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ORIGINAL ARTICLE

The Safe Functional Motion test is reliable for assessment of functional movements in individuals at risk for osteoporotic fracture

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Abstract The Safe Functional Motion (SFM) test is a performance-based tool developed to assess functional movements in individuals at risk for osteoporotic fracture. The purpose of this study was to determine the test–retest and inter-rater reliability of the scores on the short form of the SFM test (SFM-SF). A secondary objective was to evaluate the construct convergent validity of the balance domain. Community-dwelling adults with low bone mass (n=36) completed the SFM-SF on two occasions. During one visit, SFM-SF performance was scored by two testers and additional tests of balance (Timed Up and Go (TUG), Berg Balance Scale (BERG), and Community Balance and Mobility Scale (CBMS)) were completed. Test–retest and inter-rater reliability of the SFM-SF score is excellent (intraclass correlation coefficient≥0.90), and the balance domain score demonstrates acceptable associations with established clinical measures of balance (Spearman's rho=−0.69, 0.76, and 0.83 for TUG, BERG, and CBMS, respectively). SFM-SF provides reliable measures of functional movements in community-dwelling individuals at risk for osteoporotic fracture.

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Abbreviations

BERG	Berg Balance Scale
CBMS	Community Balance and Mobility Scale
CS-PFP	Continuous-scale Physical Functional Performance test
DXA	Dual-energy x-ray absorptiometry
ICC	Intraclass correlation coefficient type 2,1
MDC_{90}	Minimal detectable change at the 90% confidence level
PPT	Physical Performance Test
SEM	Standard error of the measurement
SFM	Safe Functional Motion test
SFM-SF	Safe Functional Motion test—short form
TUG	Timed Up and Go test

Introduction

Risk of osteoporotic fracture increases with age-related bone loss and has significant implications for the individual as well as the health care system [1]. The vertebral spine is the most common site of osteoporotic fracture and even those fractures, which are not detected clinically, are associated with increased morbidity and mortality [2]. It is well-established that flexion of the spine increases the risk for osteoporotic fracture, and individuals with osteoporosis are instructed to avoid exercises and activities involving trunk flexion [3]. Similarly, kyphotic curvatures of the spine are associated with increased spinal loading due to altered gravitational and muscle forces [4]. Thus trunk flexion occurs as a consequence of kyphotic postural alignment and accompanies movements that previously could be performed with the spine in neutral alignment. Forces are further magnified when individuals perform everyday activities involving flexing, twisting, reaching, lifting and carrying, and particularly when activities require combined movements and increased external loads [5, 6]. Individuals who are losing bone mass and developing kyphotic postures may not be aware of the movement strategies and body mechanics they use to complete every day activities and how these may increase their risk for fracture.

Evaluation of movement strategies and postures assumed by individuals at risk for osteoporotic fracture during typical activities of daily living is important in order to identify and minimize abnormal spinal loads and risk for falls. Two performance-based tools have been developed to assess usual functional movements in older adults, the Continuous-scale Physical Functional Performance (CS-PFP) and the Physical Performance Test (PPT) [7–10]. These tests measure physical performance during standardized functional tasks in terms of time taken to complete a task, weight lifted, and/or distance covered during a task. No emphasis is placed on quality of movement, using correct body mechanics, or the types of spine loading experienced while performing the tasks. To address these gaps, the Safe Functional Motion test (SFM) was developed by clinicians from the United Osteoporosis Centres in Gainsville, Georgia specifically for the osteoporosis population [11]. The SFM builds on the constructs and tasks included in the CS-PFP and PPT and quantifies performance in terms of body mechanics and movement strategies. In addition to the nine tasks that closely represent typical daily activities (pouring water into a glass, donning and doffing shoes and socks, picking up a newspaper, reaching overhead with a weight, sweeping, loading and unloading a washing machine, loading and unloading a dryer, sitting on the floor with legs stretched out in front, carrying weights while walking, looking side to side, and climbing stairs), there is an "emergency" task to assess proprioception [12]. For ease of administration, a short form of the SFM (SFM-SF) is used in which the sweeping and laundry tasks are excluded [11]. Using standardized verbal instructions, the patient is asked to complete each task as they typically would at home. Aspects of movements are observed and scored according to six domains (spinal loading, balance, upper body strength, lower body strength, upper body flexibility, and lower body flexibility) [12]. An ordinal scoring system reflects the quality of movement and if strategies are used, which lower the risk for osteoporotic fracture by modifying the task or environment such that loads on the spine are reduced.

