Seated Lumbar extensor strength in adults: a study of repeatability and reliability

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Abstract

Background: In this study, we examined the use of a static dynamometer chair to measure lumbar spine extensors strength in a sample of 79 healthy adults.

Methods: In this study we examined 79 healthy subjects (33 males and 46 females), 25-63 years of age. Subjects were placed in a seated position on the novel chair, secured tightly with a lap belt. In each session, the subjects were asked to extend their back against the force transducer at maximum capacity, maintaining the extension for 5 seconds. The maximal force delivered over that period was recorded. Subjects had a practice trial followed by 3 forceful extensions with pausing intervals of 30 seconds. The average force of all 3 trials were recorded. A follow up session was carried out within 14 days later.

Results: Initial session was 69.474 LBS (67.047 and 71.901). Intraclass Correlation Coefficient for single measure was 0.853 (0.765 and 0.908 with 95% CI) and for average measures, 0.921(0.867 to 0.952 with CI 95%).

Follow up session mean noted was 71.661 LBS (71.615 and 71.706). Intraclass Correlation Coefficient for single measure was 0.798 (is 0.683 and 0.874 with 95% CI) and for average measures, 0.888 (0.812 and 0.933 with CI 95%).

Relationship (average measure) between initial session and follow up session set of measurements ($r=0.80$; $p<0.001$; $R2=0.62$).

Conclusion: The use of the static dynamometer chair is reliable. It is a non-invasive, cost-effective test that facilitates the assessment of lumbar spine extensors strength in adult patients.

Background:

Proximal junctional kyphosis (PJK) is a dreaded common complication of long spinal fusion [1, 2]. Its prevalence ranges between 6 and 41% of the cases and frequently requires reoperation [1, 2]. Numerous unproven theories abound regarding PJK etiology and one of the potential causes is thought to be the posterior muscle dissection within the fused range at the time of posterior fusion [1]. If muscle dissection and resulting muscle weakness in back extensor muscle strength is the cause of PJK, then it would be expected that the degree of posterior paraspinal muscle dissection during fusion should be in direct proportion to extensor power lost post fusion. In the last decade, there has been a dramatic increase in the number of lumbar fusions performed in the developed countries [3]. Therefore, the accurate determination of back extensor strength could therefore contribute to the recognition of risk for PJK and guide strategies to alleviate that risk.

Various measurement protocols have been tested to evaluate extensor muscle strength, endurance and power in adults. The isokinetic dynamometry is considered a valid and reliable method to assess the strength of a specific muscle group [4,5]. However, it is not universally accessible being rarely clinically used due to the associated high cost, requirement for considerable user expertise, demanding functional capacity of the patient and protracted testing time. Currently, the Biering-Sørensen test is the most widely used isometric test to assess extensor muscle endurance [6]. This test evaluates the amount of time a subject can maintain his/her upper body (trunk) extended (e.g. horizontal) against gravity, while placed in a prone position at the end of therapy table. However, the Biering-Sørensen method was intended for the assessment of healthy athletic populations, and after a consensus conference with physiotherapists, PhD kinesiologist and spine surgeons at our institution, the Biering-Sørensen test was deemed unsuitable and difficult for older patients with chronic low back pain undergoing spine surgery. Additionally, our group concluded that the most easily completed test by a typical adult patient with spine deformity would be in the seated position.

Hand-held dynamometry (HHD) is an appealing alternative to isokinetic dynamometry, being highly practical for use in the clinical setting. It showed validity for measuring the upper [7,8] and lower [9,10] extremity muscle strength and excellent reliability for measuring back extensor strength [11]. However, very few studies have used HHD technique to measure lumbar spine extensor strength in the seated position. Although, Park *et al*. used a similar device in the past, the study included only a few patients [12].

Therefore, we have designed a simple method that allows us to perform lumbar spine extensors strength tests in a seated chair and comfortable position. This study aimed to assess the within day and between day reliability of this novel test to evaluate back extensor strength in healthy individuals.

Methodology:

Chair description

The dynamometer static chair is an HHD easy to assemble using affordable parts (Fig. 1). It consists of a chair with back support that has a rack back style, allowing to attach the vertical rail containing three parts; a custom-made rectangular shape piece of wood, two vertical parallel metal bars attached to the rectangular piece of wood holding the HHD. The rectangular wooden piece can slide up and down on rails. The position of the wooden piece on the rail can be accurately determined and duplicated based on a ruler running the length of the rail. A portable digital HHD (microFET®2, Hoggan Scientific, Salt Lake City, UT) was attached to the mobile wooden holder on the vertical rail. Finally, an adjustable buckle seat belt with 2-point straps was attached to each side of the chair with screws. The belt is made of comfortable and strong fabric and can accommodate different waist sizes.

