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The Reliability of Standing Sagittal Measurements of Spinal Curvature and Range of Motion in Older Women With and Without Hyperkyphosis Using a Skin-Surface Device

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Abstract

Objective: The purpose of this study was to investigate the intrarater reliability of a skin-surface instrument (Spinal Mouse, Idiag, Voletswil, Switzerland) in measuring standing sagittal curvature and global mobility of the spine in older women with and without hyperkyphosis.

Methods: Measurements were made in 19 women with hyperkyphosis (thoracic kyphosis angle ≥50°), mean age 67 ± 5 years, and 14 women without hyperkyphosis (thoracic kyphosis angle <50°), mean age 63 ± 6 years. Sagittal thoracic and lumbar curvature and mobility of the spine were assessed with the Spinal Mouse during neutral standing, full spinal flexion, and full spinal extension. Tests were performed by the same examiner on 2 days with a 72-hour interval. The intrarater reliability of the measurements was analyzed using the intraclass correlation coefficient, standard error of measurement and minimal detectable change.

Results: Intraclass correlation coefficients ranged from 0.89 to 0.99 in both groups. The standard errors of measurement ranged from 1.02° to 2.06° in the hyperkyphosis group and from 1.15° to 2.22° in the normal group. The minimal detectable change ranged from 2.85° to 5.73° in the hyperkyphosis group and from 3.20° to 6.17° in the normal group.

Conclusions: Our results indicated that the Spinal Mouse has excellent intrarater reliability for the measurement of sagittal thoracic and lumbar curvature and mobility of the spine in older women. (J Manipulative Physiol Ther 2017;40:685-691)

Key Indexing Terms: *Spinal Curvatures; Range of Motion; Aging; Kyphosis; Reliability of Results*

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Introduction

Age-related hyperkyphosis can greatly influence functional independence in older persons.[1,2] Hyperkyphosis was initially viewed as equivalent to osteoporosis and vertebral compression fracture[3,4]; however, new evidence highlights the important role back extensor muscles serve in preservation of normal spinal alignment and mobility, as well as prevention of spinal deformity.[5] Also, the benefits of therapeutic interventions on age-related hyperkyphosis have been reported.[6-8] Taken together, reliable methods are needed to assess spinal alignment and mobility and the response to treatment of age-related hyperkyphosis.

The current gold standard for quantification of hyperkyphosis is measurement of the Cobb angle of kyphosis from lateral spine radiographs.[9,10] However, this method is limited by the inability to clearly locate bony landmarks on poor-quality images,[11] dependence of the Cobb angle on endplate tilt of upper and lower vertebrae at the target curve,[3,10] and the high costs and high exposure to potentially harmful doses of radiation.[12] Many non-invasive external methods have been developed including the Debrunner kyphometer,[13] the flexicurve,[14] the inclinometer[15] and the Spinal Mouse.[16] Several studies have reported high reliability for the flexicurve ruler (intraclass correlation coefficient [ICC] 0.86-0.96)[14,17,18] and the Debrunner kyphometer (ICC 0.95-0.98)[14,19,20] tools for measurement of kyphosis among older women, and 2 studies reported no difference in the reliability of these devices.[14,17] The Debrunner kyphometer is no longer manufactured, and measurement with the kyphosis angle from the flexicurve requires additional time and a special formula.[16] Azadinia reported that the intrarater reliability of the flexicurve is acceptable (ICC >0.80) and that the inclinometer has higher intrarater reliability (ICC >0.95) than the flexicurve for the measurement of thoracic kyphosis the in age groups 10-30 years and 50-80 years.[21]

Another tool for measuring kyphosis is the Spinal Mouse, a noninvasive electronic computer-aided device that is moved along the length of the spine to quantify thoracic, lumbar, hip, and trunk curvature and mobility. A relatively unique property of this device is that it provides quick measurements of thoracic, lumbar, hip, and trunk curvature and mobility.[22] Results of previous studies on the reliability of the Spinal Mouse indicated good reliability for the measurement of spinal curvature and mobility (ICC 0.63-0.96); however, these studies were done in children and young persons.[16,22,23] The reliability of the Spinal Mouse has not been investigated in older persons with and without hyperkyphotic posture. Before widespread use of this device in clinical assessment, further research should be performed to evaluate the reliability of Spinal Mouse measurements in older adults with and without hyperkyphosis.

Given these limitations, we investigated the intrarater reliability of the Spinal Mouse for measurement of sagittal thoracic and lumbar curvature and mobility of the spine in older women with and without hyperkyphosis.