A means of quantifying body mechanics and movement strategies typically used to complete activities of daily living is needed for individuals at risk for osteoporotic fracture. Such a tool would be useful for evaluating the effectiveness of exercises and education regarding avoidance of postures and movements involving trunk flexion. Preliminary data are now available regarding measurement properties of the long form of the SFM; test–retest reliability is excellent (intraclass correlation coefficient (ICC)=0.89), and SFM scores demonstrate the expected association with PPT scores (r=0.56) [13]. The aim of this study was to provide an independent investigation of the measurement properties of the SFM-SF. The primary objective of this study was to evaluate the test–retest and inter-rater reliability of the SFM-SF scores in community-dwelling older adults at risk for osteoporotic fracture. The secondary objective was to determine the construct convergent validity of the balance domain.

Method

Design

Testing was completed at an outpatient osteoporosis clinic. Test–retest reliability was established by having participants complete the SFM-SF on two occasions according to standardized procedures. To minimize learning effects and biological changes, retesting was completed in 8.7 (5.9) days (minimum 2, maximum 21) and subjects were asked if they had experienced any changes regarding physical abilities, medication status, and/or pain levels since their previous visit. On one of these occasions, two testers independently scored performance on the SFM-SF, and participants completed additional balance tests following the SFM-SF.

Participants

Individuals attending a rheumatology outpatient clinic and from the surrounding community were invited to participate in our study. Individuals in the community were contacted through an osteoporosis workshop, seniors' health fair, and seniors' fitness programs based locally. Inclusion criteria were subjects with a diagnosis of low bone mass, able to ambulate, able to understand verbal English, and having no cognitive or visual impairments.

Ethics

The study protocol was approved by our institutional Research Ethics Review Board, and informed consent was obtained from all participants prior to testing.

Testers

Both testers were rehabilitation therapists who were instructed in the administration of the SFM-SF during a 2-day workshop provided by the developers. Credentialing was based on the association of the trainer's score for each item on the SFM with the trainee's score determined for a simulated patient who was observed performing the SFM in a training video. Reliability was characterized using the Spearman's correlation coefficient, and both testers achieved the criteria for credentialing ($r \geq 0.85$). Tester 1 completed all measures required for establishing test–retest reliability of the SFM-SF and validity of the balance domain. Testers were blind to each other's scores, and tester 1 did not have access to prior test results.

Measures

SFM-SF

The SFM-SF is available from the developers.[1] The test is easy to administer with standardized procedures and instructions. As a precaution, subjects are required to wear a safety belt during testing. Physical performance is scored according to quality of movement related to spinal loading (0 to 1 ordinal scale on nine items associated with six tasks, maximum domain score=9), balance (0 to 2 ordinal scale on 10 items and 0 to 1 ordinal scale on one item associated with 6 tasks, maximum domain score=21), upper body strength (0 to 2 ordinal scale on three items associated with three tasks, maximum domain score=6), lower body strength (0 to 2 ordinal scale on one item and 0 to 1 ordinal scale on two items associated with three tasks, maximum domain score=4), upper body flexibility (0 to 1 ordinal scale on two items associated with two tasks, maximum domain score=2), and lower body flexibility (0 to 1 ordinal scale on four items associated with two tasks, maximum domain score=4). Individuals are not required to complete a task unless they have performed it within the last 6 months. The scores for each domain are summed (maximum score=46) with the higher score indicating better balance, flexibility and strength, and lower spinal loading forces. The SFM-SF takes approximately 20 min to complete.

Timed Up and Go test (TUG)

The TUG measures the time (seconds) taken by an individual to stand up from an arm chair, walk 3 m, turn, and walk back to the chair as quickly as possible while maintaining safety, and sit down [14]. There is no limit to the amount of time an individual may take to complete the test; a shorter time indicates a higher functional ability. The assessment is easy to administer using standardized procedures and requires no formal training. The TUG has excellent inter-rater reliability (ICCs from 0.92 to 0.99) but poorer test–retest reliability (ICC=0.56) [14]. Appropriate correlations with other measures of performance suggests acceptable construct convergent validity (gait speed, $r=0.75$; postural sway, $r=0.48$; step length, $r=0.74$) [14].

