants were in a sitting position and squeezed the handle as much as they could over three trials per hand with a sufficient rest interval (at least 30 s) between the trials, and the maximum force was recorded.[20]
	Back and leg strength test	The back and leg extensor muscle strength. Excellent intra-tester reliability (ICC = 0.97).[21]	Participants stood on the base of a back-leg-chest dynamometer with the chain adjusted according to their height and the protocols for the trunk or leg extensor muscles explained previously. Then, they pulled the chain with their maximum force, holding it for 3 s. A rest period between the trials was allowed as needed (at least 30 s). The average force in the three trials for each method was recorded in kilograms.[22]
Mobility assessments	Five times sit-to-stand test	Functional lower extremity muscle strength and dynamic balance control while changing postures.[15,23] Test-retest reliability (ICC = 0.81; SEM = 0.9 s).[23,24] MDC_{95} = 2.5 s.[24] Concurrent validity with the TUG test; $r = 0.64$, $p < 0.001$.[24]	Participants were timed their ability to complete five chair-rise cycles at the fastest possible safe speed without using their arms. The average time over the three trials was reported.[25]
	Timed up-and-go test	Mobility, dynamic balance control, and risk of falling in older individuals.[26,27] Test-retest reliability (ICC = 0.97).[28] Inter-tester reliability (ICC = 0.99).[26]	Participants were timed their ability of standing up from a standard armrest chair, walking at the fastest and safe speed around a traffic cone at 3 m from the chair, returning, walking back to sit back down on the chair. The average time over the three trials was reported.[25]
	10-m walk test	Overall quality of gait, community participation, health condition, morbidity, and mortality rates.[29] Test-retest reliability (ICC = 0.92) and MDC = 0.22 m/s.[30]	Participants were timed their ability of walking at a comfortable pace along the middle 4 m of the total 10-m walkway. The average time over the three trials was then converted to a walking speed.[31,32]

Table 1. (*Continued*)

Outcome measure	Aims of the assessments/ psychometric properties	Details of the measurement
Two-minute step test	Functional capacity and physical endurance.[33] Test-retest reliability (ICC = 0.90) and concurrent validity with 1-mile walking time ($r = 0.73$).[34]	Participants raised their knee to a mid-thigh level, that is, the mid distance between the iliac crest and the patella, marking the point on the wall. The total number of steps in place, that is, the number of times the right knee reached the target level in 2 min over one trial was recorded.[33]

Notes: ICC: intraclass correlation coefficient; SEM: standard error of measurement; MDC: minimal detectable change.

Statistical analysis

Descriptive statistics were used to describe the participants' characteristics and the findings of the study. The independent samples t-test and Mann–Whitney U-test were used to compare the data between the participants who passed and failed the 1SPUT for the data with a normal and non-normal distribution, respectively (i.e., the discriminative validity). The Pearson correlation coefficient was used to analyse the correlations of continuous data between the SPUTs and standard measures (i.e., the concurrent validity). The correlation level was interpreted as being very low or negligible ($r = 0$–0.30), low ($r = 0.30$–0.50), moderate ($r = 0.50$–0.70), high or strong ($r = 0.70$–0.90), or excellent ($r = 0.90$–1.00).[14] Therefore, the closer the correlation coefficient was to 1, regardless of the direction, the stronger was the existing association, indicating a linear relationship between the SPUT data and the standard measures. The level of statistical significance was set at $p < 0.05$.

Results

In total, 82 individuals, with an average age of 74 years and a normal BMI, completed the study. Most participants were well-functioning females, physically active, and able to perform daily activities independently, without mobility devices ($n = 72$; 88%; Table 2). Of all, 57 participants were assessed for their body composition because this variable was additionally included after the initiation of the study.

All 82 participants could complete a 1SPUT; 62 participants (75.6%) passed the test and proceeded to be assessed with other forms of the SPUTs, while the rest of them ($n = 20$) failed in the test and continued with standard measures. Most participants who failed were female ($n = 18$; 90%), and approximately one-third of them ($n = 7$; 35%) used a single cane for daily movement. The average ULL-SPUT of the participants who passed was 85% of their bodyweight and for those who failed was 71% of their bodyweight ($p < 0.001$; Table 3).

Table 2. Personal data of all participants and of those who passed and failed a 1-seated push up test (1SPUT).