Methods

Participants and Experimental Design

This reliability study was carried out in a university biomechanics laboratory. Participants consisted of healthy, community-based older women (N = 38), recruited through advertisements at urban entertainment districts. Inclusion criteria were age 60-80 years, body mass index 25-33, ability to walk without an assistive device, and ability to stand independently and hold the position for the duration of testing. Participants with scoliosis, kyphoscoliosis, a history of back pain within the last year requiring medical attention, previous surgical interventions on the spine, and any spinal disease or malignancy were excluded. The study was approved by the ethics committee of Shahid Beheshti University of Medical Sciences (Tehran, Iran) (Ethics Committee No. 93617). Prior to the study, each participant signed a written informed consent.

Although a power analysis is essential for hypothesis testing, we did not test a hypothesis in our reliability study. To determine reliability, approximately 15-25 participants are required and are an adequate number in each group.[24] Eligible women were assigned at enrollment to either a hyperkyphosis (n = 20) group or normal (n = 18) group, according to the Spinal Mouse kyphosis measurement. In this study, hyperkyphosis was defined as a thoracic kyphosis ≥50°.[25,26] Five participants withdrew from the study for personal reasons (1 in the hyperkyphosis group, 4 in the normal group); therefore, 33 healthy older women (hyperkyphosis group: n = 19, normal group: n = 14) completed the study and were included in the analysis.

Instruments

A computer-assisted skin-surface device (Spinal Mouse, Idiag, Voletswil, Switzerland) used to measure spinal curvature and mobility by gliding the device manually down the back.

Procedure

Participants were tested at 2 visits within a 72-hour interval. Before the initial test day, participants attended 1 session to be familiarized with the equipment and procedures. Measurements were performed by the same examiner experienced in using the Spinal Mouse. On both test days, equipment and assessment procedures were the same. During the second test, the examiner was blinded to the test results of the previous day.

Body Composition

Height (cm) using a standard stadiometer and weight (kg) using a standard scale were collected at the initial visit. body mass index was calculated (kg/m^2).

Spinal Curvature and Mobility

Measurements of spinal curvature and mobility in the sagittal plane were performed with the Spinal Mouse in 3 test positions (Fig 1A-C):

1. Neutral standing: The participant assumed a relaxed position with the head looking forward and focused on a marker at eye level, with the feet shoulder width apart, knees straight, and arms by the side (Fig 1A).
2. Maximal flexion: With the legs straight, the participant was asked to slowly flex the trunk as far as possible, aiming to curl the head into the knees and grip hands behind the back of the lower legs for stability (Fig 1B).
3. Maximal extension: With legs straight, the participant was asked to cross arms over the front of the body and extend the trunk as far as possible (head was kept in neutral) (Fig 1C).