Berg Balance Scale (BERG)

The Berg Balance Scale (BERG) evaluates an individual's ability to assume static and dynamic positions of increasing difficulty, and subjects are scored on an ordinal scale (0 to 4) as they complete 14 tasks [15]. A higher score indicates a greater ability with a maximum score of 56 points [15]. The assessment is easy to administer using standardized procedures and minimal equipment, requires no formal training, and is completed in approximately 10 min. Test–retest and inter-rater reliability of the BERG in community-dwelling older adults is excellent (ICC=0.99 and 0.98, respectively) [16]. Appropriate correlations with other balance measures suggest good construct convergent validity (Tinetti balance assessment, $r=0.91$; TUG, $r=0.76$) [17].

Community Balance and Mobility Scale (CBMS)

The Community Balance and Mobility Scale (CBMS) is a high level balance and mobility test that incorporates multitasking and functional activities such as walking while bending to pick up object, descending stairs with a laundry basket, changing directions, and walking while looking and carrying [18]. Performance is scored according to speed, foot placement, and deviation from an 8-m track using a six-point scale (0, worst performance to 5, best performance) for a maximum score of 96 points [18, 19]. Excellent inter-rater and test–retest reliability (ICC=0.98 for both) has been reported for the CBMS when administered to high-functioning subjects with traumatic brain injury [18]. Face validity was supported in a study comparing CBMS scores for healthy individuals in different age groups [19]. CBMS has been used to determine if balance was related to falls and if a training program was effective in reducing the risk of falls [20, 21]. Subjects with BERG scores <45 did not complete the CBMS [22]. We anticipated that the community-dwelling older adults in our study would be high-functioning, and ceiling effects on the BERG would be observed.

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Statistical analysis

All statistical analyses were performed using SPSS (SPSS release 16.01, SPSS Inc, Chicago, IL, USA). All data were tested for normality (standardized skewness = skewness statistic÷standard error of the skewness statistic with values >−3.29 and <3.29 confirming normality). Data were summarized using the mean (SD) and median (minimum, maximum).

Reliability

We tested the statistical hypothesis that scores on the SFM-SF are reliable on repeated testing and when two different testers observe the same performance using type 2,1 ICC [23], the standard error of the measurement (SEM), and the minimal detectable change at the 90% confidence interval (MDC_{90}; $MDC_{90} = SEM \times \sqrt{2} \times 1.65$) [24]. Investigation of systematic errors in duplicate scores (for both time and tester) on the total SFM-SF and each domain was conducted using Bland and Altman plot analysis [25]. A sample size of 36 participants was determined based on the objective of estimating a reliability of 0.85 (using the ICC) with a projected 95% lower limit of 0.75 [26].

Construct convergent validity

We tested the statistical hypothesis that the balance domain of the SFM-SF is negatively associated with TUG scores and positively associated with BERG and CBMS scores using Spearman's correlation coefficients. We hypothesized that the association with CBMS would be stronger since it includes functional movements with a similar level of difficulty as those in the SFM-SF. Furthermore, the BERG contains tasks not normally completed during typical daily activities, and the TUG characterizes better balance according to speed rather than quality of movement. An acceptable association was set at $r \geq 0.65$ for establishing construct convergent validity.

Results

Participants

Fifty-three individuals expressed interest in our study. Of these individuals, 15 declined to participate, one did not meet inclusion criteria, and one was unable to return for the second visit. The 36 participants had a mean age (SD) of 69 (8.1) years, and the majority were women (n=31), recruited from the Osteoporosis Clinic (n=28), and ambulated without a cane or walker (n=34). Based on t scores determined using dual-energy x-ray absorptiometry (DXA), 32 participants were classified as having osteoporosis, and four participants were classified as having ostepenia. All participants were taking medication to prevent bone loss.

Only two subjects reported a change in pain status prior to being re-tested. These changes in pain symptoms were unrelated to osteoporosis or prior testing and did not impact performance on the SFM-SF.