Subjects

Seventy-nine healthy subjects with no pervious history of spine pathology, surgery or history of chronic lower back pain (LBP) were recruited from the orthopedic staff, residents and fellows working at the Montreal General Hospital at McGill University.

Extensor Muscles Strength Testing

Each subject attended an initial session (S1) for extensor muscle stress testing. A follow up session (S2) was carried out at any point within 14 days to allow extensor muscles to rest after forceful contraction. The measurements were conducted by three orthopedic residents who were trained to accurately perform the testing. First, the chair was placed against a wall to support its back, then subjects were placed in a seated position on the novel chair and secured tightly with a lap belt (Fig. 1). Subjects were asked to cross their arms over the chest and to place their legs at 90 degrees with their feet resting on the floor. Subjects were also instructed to not push with their legs, but to strictly use their back to push against the chair. The vertical rail, positioned upright against the backside of the chair, was used to manipulate the height of the force transducer, allowing it to be at the level of the apex of the thoracic curve. The height of the force transducer on the rail was recorded and used for subsequent measurements. The unit on the force transducer was used to measure the extensor strength is pounds (LBS). In each session, subjects were asked to extend their back against the force transducer at maximum capacity, maintaining the extension for 5 seconds. The maximal force delivered over that period was recorded with the HHD. Subjects had a practice trial followed by 3 forceful extensions trials with pausing intervals of 30 seconds. The average force of all 3 trials was recorded. The force measured is deemed proportional and equivalent to strength.

Data analysis:

A pre-test power analysis showed that for an expected test-retest reliability of a measurement tool with an ICC of 0.85 and the lowest acceptable ICC of 0.75, with the measurement taken on two occasions with 3 raters per subject, and an expecting 10% drop out rate, a sample size of 78 adequately powers this study at 80%.

Descriptive statistics of participant characteristics were presented as means ± standard deviations. Results from the novel chair were graphed using the STATA software (Version 12.0) and SPSS statistical program. Intra-class correlation coefficients (ICCs) were used to assess the consistency and reliability of this novel measurement method. ICCs and corresponding 95% confidence interval (CI) were calculated using a two-way random effect model, with absolute agreement, and single measure. The reliability was examined as a group as well as by sex (e.g. male vs. female). The ICCs were interpreted using the following guidelines: ICCs < 0.5 = poor reliability, ICCs between 0.5 and 0.75 = moderate reliability, ICCs between 0.75 and 0.90 = good reliability and ICCs > 90 = excellent reliability. Pearson's correlations were used to assess the relationship between strength, BMI, height, weight and sex. A p-value equal or less than 0.05 was accepted as significant.

Results:

Demographic data was collected and summarized in Table 1. A total of 79 healthy participants (33 males, 46 females) aged 25–63 years participated in S1. Out of these 79 subjects, 60 (24 males and 36 females) were available and had second session (S2) 1–14 days after (average was 3 days after). The mean of force of all 3 trials showed little difference between S1 and S2, and the results are consistent.

Where the S1 mean noted was 69.474±27.064 LBS (range: 67.047–71.901) and S2 mean was 71.661± 27.789 LBS (range: 71.615–71.706).

The reliability for S1 was good to excellent, with an ICC = 0.853 (95% CI: 0.765–0.908). The reliability for S2 was moderate to good and ICC of 0.798 (95% CI: 0.683–0.874). There was a strong correlation between the average measure of S1 and S2 ($r = 0.80$; $p < 0.001$; R2 = 0.62) (Fig. 2).

There was a significant difference ($p < 0.001$) in strength (e.g. using the mean value of S1 and S2 combined) between males and females with mean strength value of 79.541±27.496 LBS (range: 52.248–106.834), 64.060±24.909 LBS (range: 39.772–88.348), respectively.

The mean of force for males for S1 was 77.691 ± 28.261 LBS (range: 73.668–81.715), and the reliability was poor to excellent with an ICC = 0.802 (95% CI: 0.593–0.903). Females had lower mean force of 63.266 ± 24.288 LBS (range: 62.044–64.487) for SI and the reliability was good to excellent with an ICC = 0.887 (95% CI: 0.803–0.936) for single measures. Similar results were found for S2 with a mean force for males of 80.801 ± 26.917 LBS (range: 79.061–82.540), and ICC = 0.677 (95% CI: 0.393–0.843. Females had a mean of force of 64.990 ± 26.042 LBS (range: 63.811–66.168) for S2 with an ICC = 0.856 (95% CI: 0.751–0.929).