Variable	Total (n=82)	Fail ($n = 20$)	Pass ($n = 62$)	P-value
Age[a] (years)	74.6 ± 6.5 (73.1–76)	76.5 ± 7.4 (73–79.9)	74 ± 6.1 (72.4–75.5)	0.120
Gender[b] (female)	49 (61)	18 (90)	29 (46.7)	0.002*
Bodyweight[a] (kg)	55.6 ± 9.9 (53.5–57.8)	55.9 ± 11.9 (50.3–61.5)	55.6 ± 9.3 (53.2–57.9)	0.893
Body height[a] (m)	1.5 ± 0.1 (1.5–1.6)	1.5 ± 0.1 (1.5–1.6)	1.6 ± 0.1 (1.5–1.6)	0.906
Body mass index[a] (kg/m^2)	23 ± 3.2 (22.3–23.8)	3.9 ± 3.7 (22.2–25.6)	22.8 ± 3.1 (22–23.6)	0.185
Daily walking device[b] (Cane)	10 (12.2)	7 (35)	3 (4.8)	< 0.001*

Notes: Participants who could lift the body up from the floor successfully in at least two over the three trials were arranged into the "pass" group, if not, they were placed in the "fail" group. [a]Data are presented as mean ± SD (95% confidence intervals), and compared between the pass and fail groups using the independent samples t-test. [b]The data are presented using number (%) and compared between the groups using the *Chi* square test. *Indicated significant differences between the groups.

Table 3. Data comparisons between participants who passed and failed a one-time seated push up test (1SPUT).

Variable		Total ($n = 82$)	Fail ($n = 20$)	Pass ($n = 62$)	P-value
Upper limb loading during a seated push up test (ULL-SPUT)					
	ULL-SPUT (BW%)	82.3 ± 9.8 (80.1–84.5)	71.2 ± 12.9 (65.2–77.2)	85.9 ± 5.1 (84.6–87.2)	$< 0.001^a$
Standardmeasures					
Body composition[c]	Lean body mass (BW%)	65.1 ± 7.5 (63.1–67.1)	60.5 ± 5.1 (56.6–64.5)	66.0 ± 7.6 (63.8–68.2)	0.016^a
	Bone mineral content (BW%)	3.4 ± 0.7 (3.3–3.6)	3.2 ± 0.3 (2.9–3.4)	3.5 ± 0.7(3.3–3.7)	0.044^a
	Fat mass (BW%)	31.4 ± 8 (29.3–33.5)	36 ± 6 (31.4–40.7)	30.5 ± 8 (28.2–32.9)	0.033^a
Muscle strength	Hand grip test (kg)	20.3 ± 5.4 (19.2–21.5)	16.4 ± 3.7 (14.6–18.1)	21.6 ± 5.3 (20.3–23)	$< 0.001^a$
	Back extensor (kg)	26 ± 14.5 (22.8–29.2)	19.6 ± 10.6 (14.6–24.5)	28.1 ± 15 (24.3–31.9)	0.037^b
	Leg extensor (kg)	30.1 ± 18 (26.1–34)	20 ± 12.3 (14.3–25.8)	33.3 ± 18.5 (28.6–38)	0.02^b
Mobility	Five times sit-to-stand test (s)	13 ± 3.1 (12.4–13.7)	16.5 ± 3.2 (15–18)	11.9 ± 2 (11.4–12.4)	$< 0.001^a$
	Timed up and go test (s)	13.9 ± 3.2 (13.2–14.6)	16.1 ± 3.2 (14.6–17.6)	13.2 ± 2.9 (12.5–14)	$< 0.001^b$
	10-m walk test (m/s)	1 ± 0.2 (0.9–1)	0.8 ± 0.2 (0.7–0.9)	1 ± 0.2 (1–1.1)	$< 0.001^a$
	2-min step test (times)	54.7 ± 14.8 (51.5–57.9)	47.1 ± 16.3 (39.5–54.7)	57.2 ± 13.5 (53.7 ± 60.6)	0.007^a

Notes: The data are presented using mean ± standard deviation (95% confidence interval), BW = bodyweight, s = second, m = meter. Superscripts indicates the p-values from [a]the independent samples t-test, [b]the Mann-Whitney U-test, [c]there were 57 participants in this variable as it was additionally included after initiation of the study, with 48 participants passed and 9 participants failed a 1SPUT.

Table 4. The correlation between outcomes of seated push up tests and standard measures, including body compositions, muscle strength and mobility measures of the participants.