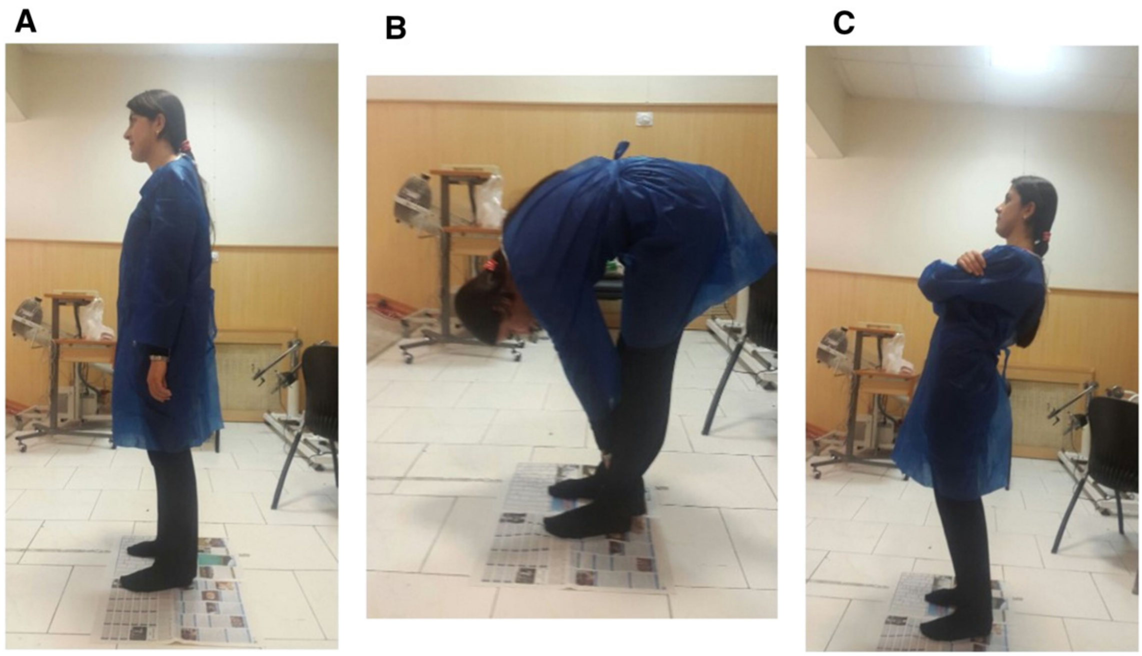

Fig 1. *Test positions for spinal measurements. (A) Neutral standing. (B) Maximal flexion. (C) Maximal extension.*

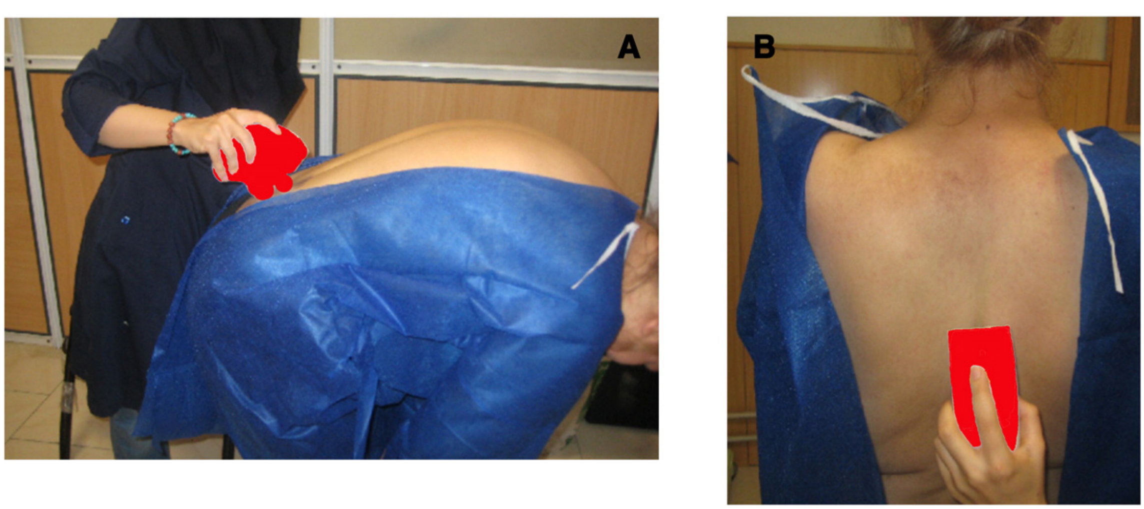

Fig 2. *Example of a typical measurement with the Spinal Mouse. (A) Full flexion. (B) Full extension. To achieve accurate recordings, both wheels of the Spinal Mouse need to stay in contact with the skin at all times.*

These positions were first described and demonstrated by the examiner and practiced once by the participant. No warm-up was performed before the measurement.[22] The spinous process of C7 and the top of the anal crease (approximately S3) were marked with a cosmetic pencil, and the Spinal Mouse was placed at C7 and manually guided along the midline of the spine to the top of the anal crease. Both wheels of the Spinal Mouse were maintained in contact with the skin and were guided along the midline at slow and constant speed (Fig 2). Three sets of measures in each position were carried out 1 to 2 minutes apart.

Sagittal curvature was calculated in each of the 3 described positions using the Spinal Mouse software. Thoracic curvature was calculated from T1-12, lumbar curvature from L1-S1, and angle of inclination from an angle between the vertical and a line joining C7 to the sacrum. For each region of thoracic, lumbar, hip, and whole trunk, the range of motion is calculated based on the mobility in the sequence of full flexion minus full extension. These procedures were repeated on the next day of testing, at approximately the same time, for each participant.

