

## Inter-tester and Intra-tester Reliability of a Clinically Based Spinal Height Measurement Protocol

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### Abstract

**Background:** Spine height is related to disc hydration and activity. We aimed to establish inter- and intra-tester reliability for spine height measurements using a commercially available stadiometer that can be utilized in clinical settings.

**Methods:** Twenty-nine healthy men and women (mean age = 29 ± 3.2 years) volunteered to participate. Each subject was seated in the stadiometer for 10 minutes with a 4.5 kg weight placed on each shoulder. The load was removed and spine height was measured every minute for five minutes by two different testers. Measurements were repeated twice more by one tester.

**Results:** The means of the standard deviations were smaller than the mean differences, suggesting low variability and good reliability. The intraclass correlation coefficient was 0.99 for both testing sequences.

**Conclusions:** This is the first study to establish the inter-tester and intra-tester reliability of measuring spinal height using a commercially available clinic based stadiometer protocol.

**Keywords:** Intervertebral disc; Spinal height; Stadiometer

### Introduction

The intervertebral disc controls spine segmental movements, accept loads and transmit forces during functional activities [1]. The amount of fluid in the intervertebral disc has a direct relationship to the intervertebral discs ability to sustain and transmits these loads [2].

Eklund and Corlett [3] were the first to report that measures of changes in spinal height were representative of changes in intervertebral disc height [3]. Subsequent researchers found that the time of day had an influence on disc height, ultimately discovering that there was a 19.3 mm height increase after subjects had slept for six hours [4]. Exercise activities have been shown to influence disc volume and spinal height and consequently effects the disc's ability to distribute loads [5-8].

Instrument and methodological reliability are at the foundation of clinical measurement. Numerous investigators have used stadiometric measurements to examine spinal height changes. Some of these studies have been designed to examine the reliability of custom laboratory based stadiometer protocols. Stothart and McGill [9] studied the variability of trunk height measurements when subjects performed the same task on three consecutive days [9]. The authors found that there was an appreciable amount of measurement variability within subjects over repeated exposures to identical conditions on different days. Additionally, they tested the consistency of the stadiometer measurements using two different methods. The first method asked 10 subjects to step in and out of the stadiometer apparatus for 10 trials "in-out" method (Range of SD = 0.84mm to 1.3mm). The second method asked subjects to remain in the stadiometer apparatus for the 10 trials "staying-in" method (Range of SD = 0.42mm to 0.66mm). The results demonstrated a greater variability for the "in-out" method for the 10 measurements versus the "staying-in" method.

Kanlayanaphotporn et al. [10] examined the reproducibility of spine height changes using a custom laboratory based stadiometer measurement protocol [10]. Asymptomatic and low back pain subjects

were measured on two consecutive days under both loaded and unloaded conditions. The reliability of measuring the asymptomatic subjects at the same time on two different days produced moderate-to-good Intraclass Correlation Coefficients (ICC: 0.59 to 0.85). The low back pain group values ranged from poor to good (ICC = 0.26 to 0.79).

Rodacki et al. [11] examined spine height changes in 10 subjects that were seated and 10 subjects that were standing in a custom made laboratory based stadiometer measurement apparatus. Each subject was measured three times for 10 sets of 5 measurements [11]. Both sitting and standing groups attained a standard deviation below 0.5 which has been established as an acceptable level of variation [3,5].

The most recent reliability study was performed by Healey et al. [12] using a custom laboratory based stadiometer protocol [12]. In this study, twelve subjects with non-disabling low back pain and twelve asymptomatic subjects were asked to sit and stand in the stadiometer apparatus for three sets of ten trials, consisting of five measurements per trial. This same procedure was repeated at the same time of day two weeks later. An ICC of 0.99 was obtained for all subjects in the three sets on the first and second day. This study demonstrated that there is repeatability of spine height measurements between subjects on two different days.