There was a significant positive correlation between height and extensor strength ($r = 0.321$; $p = 0.004$). BMI and extensor strength were also positively correlated ($r = 0.232$; $p = 0.039$). However, weight and age showed no correlation ($r = 0.217$; $p = 0.055$), ($r = 0.017$; $p = 0.885$) with extensor muscle strength, respectively.

Discussion:

The aim of this study was to develop a clinically simple and amenable test of back extensor strength and evaluate its convergent test retest reliability. We designed a static dynamometer chair to perform this test in a comfortable seated position. Our novel chair showed excellent test retest reliability results in healthy population.

Previously published reviews[13,14] have demonstrated a level of inter-instrument validity between handheld and isokinetic muscle strength testing for upper and lower limb. However, few studies have investigated trunk extensor strength using HHD [15,16] as well as established reliability of trunk extensors strength in a comfortable seated position [12,17]

Moreland et al used a variant of the prone Biering-Sørensen test to investigate the interrater reliability of maximal isometric back extensor strength on 39 subjects [15].The authors did their trials with a 30 seconds rest period in between consecutive measurements. However, their test had several weak points. The dynamometer was stabilized by the examiner which made it in open chain and highly dependent on examiner strength. In addition, the dynamometer fixation was affected by the grip strength, gender and lean body mass[18]. Furthermore, Biering-Sørensen test has significant source of inter-individual variation because it's affected by hip extensor activation, along with the mass of the upper extremities and torso.[5]

Valentin et *al* showed that test retest reliability of a modified Biering-Sørensen test improved by using external belt fixation of the HHD in patients with osteoporosis and low trauma vertebral fractures[16]. However, using the prone position in their test produced discomfort which limited maximal extension production in some patients. In fact, repeated testing was difficult for one participant because of back pain following the first session. In addition, one participant had difficulty raising the chest from the examination table because of muscle weakness and another one terminated testing due to dyspnea in prone position. These findings supported the fact that inducing pain is an important discouragement for clinical testing.[19]

To overcome the problem of testing in discomforting position, Harding et *al*. assessed healthy individuals in standing position using a closed chain wall fixation and determined the relationship between extensor muscle strength and bone mineral density (BMD). However, since most spine patients are either old or assessed post-operatively, testing them for maximal trunk extension in standing position makes patients uncomfortable and puts at risk the patients with poor balance. In addition, this position does not eliminate the hip extensors and gluteal muscles which might give misleading results. Furthermore, testing subjects in standing position may not be feasible in many kyphotic individuals. [20]

A limited number of studies looked at examining lumbar spine extensors strength in comfortable seated position to overcome all the pervious concerns. Park et *al*, designed a similar chair with HHD device that is attached to it, to measure lumbar spine extensors strength. The chair test retest results were reliable with Intraclass Correlation Coefficient 0.82 (0.65–0.91 Ci 95%). Also, when they compared the chair with isokinetic dynamometer machine PrimusRS, it showed good validity. However, their study included only a few patients (30 patients in total)[12]. Yang et *al*, examined lumbar spine extensors strength in three different postures: prone, standing and setting using HHD. For sitting position, they used a chair without a back support that is fixed to the wall, then they fixed the HHD device to the wall separately. They compared the results of the test with isokinetic dynamometer for validation. Their conclusion for the test in a sitting position was reliable with interclass Correlation 0.90 (0.83–0.94 CI 95%), however, has a low validity [17].

Our protocol involves testing subjects in seated position and secured tightly with seat belt which helps to eliminate other muscles function and isolate the extensor muscles. In addition, this technique maximizes the comfort and safety of tested subjects, especially for old, post-operative patient or individuals with poor balance.

The HHD was fixed on the chair and the chair was stabilized against the wall which eliminates examiner-based variability, making the test feasible for all patient including kyphotic patients, is not influenced by upper body mass and doesn't induce pain during or after testing in our tested sample. Furthermore, compare to other tests our novel technique is cost effective and the simplicity of design and small size make it easy to access and transport in the clinic setting.

Testing patient using our novel protocol showed excellent reliability in measuring the lumber extensor muscle strength and its results are reproducible with each time subjects take the test. These promising results on healthy adults, without a history of spine disease or LBP is a first step in an investigation into the changes in spinal extensor muscle power following spine surgery.