Reliability

Scores on SFM-SF spinal loading and lower body flexibility domains were normally distributed (Table 1). The skewed distribution of scores on the other four domains and total test is indicative of the high level of physical function observed for most subjects (Table 1). The upper body flexibility domain of the SFM-SF was minimally demanding, and no variance among subjects or between occasions was observed.

Test–retest reliability

Test–retest reliability of the SFM-SF total score and the balance domain was excellent (Table 2). However, the precision of the estimated reliability for the spinal loading domain was poor (95%CI 0.33, 0.77). The Bland–Altman plots for each task contributing scores to this domain were reviewed. No systematic differences in test–retest scores for the total SFM-SF and spinal loading domain were observed as a function of the mean values (Fig. 1, closed circles). The removal of the scores for items related to the pour task did not adversely affect the level of agreement for the total SFM-SF scores on visit 1 and visit 2 (Fig. 1a, dashed lines) and improved the level of agreement for spinal loading domain scores (Fig. 1b, dashed lines). Deletion of the pour task scores lowered the maximum possible score for the spinal loading domain by three points and the total SFM-SF by nine points.

Inter-rater reliability

Inter-rater reliability was excellent for the SFM-SF total score and balance domain score (ICC=0.95 (0.91, 0.98) and 0.95 (0.90, 0.98), respectively) and good for the spinal loading domain (ICC=0.80 (0.63, 0.89)).

Construct convergent validity

Thirty-two individuals completed the CBMS. Three individuals did not complete the CBMS because their BERG score was less than 45, and one individual opted not to complete the test. Only the CBMS scores were normally distributed (Table 3). The skewed distribution of scores on

Table 1 Total and domain scores on the safe functional motion—short form test recorded on two occasions and by two raters

SFM-SF test score (maximum possible score)	Median	Min, Max	Standardized skewness[a]
Total (46)			
Visit 1	40	17, 44	−5.18
Visit 2	40	16, 45	−5.38
Rater 1	40	17, 45	−5.18
Rater 2	39.5	17, 45	−4.85
Spinal loading domain (9)			
Visit 1	6	1, 8	−2.29
Visit 2	6	3, 8	−0.75
Rater 1	6	3, 8	−1.08
Rater 2	6	2, 9	−0.67
Balance domain (21)			
Visit 1	19.5	10, 21	−4.28
Visit 2	19.5	5, 21	−5.37
Rater 1	19.0	10, 21	−3.62
Rater 2	19.5	8, 21	−4.08
Upper body strength domain (6)			
Visit 1	6	0, 6	−6.04
Visit 2	6	1, 6	−5.97
Rater 1	6	0, 6	−7.37
Rater 2	6	0, 6	−6.99
Lower body strength domain (4)			
Visit 1	4	1, 4	−3.95
Visit 2	4	0, 4	−4.17
Rater 1	4	1, 4	−3.89
Rater 2	4	1, 4	−3.35
Upper body flexibility domain (2)			
Visit 1	2	2, 2	no variance
Visit 2	2	2, 2	no variance
Rater 1	2	2, 2	no variance
Rater 2	2	2, 2	no variance
Lower body flexibility domain (4)			
Visit 1	3	1, 4	−1.12
Visit 2	3	1, 4	−2.60
Rater 1	3	1, 4	−1.55
Rater 2	3	2, 4	−1.28

SFM-SF Safe Functional Motion—short form, *Min* minimum, *Max* maximum

[a] Standardized skewness=skewness statistic÷the standard error of the skewness statistic; standardized skewness >−3.29 and <3.29 indicates that data have a normal distribution

the other balance measures reflects the high level of physical function in most of the subjects (Table 3). Eleven subjects achieved the maximum score of 56 on the BERG; 13 subjects achieved the maximum score of 21 on the balance domain of the SFM-SF. Construct convergent validity of the SFM-SF was good to excellent (TUG, r=−0.69 (95%CI −0.83, −0.47); BERG, r=0.76 (95%CI 0.57, 0.87); CBMS, r=0.82 (95%CI 0.65, 0.91)).