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**Received** December 11, 2011; **Accepted** January 09, 2012; **Published** January 15, 2012

**Citation:** Pennell PL, Owens SC, Brismée J, Dedrick G, James CR, et al. (2012) Inter-tester and Intra-tester Reliability of a Clinically Based Spinal Height Measurement Protocol. J Spine 1:109. doi:10.4172/2165-7939.1000109

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Prior studies that assessed the reliability of stadiometric measurement methods of spinal height used custom laboratory based stadiometer apparatus and procedures. To our knowledge there has been no study to determine if a single tester can reproduce similar trunk height measurements or if multiple testers can reproduce reliable trunk height measurements, using commercially available clinically applicable stadiometer apparatus and measurement protocol. The purposes of this study were to (1) establish the intra-tester reliability of spinal height measurement protocol using a commercially available clinically applicable stadiometer apparatus; (2) establish the inter-tester reliability of spinal height measurements using the same stadiometer measurement protocol and apparatus. We hypothesized that our clinically based measurement protocol would demonstrate acceptable inter and intra-tester reliability.

## Methods

### Study design

A test-retest design was utilized in this study to determine inter and intra-tester reliability commercially available clinically applicable stadiometer apparatus and measurement protocol.

### Subjects

The study was reviewed and approved by the Texas Tech Health Sciences Center Institutional Review Board. Subjects were recruited from the local university work force and student body to participate in study. Before participation in the study all subjects read and signed an informed consent form.

Subjects were healthy individuals who reported neither current spine related symptoms nor any history of spinal pain that required consultation by a physician or hospitalization. Subjects were excluded if they were unable to sit or lie for a minimum of ten minutes without pain or discomfort, reported current upper respiratory symptoms, neurological disorder, or had uncorrectable visual impairments. A diagnosis of spinal deformity including scoliosis and Scheuermann's Disease were also excluded secondary to increased potential for anatomical intervertebral disc abnormality.

### Test apparatus

Spine height was measured using a commercially available stadiometer (235 Heightronic™ Digital Stadiometer, Measurement Concepts, Quick Medical, Snoqualmie, WA). The stadiometer was mounted to a wooden frame.

### Test procedures

All spine height measurements were taken with subjects sitting on a wooden chair, which was securely fixed to the frame. Hip, knee, and ankle positions were consistent with previously published protocols [13,14]. Lumbar and cervical spine foam supports were fitted at both regions for comfort and to assist subjects with maintaining consistent body positioning. The size and position of each foam support was recorded for each subject. Safety glasses with a laser pointer attached to the lateral side of the frame were secured with an elastic strap to ensure a snug fit. The laser was projected on a non-reflective board 2.74 m in front of the subject. The projected point was marked by a square magnet attached to the board. Subjects were instructed to maintain the laser image directly on the square to maintain a consistent head position during all measurements. Once subjects were correctly positioned, the stadiometer head caliper was lowered to the top of the subject's head. Once full contact was achieved, stadiometer (spine height) readings were recorded.

### Testing sequence

A familiarization session was conducted, where the subjects were trained on positioning in the stadiometer. The subjects positioned themselves into the stadiometer in the manner described above. A measurement was taken followed by the subjects getting out of the stadiometer and walking two laps around the room. Subjects then repositioned themselves into the stadiometer and a measurement was taken. This sequence was repeated for ten trials. These practice sessions of ten were repeated until subjects were able to reposition in the stadiometer with a standard deviation of equal or less than 1.3 mm for five consecutive trials [9]. Additional practice trials were performed until this standard deviation criterion was achieved.

After practice and prior to the initial stature measurement, subjects lay supine for ten minutes. After this height normalization, subjects were assumed the stadiometer measurement position previously described above (Figure 1). A 4.5 kg sand bag weight was placed over each shoulder. Following five minutes of this loaded sitting, the load was removed and the testers recorded stadiometer measurements. Measurement outcomes on the computer were masked during the testing procedures, to ensure blinding of the testers.

To establish the inter-tester reliability, stadiometry measurements were recorded at the beginning and at every minute for a total of five minutes independently by two testers (Tester 1 and Tester 2), with the order of the tester performing the measurements randomized. After the subject was properly positioned, a tester (Tester 1 or 2, depending on the randomization) entered the room and then lowered the stadiometer head platform to the top of the subject's head. Once full contact was achieved, the subject inhaled and then maximally exhaled. The stadiometer (trunk height) readings were recorded at the end of the exhalation. After the first tester exited the room, the other tester immediately entered the room and recorded a trunk height measurement in the same fashion as the first tester. This "staying-in" method of measurement by two testers was conducted as soon as the weight was removed and repeated every minute for five minutes in the manner described above (Figure 2).

To establish intra-tester reliability, Tester 1 performed three measurements on the same subject using the "in-out" method. Tester



Figure 1: Stadiometer with subject in test position.