Conclusion:

Our novel chair showed excellent reliability in testing the back-extensor muscles strength. It considers comfortable and safe options for all patients. Further research on this novel technique is needed specially on post-operative patients.

Limitations:

First, the study design was observational in nature involving only healthy participants. It would be beneficial to compare the results with those having spine disease. Also, the device used, although quite reliable, was not validated and compared with the gold standard. Nevertheless, the authors are currently working on validating the device.

Abbreviations:

Proximal junctional kyphosis (PJK), Hand-held dynamometry (HHD), initial session (S1), follow up session (S2), pounds (LBS), Intra-class correlation (ICC), confidence interval (CI), bone mineral density (BMD), lower back pain (LBP)

Declarations:

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Authors contribution:

Concept/idea/ research design: P. Jarzem, M. Weber, J, Ouellet.

Writing: A.Alshammari, Nabil Algarni, Y.Marwan

Data collection: A.Alshammari, Nizzar Algarni

Data analysis: A.Alshammari, Nabil Algarni, Y.Marwan, M. Fortin

Project management: A.Alshammari, Nizzar Algarni, P. Jarzem, Consultation (including review of manuscript before submitting): A.Alshammari, Nizzar Algarni, P. Jarzem, M. Weber, J, Ouellet, M. Fortin

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Availability of data and materials

The data used to support the fndings of this study are available from the corresponding author upon request.

Ethics approval and consent to participate

This study was approved by the Mcgill University Health Center Research Ethics Board

Competing interests

There is no confict of interest to declare

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Table:

Table 1: Demographics

Characteristics	Males (n = 33, 42%)	Females (n = 46, 58%)	Total (n = 79)
Age* [year]	34.8 ± 8.4	39.2 ± 11.3	37.2 ± 10.4 range 25-63 years
BMI* [kg/m^2]	27.1 ± 5.2	24.5 ± 5.6	25.6 ± 6.0
Hight* [m]	175.4 ± 7.2	166.8 ± 6.9	168.5 ± 19.9
Weight* [kg]	83.2 ± 16.0	68.1 ± 12.1	74.0 ± 16.9

*All data are expressed in mean +/- standard deviation.

Figures

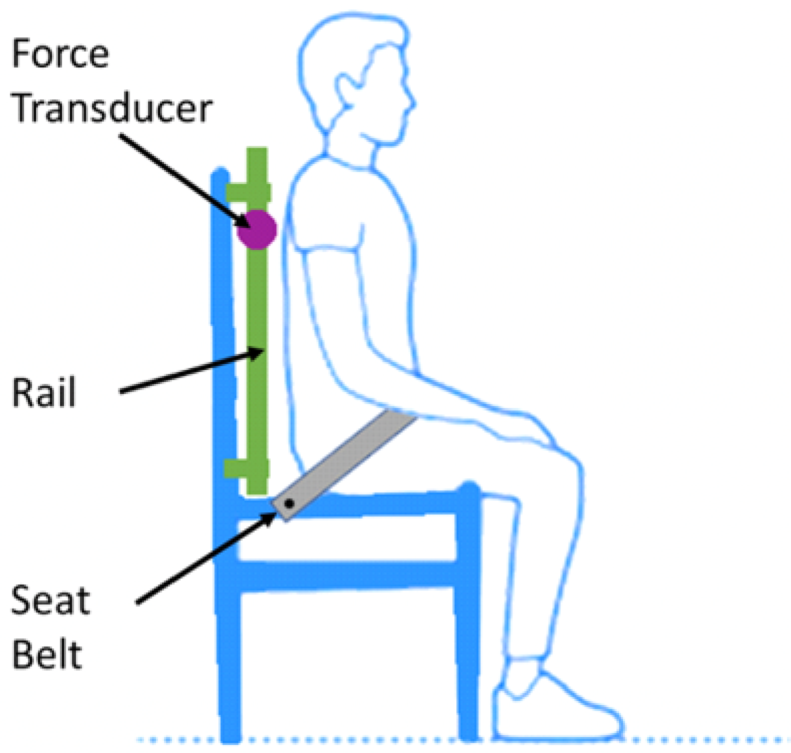

Figure 1

The dynamometer static chair.