	Body compositions (g)			Muscle strength (kg)			Mobility			
Variable	Lean body mass	Bone mineral content	Body fat mass	Handgrip	Back muscles strength	Leg muscles strength	Five times sit-to-stand test (s)	Timed up and go test (s)	10-m walk test (m/s)	2-min step test (times)
ULL-SPUT[a](kg)	**0.785****	**0.628****	**0.515****	**0.547****	**0.456****	**0.345****	**−0.416****	**−0.288****	**0.332****	**0.247***
p-value	< **0.001**	< **0.001**	< **0.001**	< **0.001**	< **0.001**	**0.001**	< **0.001**	**0.009**	**0.002**	**0.025**
5SPUT[b] (s)	−0.0281	**−0.306***	−0.059	−0.182	−0.115	−0.059	**−0.393****	0.173	**0.364****	**0.398****
p-value	0.053	**0.035**	0.691	0.156	0.372	0.650	**0.002**	0.178	**0.004**	**0.001**
10SPUT[b] (s)	−0.166	−0.164	−0.032	−0.049	−0.149	−0.126	**−0.355****	0.207	**0.361****	**0.357****
p-value	0.261	0.264	0.828	0.703	0.247	0.329	**0.005**	0.107	**0.004**	**0.004**
1minSPUT[b] (times)	**0.325***	0.244	−0.100	**0.356****	**0.425****	**0.466****	**−0.526****	**−0.306***	**0.332****	**0.421****
p-value	**0.024**	0.095	0.498	**0.005**	**0.001**	< **0.001**	< **0.001**	**0.016**	**0.008**	**0.001**

Notes: p-values were derived from Pearson correlation coefficients. Bold characters indicate the data with significant correlation at $^{*}p < 0.05$ and $^{**}p < 0.01$. [a]This variable was analysed in 57 participants for body compositions, and 82 participants for muscle strength and mobility measures. [b]These variables were analysed in 48 participants for body compositions, and 62 participants for muscle strength and mobility measures. ULL-SPUT: Upper limb loading during a seated push up test; 5SPUT: five-time seated push-up test; 10SPUT: 10-time seated push-up test; 1minSPUT: 1-min seated push-up test.

The body composition, muscle strength, and mobility also showed significant differences between the groups ($p < 0.05$; Table 3). The findings further indicated a moderate to strong correlation between the ULL-SPUT data, and all body composition ($r = 0.515$–0.785; $p < 0.001$; Table 4), muscle strength, and mobility measures ($r = 0.247$–0.547; $p < 0.05$) of the participants (Table 4).

All participants who passed the 1SPUT could complete other forms of SPUTs ($n = 62$). Their average 5SPUT time was 9.2 ± 4.1 s (95% confidence interval [CI]: 8.6–9.7 s), 10SPUT time was 17.7 ± 3.5 s (95% CI: 16.9–18.7 s), and 1minSPUT repetitions was 28.3 ± 8.0 times (95% CI: 26.4–30.3 times). There were no adverse events related to the SPUTs reported by any of the participants. The outcomes of the 1minSPUT showed a significant low to moderate correlation to LBM and muscle strength tests and mobility measures ($r = -0.306$–0.526; $p < 0.05$; Table 4) but not to BMC or body fat mass ($p > 0.05$). By contrast, the 5SPUT and 10SPUT data showed a significant low correlation to only the five times sit-to-stand test (FTSST), 10-m walk test (10MWT) and 2-min step test (2MST) ($r = -0.355$–0.398; $p < 0.01$; Table 4).

Discussion

This study assessed the validity and feasibility for various types of SPUTs among community-dwelling older people. All participants could complete the 1SPUT and ULL-SPUT, wherein a pass or fail in a 1SPUT could clearly discriminate participants with different body composition, muscle strength, and mobility outcomes ($p < 0.05$; Table 3). In addition, the ULL-SPUT showed a significant correlation to all body composition, muscle strength, and mobility measures (Table 4). Among the time-based SPUTs, the 1minSPUT showed significant correlation with LBM and all muscle strength and mobility measures, whilst the 5SPUT and 10SPUT showed a significant low correlation with only some mobility measures (Table 4).

Of all forms of SPUTs investigated in this study, the 1SPUT along with its ULL-SPUT are the least demanding measures and, thus they could be completed by all participants with poor and good functional ability (Table 3). Participants who passed a 1SPUT had the ULL-SPUT approximately 85% of their bodyweight which was significantly greater than that of those who failed the test (at approximately 71% of their bodyweight; $p < 0.001$; Table 3). Previous studies reported that the ability to increase the ULL-SPUT requires the complex interaction of many upper limb and upper trunk muscles, as well as perceptual information working cooperatively to generate muscle force and joint torque to lift the body upward by both arms.[9–11] Such ability requires SMM, a major part of LBM, in order for the muscles involved in the task to convert chemical energy into mechanical energy for force and power generation.[10,19] Muscular contraction also imposes mechanical loading onto the bones, along with cardiovascular stress, while body fat mass acts as resistance when completing the task.[19,20] Therefore, the 1SPUT and ULL-SPUT outcomes significantly correlated to body composition of the arms. Then the age-related physiological changes occurring throughout the body and in all body systems enabled outcomes of the tests involving upper limb and upper trunk muscles to reflect standard measures involving other body parts.[1,2] Consequently, the present findings indicate a significant correlation between the ULL-SPUT and all body composition, muscle strength, and mobility measures investigated in this study (Table 4). Furthermore, the participants who passed the 1SPUT had the outcomes of body composition, muscle strength, and mobility measures significantly better than those of the participants who failed the test ($p < 0.05$; Table 3).