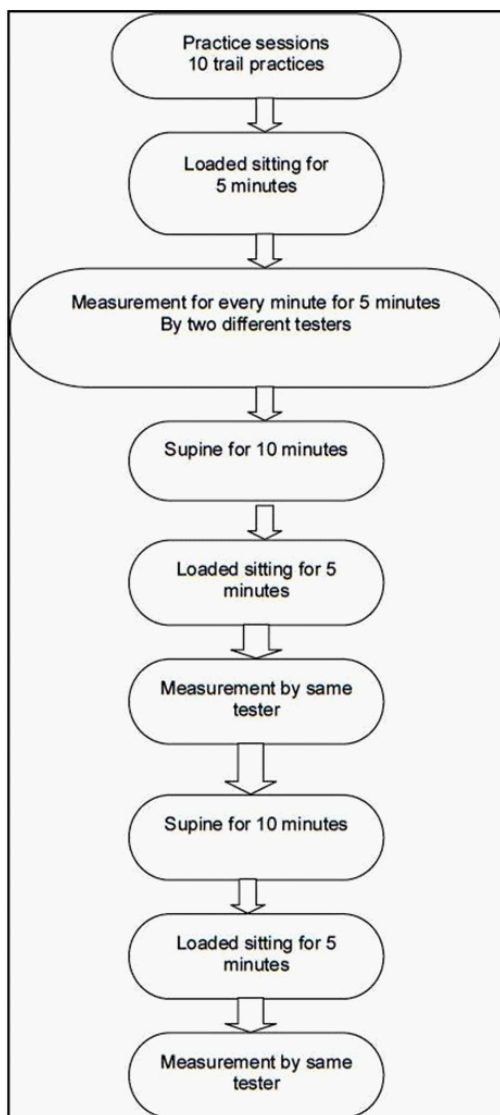


Figure 2: Time line of testing sequence.

I recorded the first measurement after weights were removed from the subject. The subject was supine for 10 minutes in the position described above. After 10 minutes the subject was repositioned in the stadiometer and weights were placed on each shoulder for 5 minutes. Weights were immediately removed and subject’s height was recorded at the end of the maximal exhalation. The sequence of supine lying and sitting in the stadiometer was repeated one more time for a total of three measurements taken by one tester (Figure 2).

### Data analysis

An intraclass correlation coefficient (ICC) was used to analyze the consistency and agreement of the single-tester measurement and the two-tester measurements. Means and standard deviations (SDs) were calculated for spinal height changes measured after 5 minutes of loaded sitting, and measurements after the load had been removed. A factorial ANOVA was used to determine the difference in the SDs of the measurement sets for the single-tester measurement and two-tester measurements. All analyses were performed on SPSS version 14.0 for Windows.

### Results

Thirty-one subjects (18 men and 13 women) with a mean weight of  $72.5 \pm 5.7$  kg, height of  $171.8 \pm 5.4$  cm and mean age of  $27.5 \pm 7.7$  years participated in the study. Two subjects were omitted because of a computer malfunction. Consequently, 29 data sets were used.

For the inter-tester portion (two-tester “staying-in” method) the difference of the means for all five measurements ranged from 0.09 mm through 0.97 mm and the SD means for the measurements ranged from 0.06 mm through 0.68 mm (Table 1).

Conversely, the intra-tester (one-tester “in-out” method) difference of the means ranged from 1.26 mm through 1.65 mm and the means of the SDs ranged from 0.89 mm through 1.17 mm (Table 2).

The ICCs (1,1) for both the two-tester and one-tester measurements were 0.99, thus indicating that there is consistency and agreement in the two- and one-tester measurements.

### Discussion

We aimed to determine the inter-tester and intra-tester reliability for measuring spinal height with a commercially available clinic based stadiometer measurement protocol. There have been several studies investigated the reliability of stadiometric measures, however, all of those studies utilized custom laboratory based stadiometer measurement protocols [9-12]. The current study establishes the reliability of our commercially available clinic based stadiometer measurement protocol, thus making further research on spinal height changes more feasible in a clinical setting.

The reliability coefficients were “almost perfect” (0.99) for the one-tester and two-tester models demonstrating that there is reliability on a commercially available stadiometer [15]. The current study has similar reliability values to those reported by Stothart et al. [9] when using the “in-out” method (SDs ranged from 0.84 to 1.30 mm) [9]. The “in-out” method with subjects seated is the most likely method to be employed when using a stadiometer for research in the clinical setting.