Statistical Analysis

Baseline demographic characteristics are presented as the mean ± standard deviation (SD). Normality of distribution for all variables was determined using the Shapiro-Wilk test in both groups ($P > .05$). To evaluate intratester reliability of the spinal curvature and mobility measurements, intraclass correlation coefficients (ICCs) (1-way random model, average measures) were calculated with corresponding 95% confidence intervals. The criteria of Munro were used for interpretation of ICC: 0.00-0.29 = very low correlation, 0.30-0.49 = low correlation, 0.50-0.69 = moderate correlation, 0.70-0.89 = high correlation, and 0.90-1.00 = very high correlation.[27] Also, the standard error of measurement (SEM) (SEM = SD of first test × square root of 1 – ICC) and minimal detectable change (MDC) (MDC= SEM × 1.96 × square root of 2) for all variables were calculated. For all statistical tests, a significance level of .05 was used. All analyses were performed with the SPSS statistical software (Version 16.0) (SPSS Inc, Chicago, Illinois).

Results

The study population consisted of 2 groups of healthy, community-dwelling women, 19 with hyperkyphosis (mean kyphosis = 55.5°, SD = 6.4°) and 14 with a normal curvature (mean kyphosis = 39.5°, SD = 5.3°). The mean age was 67 (SD = 5.0) in the hyperkyphosis group and 63 (SD = 6.0) in the normal group (Table 1). The values of the mean for all measurements on 2 testing days are provided in Table 2.

The ICC ranged from 0.89 to 0.99 in both groups (0.90-0.99 in the hyperkyphosis group and 0.89-0.99 in the normal group) (Table 3). The majority of ICCs (87% in the hyperkyphosis group and 75% in the normal group) were >0.90.

The between-day SEM ranged from 1.02° for inclination angle to 2.06° for range of motion of the hips in the hyperkyphosis group, and from 1.15° for inclination angle to 2.22° for range of motion of the trunk inclination in the normal group. The MDC ranged from 2.85° for inclination angle to 5.73° for range of motion of the hips in the hyperkyphosis group, and from 3.20° for inclination angle to 6.17° for range of motion of the trunk inclination in the normal group (Table 3).

Discussion

The present study evaluated the reproducibility of the Spinal Mouse for measuring spinal curvature and mobility. To our knowledge, this is the first study investigating the intrarater reliability of Spinal Mouse assessment of spinal curvature and mobility in older women. Our results revealed that the Spinal Mouse has excellent intratester reliability for measuring spinal curvature and mobility in women with and without hyperkyphosis (ICC 0.89-0.99). Our results suggest that the Spinal Mouse device is capable of measuring these variables with consistency.

We report higher reliability (ICCs 0.89-0.98) of the Spinal Mouse for measuring spinal curvature than previously reported in other studies. Kellis et al investigated intrarater reliability of spinal curvature using the Spinal Mouse in 81 healthy children (10.6 ± 1.7 years). The intrarater ICC ranged from 0.67 to 0.93.[23] In another study, Mannion et al examined the interrater reliability (2 raters) and test–retest reliability of the Spinal Mouse in 20 healthy volunteers (mean age: 41 ± 12 years).[16] Intrarater ICCs ranged between 0.73 and 0.90 and between 0.83 and 0.93 for examiners 1 and 2, respectively. In the Mannion et al study, the majority of ICCs were >0.80,[16] but the ICC values were lower than in the present study. These discrepancies can be explained by differences in age of the study samples given that Kellis et al enrolled children and Mannion enrolled participants with a mean age of 41 ± 12 years. Although our participants were older women, they were physically active and robust enough to be able to follow the testing protocols. Furthermore, in our study, particpants attended in 1 session prior to the testing session to familiarize themselves with the study protocol, which could have improved results.[28] On the other hand, our results for reliability of spinal curvature measurements are within the range of previously reported values for the Debrunner kyphometer,[19] the flexicurve ruler,[14] and the inclinometer.[21] Similar to the Spinal Mouse, these tools are inexpensive, easy to use, and do not involve high cost or high exposure to radiation. In contrast to the flexicurve ruler, the Spinal Mouse is also capable of quick, precise, and real-time detection of variations of different spinal regions without needing a special formula to calculate results.

For spinal mobility, we report similarly higher intrarater ICCs in both our groups (0.96-0.99) compared with the results of Kellis et al (ICCs 0.63-0.96)[23] and Mannion et al (ICCs 0.70-0.94).[16] This difference may be related to inconsistencies in both participant performance (participant might not be in the same position on the 2 days)[22] and rater performance (inconsistent marking of the spinous processes

Table 1. *Baseline Demographic Characteristics of the 33 Participants*

Variable	Hyperkyphosis Group (n = 19) [a]	Normal Group (n = 14) [a]
Age (years)	67 ± 5	63 ± 6
Height (cm)	156 ± 4.8	153 ± 5.5
Weight (kg)	69.3 ± 7.7	62.7 ± 9.8
Body mass index (kg/m^2)	28.5 ± 3.4	26.7 ± 3.4
Thoracic kyphosis (°)	55.5 ± 6.4	39.5 ± 5.3
Lumbar lordosis (°)	–35.3 ± 9.8	–33. ± 8.1

[a] Mean ± standard deviation.