Nonetheless, outcomes of the 1SPUT and ULL-SPUT may face ceiling effects in older individuals with good ability (i.e., score limitation at the top of a scale, i.e., always getting a *pass* in the test or nearly 100% of their bodyweight[35]). Thus the 1SPUT and ULL-SPUT outcomes in these cases may not represent the changes occurring in these participants, even there is actual change in the participants' body composition, muscle strength, or mobility. In such cases, other timed-based SPUTs (e.g., the 5SPUT, 10SPUT, and 1minSPUT)—which can be applied only in those who pass the 1SPUT—may be utilised to further challenge the ability of these individuals. However, the 5SPUT and 10SPUT, which can be completed within a short duration, may be unable to clearly reflect the variability in ability level among these participants. Therefore, the 5SPUT and 10SPUT outcomes showed a low correlation to only some mobility measures, including the FTSST, 10MWT, and 2MST ($r = -0.355$–0.398; $p < 0.01$; Table 4). On the contrary, outcomes of the most challenging form of SPUT investigated in this study—namely, the 1minSPUT—might be able to detect the variability of participants with good functional ability. Therefore, 1minSPUT outcomes showed significant correlation with LBM, muscle strength and mobility of the participants ($r = -0.306$–0.526; $p < 0.05$; Table 4).

Previous studies have suggested that the slightest physical reduction could transform a person from independence into one with disability. Therefore, it is highly suggested to detect and monitor any abnormality early on, as well as to improve their physical conditions since they are still functioning independently, so that disability can be prevented or delayed.[36,37] The present findings suggest the feasibility and validity of the SPUTs—in various forms—as another practical upper limb measure to indicate body composition, muscle strength, and mobility, which are necessary for the independence and safety of community-dwelling older individuals. Such measures can be completed in a small area over a hard and smooth surface (e.g., over a bed); and thus they can be applied in various clinical, community-, and home-based settings.

However, there are some noteworthy limitations to this study. First, the study was conducted cross-sectionally among mostly well-functioning older participants who had a BMI of less than 30 kg/m^2. Thus, the findings may not clearly indicate the ability of the SPUTs to monitor changes in the body composition, muscle strength, and mobility of older individuals over time or of those who are frail or obese. Second, the SPUT measurements were taken using clinical push-up boards of a standard size, which may influence the outcomes of the test for participants with different heights. Third, only 57 participants (69.5%) were assessed for their body composition because this variable was additionally included after the initiation of the study. The lower number of participants as compared to that required in this study may affect clinical contribution for the findings of this variable, i.e., the correlation between SPUTs and body composition. Thus, a further study addresses all these limitations, as well as other psychometric properties needed for clinical application are still required to confirm the present findings and extend clinical benefit of SPUTs.

In conclusion, particular forms of SPUTs are feasible and valid measures to reflect body composition, muscle strength, and mobility among well-functioning older individuals. The 1SPUT and ULL-SPUT can be applied among those with good or poor functional ability, and they may be completed using a digital bathroom scale placed on a hard and even surface. The 1minSPUT—which may be assessed using an armchair or using small wooden boxes placed on a firm surface—can be employed to further challenge older individuals who have good functional ability. Such measures may be applied to early detect the abnormality relating to their muscle strength, mobility and body composition change that may occurred in older individuals, especially among those with lower limb limitations or in settings with limited area and equipment.

Conflicts of Interest

The authors have no conflicts of interest relevant to this paper.

Funding/Support

This study was supported by funding from the Royal Golden Jubilee (RGJ) Ph.D. programme, Thailand Research Fund (TRF, grant no. PHD/0174/2560). For the remaining authors none were declared.

Author Contributions

All authors were involved in concept, design, and planning of the study. In addition, all of them also took part in critical revision of the paper for intellectual content and finalised the manuscript. PP, PC and RI additionally contributed in collection and assembling of the data. PP and SP also took part in drafting of the manuscript. SA, SP and PA provided the study materials and technical support. SA additionally provided the funding support and administration of this project.

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