Table 2 Test–retest reliability of the Safe Functional Motion test—short form (SFM-SF) total, spinal loading domain, and balance domain scores for 36 participants at risk for osteoporotic fracture

	ICC (95%CI)	SEM	Limits of agreement	MDC_{90}
Total SFM-SF score	0.90 (0.81, 0.95)	1.85	−5.47 to 4.97	5
Spinal loading domain score	0.59 (0.33, 0.77)	0.99	−3.02 to 2.63	3
Balance domain score	0.87 (0.77, 0.93)	1.16	−3.08 to 3.47	3

ICC intraclass correlation coefficient (type 2,1), *CI* confidence interval, *SEM* standard error of the measurement, MDC_{90} minimal detectable change at the 90% confidence level

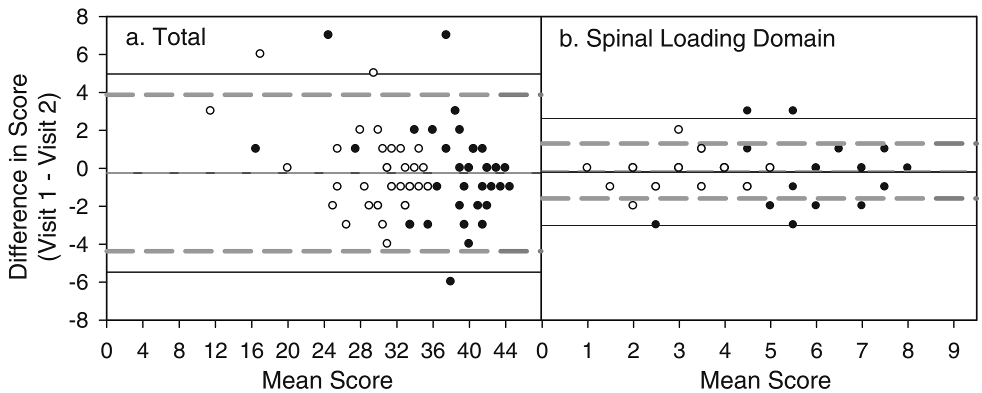

Fig. 1 Difference in scores acquired on two different test days plotted as a function of the mean score for each of the 36 volunteers on the **a** SFM-SF total test and **b** SFM-SF spinal loading domain. *Closed circles* represent the scores when the pour task items are included, and *open circles* represent the scores when the pour task items are removed from the score. Upper and lower reference lines represent the 95% confidence levels for the mean difference in scores with and without the pour task items (*solid* and *dashed lines*, respectively)

Discussion

The main purpose of this study was to establish the reliability of the SFM-SF. In high-functioning community-dwelling older adults at risk for osteoporotic fracture, test–retest and inter-rater reliability of the overall test score is excellent (ICC≥0.90). The spinal loading and balance domains within the SFM-SF are of particular interest for persons at risk for osteoporotic fracture. Test–retest and inter-rater reliability are excellent for the balance domain (ICC=0.87 and 0.95, respectively) but not for the spinal loading domain (ICC=0.59 and 0.80, respectively). Deletion of the pour task items contributing to the spinal loading domain improves the level of agreement between duplicate scores for this domain and does not adversely affect the level of agreement for the SFM-SF total score. Furthermore, the construct validity of the balance domain is supported by the anticipated associations with established performance-based measures of balance.

Scores on the SFM-SF are more consistent when a single performance is scored by two different testers than when two separate performances are scored by the same tester. Reliability of scores is more dependent on the typical variation in the way people perform these routine tasks, particularly with respect to the way they load their spine when bending, reaching, and turning while performing the pour task. This variability notwithstanding, novice testers are able to obtain highly reliable total SFM-SF scores.

Deletion of the pour task items contributing to the spinal loading domain improved the agreement between SFM-SF scores on duplicate testing. The decision to omit these items was guided by inspection of the scores on visits one and two and further supported by literature describing the development of the CPS-PFP short form (PFP/10). In the latter performance-based measure, researchers eliminated a pour task with very similar components to that of the SFM-SF pour task because it did not discriminate between persons living independently and those living dependently [27]. It appears that each person uses a variety of movement strategies to perform this pour task (placing varying loads on the spine each time), which exceeds the variation observed from person to person. There are two advantages

Table 3 Distribution of scores on balance tests

Balance tests (maximum possible score)	Median	Min	Max	Standardized skewness[a]
SFM-SF balance domain (21)	19.5	5	21	−5.37
TUG[b] (s)	8	4	22	5.60
BERG[c] (56)	53.5	32	56	−4.57
CMBS (96)	62	8	87	−1.67