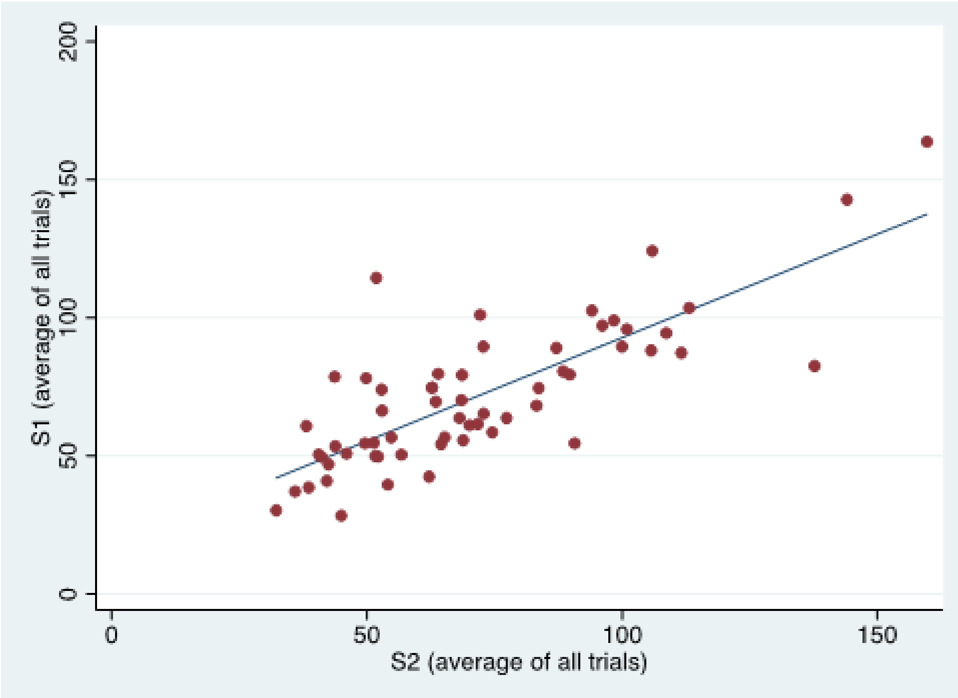

Figure 2

Relationship of Average measures between initial session (S1) and follow up session (S2), (r=0.80; p<0.001).

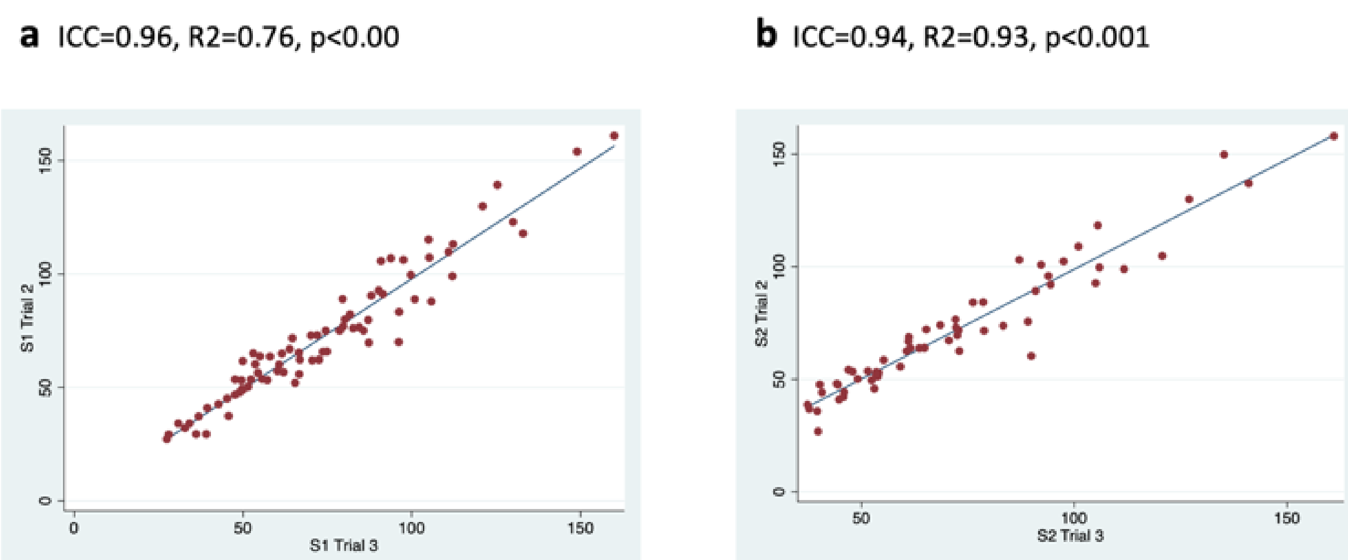

Figure 3

Relationship between measurements of maximal lumbar spine extensors force using the novel chair (a) short-term reliability of initial session (S1) and (b) short-term reliability of follow up session (S2).