Table 2. *Descriptive Statistics for All Measurements on 2 Different Days*

	Hyperkyphosis Group (n = 19)		Normal Group (n = 14)	
Variable	Test [a]	Retest [a]	Test [a]	Retest [a]
Thoracic kyphosis (°)	55.5 (6.4)	54.4 (7.4)	39.5 (5.3)	40 (5)
Lumbar lordosis (°)	–35.3 (9.8)	–34.5 (10)	–33 (8.1)	–33 (9)
Hip (°)	14.6 (9.6)	14.7 (9.8)	16.6 (7.5)	17.4 (8.1)
Trunk inclination (°)	–0.1 (3.2)	0.3 (4)	–0.8 (3.5)	0.3 (3.7)
Thoracic ROM (°)	14.1 (9.5)	13.4 (10.6)	18.1 (11.5)	19.5 (10.7)
Lumbar ROM (°)	42.8 (13.7)	43.5 (13.2)	52.6 (14.5)	52.3 (16.1)
Hip ROM (°)	74.4 (20.7)	74.7 (21.7)	63.3 (17)	63.4 (17.8)
Trunk inclination ROM (°)	116.9 (14.4)	117 (14.8)	114.3 (15.8)	114.6 (15.7)

ROM, range of motion.
[a] Mean (standard deviation).

Table 3. *Intrarater Reliability of Spinal Curvature and Mobility Assessments*

	Hyperkyphosis Group (n = 19)			Normal Group (n = 14)		
Variable	ICC (95% CI)	SEM (°)	MDC (°)	ICC (95% CI)	SEM (°)	MDC (°)
Thoracic kyphosis	0.94 (0.86-0.98)	1.56	4.33	0.89 (0.69-0.96)	1.75	4.86
Lumbar lordosis	0.97 (0.92-0.98)	1.70	4.71	0.97 (0.93-0.99)	1.41	3.91
Hip	0.98 (0.96-0.99)	1.36	3.77	0.94 (0.84- 0.98)	1.83	5.09
Trunk inclination	0.90 (0.74- 0.96)	1.02	2.85	0.89 (0.67-0.96)	1.15	3.20
Thoracic ROM	0.96 (0.90- 0.98)	1.90	5.28	0.97 (0.92-0.99)	1.99	5.52
Lumbar ROM	0.98 (0.97- 0.99)	1.93	5.36	0.98 (0.96- 0.99)	2.05	5.69
Hip ROM	0.99 (0.98- 0.99)	2.06	5.73	0.99 (0.98- 0.99)	1.69	4.69
Trunk inclination ROM	0.98 (0.97-0.99)	2.04	5.65	0.98 (0.96-0.99)	2.22	6.17

CI, confidence interval; *ICC,* intraclass correlation coefficient; *MDC,* minimal detectable change; *ROM,* range of motion; *SEM,* standard error of measurement.

and incorrect movement of the mouse over these points in full flexed and extended positions) in the other studies. Another study examined the interrater reliability (2 raters) and test–retest reliability of global and segmental thoracic and lumbar end-range motion measurements using the Spinal Mouse in 40 adult participants (20 with low back pain [group 1], 20 without low back pain [group 2]). This study determined intra-rater reliability as the within-session, intertrial ICC. The ICCs of global thoracic ROM in both groups ranged from 0.76 to 0.85 and from 0.80 to 0.86 for testers 1 and 2 respectively. The ICCs of global lumbar ROM in both groups ranged from 0.46 to 0.96 and from 0.77 to 0.92 for testers 1 and 2, respectively. They reported inconsistent contact between device and spine in several cases that resulted in decreased reliability.[29] We decreased the potential for positioning errors by developing specific standardized protocols and rater performance errors by providing standardized verbal commands and we also provided participants with a session to familiarize them with the protocol. However, Guermazi et al evaluated the reliability of the Spinal Mouse for assessment of lumbar flexion in 45 younger adults (20-29 years old), and they reported somewhat similar reliability (ICC 0.95) for global lumbar motility.[30]