Min minimum, *Max* maximum, *SFM-SF* Safe Functional Motion—short form, *TUG* Timed Up and Go test, *BERG* Berg Balance Scale, *CMBS* Community Balance and Mobility Scale (n=32)

[a] Standardized skewness=skewness statistic÷the standard error of the skewness statistic; standardized skewness <−3.29 or >3.29 indicates that data have a normal distribution

[b] Values ≤13.5 s indicate balance within normal limits [14]

[c] Values ≥45 indicate balance within normal limits for community-dwelling older adults [22]

to removing the pour task from the battery of tasks. Firstly, the level of agreement for test–retest scores on the spinal loading domain score is improved. Secondly, the time and equipment required to administer the SFM-SF is reduced. Further study is needed to determine the utility of using the spinal loading domain score in isolation and to evaluate the measurement properties of the tool when six tasks are performed.

It is challenging to compare our findings regarding test–retest and inter-rater reliability of the SFM-SF total score with that of the other the activity-based measures of physical function appropriate for community-dwelling older adults due to differences in statistical approach and absence of published confidence intervals characterizing the precision of the estimated reliability. Test–retest reliability of CS-PFP scores have been reported using the Pearson correlation coefficient (r=0.97, that is, 94% of the variance in scores at time one is explained by the variance in scores at time two). This estimate of reliability corresponds closely with the test–retest reliability of SFM-SF observed in our study (seven tasks, ICC=0.90) and that of the PPT scores (eight tasks, ICC=0.88). Inter-rater reliability of CS-PFP scores (r=0.98, that is, 96% of the variance in scores assigned by rater 1 is explained by the variance in scores assigned by rater 2) [7] and PPT scores (eight task version, r=0.96; 92% of the variance in scores assigned by rater 1 is explained by variance in scores assigned by rater 2) [9, 28] compare well to the inter-rater reliability of the SFM-SF total scores (95% of the variance explained by subjects and raters).

Construct convergent validity of the balance domain was supported by the associations observed with other established balance measures. Most of our subjects completed the TUG in less than 13.5 s, indicating that they had no balance problem [14]. On average, the subjects in our study performed marginally better on the BERG and completed the TUG more quickly than community-dwelling older adults participating in a balance training program [29], suggesting that physical function levels were generally high. Indeed, ceiling effects were noted on the balance domain of the SFM-SF and the BERG. In contrast, no participants scored higher than 87 out of 96 on the CBMS. As expected, the correlation between the scores on the SFM-SF and the CBMS tended to be stronger as compared to the less physically demanding performance-based balance tasks. However, the overlapping confidence intervals suggest that these differences are not significant.

The limitations of our study must be considered when interpreting these findings. Our study is subject to volunteer bias and scores on the SFM-SF, and other measures of balance indicate that the majority of our volunteers had a high level of physical function. Reliability and validity of the SFM-SF need to be confirmed in individuals at risk for osteoporotic fracture who are less mobile. A second limitation may be the timing of the visits for establishing test–retest reliability. The time interval was selected in order to limit recall of previous performance while minimizing the potential for true biological change. The subjects were instructed to avoid reflection or discussion of their initial performance; however the impact of this memory cannot be discounted. Memory of performance appeared to have a minimal effect given that some subjects opted to perform different tasks during each of the visits when asked if they had performed the task in the last 6 months. Third, neither tester had previous experience using the tool beyond the training workshop. This may have resulted in an underestimation of the reliability of the SFM-SF. However, inter-rater reliability was excellent and, thus, supports the effectiveness of the training and the ability to interchange trained testers.

In this study, we demonstrate that the SFM-SF provides a reliable measure of functional movements and a valid measure of balance in individuals at risk for osteoporotic fracture. The results presented can be applied to evaluate the effect of treatments aiming to improve postural alignment, body mechanics, and physical function. For example, when using the SFM-SF total score, there is 90% certainty that a change of five points represents true improvement or deterioration in performance. Reliability and validity of the balance domain score are acceptable and may be of particular interest for individuals at risk for osteoporotic fracture. To optimize test–retest reliability, we recommend omission of the pour task. Further studies are warranted to investigate the impact of this recommendation on the measurement properties and clinical utility of SFM-SF.

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