The ICC (1,1) values of 0.99 are supported by the means of the SDs. The means of the SDs were lower than the mean differences of the SDs, indicating that there is trustworthy reliability. In both instances the means of the SDs were smaller than the mean differences, indicating that the one- and two-tester models had a small error and high reliability.

Other reliability studies have utilized ICC values and the means of the SDs to confirm the reliability of measurements. Rodacki et al. [11] and Stothart et al. [9] used only the means of the SDs to determine reliability. The SDs for the “in-out” method ranged from 0.84 to 1.30 mm [9,11]. Our results for the intra-tester reliability that employed the “in-out” method were similar, with SDs ranging from 0.99 through 1.23 mm.

Selected investigators used both ICCs and means of the SDs as dependent variables. Healey et al found high ICCs for both normal subjects and chronic low back pain patients [12]. Kanlayanaphotporn et al. [16] demonstrated moderate-to-good reliability coefficients

Measurements	0	1	2	3	4	5
ICC's	1.0	1.0	1.0	1.0	1.0	1.0
Difference of the Means (mm)	0.54	0.2	0.97	0.49	0.85	0.09
Means of SD (mm)	0.38	0.14	0.68	0.34	0.59	0.06

Table 1: Inter-Tester reliability outcomes using the Intraclass Correlation Coefficient (ICC).

Measurements	Measurement 0 compared to measurement 1	Measurement 1 compared to measurement 2	Measurement 0 compared to measurement 2
ICC's	1.0	1.0	0.99
Difference of the Means (mm)	1.26	1.65	1.37
Means of SD (mm)	0.89	1.17	0.97

**Table 2:** Intra-Tester reliability outcomes using the Intraclass Correlation Coefficient (ICC).

for normal subjects and poor reliability coefficients for subjects with chronic low back pain [16]. The mean of the SDs and standard error of the means did not exhibit appreciable differences, possibly explaining why the ICCs were lower in their study versus the Healey et al study and the current study. The subjects in the Kanlayanaphotporn et al. [16] study were measured in a seated position with no load, then measured after 10 minutes of a load equal to 15% of subject's body weight while sitting, and then measured again after 10 minutes of unloaded sitting. There may not have been sufficient change in spinal height in the subjects because after being loaded for 10 minutes they sat in an unloaded position for 5 minutes versus lying in a supine position for 10 minutes. Healey et al asked subjects to return two weeks later for spinal height re-measurement after proceeding through the testing sequence, which could have resulted in less consistency in spinal height. Conversely, our current study measured subjects after 10 minutes of lying supine, followed by an applied load. Measurements were taken after the load was removed, thus giving a larger change in the spinal height versus the continuous seated position utilized by Kanlayanaphotporn et al. [16].

To our knowledge no other reliability studies have examined the inter-tester reliability of measuring spinal height using a commercially available clinic based stadiometer protocol. This study established that multiple testers can reliably measure spinal height changes. In addition, the high inter-tester reliability confirms the value of our protocol for future clinical research regarding the lumbar spine and spinal height. The high ICC values in our current study could be the consequence of the simple design of the stadiometer. Once subjects were familiar with the stadiometer and were able to reproduce their head positions, the starting positions were easily replicated.

Currently, clinicians employ many treatment techniques aimed at affecting the lumbar disc. Additionally, clinicians routinely prescribe a variety of positions for the management of low back pain in athletes that are aimed at changing intradiscal pressure and ultimately the height of the disc. One study has already examined the changes that hyperextension can have on the lumbar disc height using the stadiometer. Magnusson found that 20 degrees of lumbar extension sustained for 20 minutes produced a significant increase in spinal height [17]. Further research with a stadiometer could provide evidence for the efficacy of these positions as treatment techniques for influencing disc changes. If a commercially available stadiometer could be utilized for this research, a greater body of evidence can be collected that will provide a better understanding of clinical interventions for low back pain.

## Conclusion

This is the first study to establish inter-tester and intra-tester reliability for measuring spinal height changes in a seated position using a commercially available clinic based stadiometer measurement protocol. Precise reliable measurement of spinal height changes by

one or more testers increases the likelihood of the stadiometer being employed as a clinical research tool. Adding research tools that are applicable in the clinical setting is essential for increasing the body of evidence that supports management interventions for low back pain in athletes.

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