Because ICC values alone do not reveal absolute differences between measurements,[31] the SEM and MDC are often calculated to estimate the amount of error of the measurement and to help separate true change from measurement error.[32] For the spinal curvature variables, the values of SEM of the present study were lower than those in the studies of Mannion et al (SEM 1.0°-4.2°)[16] and Kellis et al (1.19°-4.01°).[23] Furthermore, our SEMs of variables of mobility were lower than those in the studies of Kellis et al (SEM 4.24°-9.55°) and Mannion et al (4.0°-6.7°), indicating better reproducibility in our study than previously reported for spinal curvature and mobility. Although error is inevitable with the contribution of multiple segments of spine,[23] we used a precise standardized protocol and an experienced assessor, which may have reduced the error and improved consistency in our measurements. It might also be possible that the spine in older women is easier to measure reliably because it is less flexible than the spine of younger adults and children. Regardless, Atkinson et al argue that SEM underestimates true change and suggests that the MDC should be used instead,[33] because the MDC, the threshold of measurement considered the minimum amount of change in a patient's score that ensures the change is not the result of measurement error, provides a better index of difference between measurements.[34] The MDCs we calculated ranged from 2.85° to 5.73° in the hyperkyphosis group and from 3.20° to 6.17° in the normal group across all variables. None of the previous studies calculated MDC values, so we are unable to make a comparison.

Based on the results of our study, we suggest that the Spinal Mouse can be used in a clinical setting for reliable assessment of spinal curvature and mobility in older women with and without hyperkyphosis, and considering the ease of use and low health risk for the patient, this device may also be useful in serial monitoring of the change in spinal curvature over time. According to the SEM results of the current study, in hyperkyphotic women, a decreased kyphosis angle >2° should be considered true change. If we use MDC values, a decreased kyphosis angle >6° is a therapeutic effect. In comparison with the SEM, MDC is more conservative and may cause clinicians to ignore less robust effects of clinical interventions.[35]

Limitations and Strengths

Our study has several limitations. First, we did not investigate intertester reliability, because participants would have to repeat the testing by 2 testers on 2 days, and we considered this an excessive burden on our participants. Second, we were not able to compare ICCs of the current study with those of other published studies in the same population of older adults because there have been no previous studies testing the reliability of the Spinal Mouse in older adults. Therefore, our results cannot be generalized to the overall population, although we have now contributed data that can be useful for future age-grouped comparisons. Third, we included only women in our study even though age-related hyperkyphosis affects both sexes. Future studies should investigate the reliability of the Spinal Mouse in older men.

Our study had a number of strengths. First, it was the first study we know of that examined the reproducibility of the Spinal Mouse in 2 groups of older women, with and without hyperkyphosis. Second, we included 1 familiarization session. Third, all measurements were performed by 1 experienced examiner using specific and standardized instructions during measurements, which likely decreased potential error and produced better results than reported by previous studies. Future studies are needed to assess the intrarater reliability of the Spinal Mouse in older men, and the interrater reliability of the Spinal Mouse in participants of both sexes and among individuals with different degrees of thoracic kyphosis.

Conclusion

Our study reports very high intrarater reliability of the Spinal Mouse for the measurement of spinal curvature and mobility in older women with and without hyperkyphosis. Although the Spinal Mouse cannot replace the gold standard evaluation of spinal curvature with lateral spinal radiographs, our study suggests that this device can be used to reliably assess spinal curvature and mobility in older women with and without spinal deformities. We determined the standard error of measurement and minimal detectable change for all spinal measurements and this information can be used by clinicians and researchers when assessing spinal curvature and mobility with the Spinal Mouse after an intervention.

Funding Sources and Conflicts of Interest

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Contributorship Information

Concept development (provided idea for the research): T.R., M.K.Z., S.T., W.K.
Design (planned the methods to generate the results): T.R., S.T., A.R.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): W.K.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): T.R., M.K.Z.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): T.R., S.T., A.R., F.D.M., A.A.B.
Literature search (performed the literature search): T.R., M.K.Z., F.D.M.
Writing (responsible for writing a substantive part of the manuscript): T.R., N.K., A.A.B., W.K.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): T.R., M.K.Z., A.R., S.T., F.D.M., A.A.B., N.K., W.K.

Practical Applications

- Spinal Mouse is a reliable and easy-to-use tool to evaluate standing sagittal measurements of spinal curvature and mobility in older women with and without hyperkyphosis.
- The standard error of measurement and minimal detectable change provide guidance as to what changes in the kyphosis angle constitute real change of an intervention.

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