

Within-day and between-day reliability of a novel test to evaluate back extensor strength in healthy individuals.

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Research Article

Keywords: Lumbar muscle strength, reliability, muscle strength test, handheld dynamometry

Posted Date: January 9th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-2440454/v1>

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Abstract

Background

Proximal junctional kyphosis (PJK) is a common complication of long spinal fusion. The prevalence of PJK ranges between 6 and 41% and frequently requires reoperation. One of the potential causes is thought to be posterior muscle dissection within the fused range at the time of posterior fusion. Various measurement protocols have been tested to evaluate extensor muscle strength, endurance and power in adults. However, it is not universally accessible and is rarely used clinically due to the high cost, requirement for considerable user expertise, demands on the functional capacities of the patient and protracted testing time. Currently, the Biering–Sørensen test is the most widely used isometric test for assessing extensor muscle endurance. But, it was deemed unsuitable and difficult for older patients with chronic low back pain undergoing spine surgery.

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

Methods

In this study, we examined 79 healthy subjects (33 males and 46 females), who were 25–63 years of age. The subjects were placed in a seated position on the novel chair and secured tightly with a lap belt. In each session, the subjects were asked to extend their backs against the force transducer at maximum capacity, maintaining the extension for 5 seconds. The maximal force delivered over that period was recorded. The subjects had a practice trial followed by three forceful extensions with pausing intervals of 30 seconds. Measurements were obtained by one of three trained raters, and the average force of all three trials was recorded. A follow-up session was carried out within 14 days. Intra-class correlation coefficients (ICCs) were used to assess within-day and between-day reliability.

Results

The mean force in the initial session was 314.6 ± 118.3 N, and it was 318.6 ± 123.6 N in the follow-up session. The ICCs for within-day reliability and between-day reliability were 0.89 [95%CI: 0.83–0.92] and 0.88 [95% CI: 0.81–0.93], respectively. There was a strong correlation between the average measures of the initial and follow-up sessions ($r = 0.80$; $p < 0.001$; $R^2 = 0.62$).

Conclusion

The use of the static dynamometer chair is a reliable, non-invasive, cost-effective test that facilitates the assessment of the strength of lumbar spine extensors in healthy adults.

Background

Proximal junctional kyphosis (PJK) is a common complication of long spinal fusion.^{1,2} The prevalence of PJK ranges between 6 and 41% and frequently requires reoperation.^{1,2} Numerous unproven theories abound regarding the aetiology of PJK, and one of the potential causes is thought to be posterior muscle dissection within the fused range at the time of posterior fusion.¹ If muscle dissection and the 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 directly proportional to the amount of extensor power lost post fusion. In the last decade, there has been a dramatic increase in the number of lumbar fusions performed in developed countries.³ Therefore, the accurate determination of back extensor strength could contribute to the understanding of PJK risk and guide strategies to alleviate that risk.

Various measurement protocols have been tested to evaluate extensor muscle strength, endurance and power in adults. Isokinetic dynamometry is considered a valid and reliable method for assessing the strength of a specific muscle group.^{4,5} However, it is not universally accessible and is rarely used clinically due to the high cost, requirement for considerable user expertise, demands on the functional capacities of the patient and protracted testing time. Currently, the Biering–Sørensen test is the most widely used isometric test for assessing extensor muscle endurance.⁶ This test evaluates the amount of time a subject can maintain his or her upper body (trunk) extended (e.g. horizontal) against gravity while placed in a prone position at the end of a therapy table. However, the Biering–Sørensen method was intended for the assessment of healthy athletic populations, and after a consensus conference with physiotherapists, a PhD kinesiologists and spine surgeons at our institution, it 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.

Handheld dynamometry (HHD) is an appealing alternative to isokinetic dynamometry, as it is highly practical in the clinical setting. It has shown validity for measuring upper^{7,8} and lower^{9,10} extremity muscle strength as well as excellent reliability for measuring back extensor strength.¹¹ However, few studies have used HHD to measure lumbar spine extensor strength in the seated position. While Park *et al.* used a similar device, the study included only a few patients.¹²

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

Methodology

Chair description

The dynamometer static chair is an HHD device that is easy to assemble using affordable parts (Fig. 1.A). It consists of a chair with a back support that has a rack back style, allowing the attachment of a vertical rail containing three parts: a custom-made rectangular shape piece of wood and two vertical parallel metal bars attached to the rectangular piece of wood holding the HHD. The rectangular wooden piece height is adjustable and 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 (Fig. 1.B) (microFET®2, Hoggan Scientific, Salt Lake City, UT) is attached to the mobile wooden holder on the vertical rail. Finally, the seat has an adjustable buckle seat belt with two-point straps attached to each side of the seat with screws. The belt is made of comfortable and strong fabric and can accommodate different waist sizes. The height and depth of the chair are not adjustable.

Subjects

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

Extensor Muscle 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 the extensor muscles to rest after forceful contraction. The measurements were conducted by one of three orthopaedic residents, who were trained to accurately perform the testing. First, the chair was placed against a wall to support its back, and then subjects were placed in a seated position on the chair and secured tightly with a lap belt. No adjustments could be made for the height and the depth of the seat. The subjects were asked to cross their arms over the chest and to place their legs at a 90-degree angle with their feet resting on the floor in line with their hips (Fig. 1.C). The 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. In each session, the subjects were asked to extend their backs against the force transducer at maximum capacity and encouraged to push as much as possible while maintaining the extension for 5 seconds. The peak force was recorded in Newton (N) with the HDD. The subjects had a practice trial followed by three maximal extension trials with pausing intervals of 30 seconds. The average force of all three 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 intra-class correlation coefficient (ICC) of 0.85 and the lowest acceptable ICC of 0.75, with the

measurement taken on two occasions by one of three raters and an expected 10% dropout rate, a sample size of 78 would adequately power this study at 80%.

Descriptive statistics of the participants' characteristics were presented as means \pm standard deviations. Results from the novel chair were graphed using STATA software (Version 12.0) and the SPSS statistical program. ICCs were used to assess the within-day and between-day reliability of this novel measurement method. All three trials were used to assess the within-day reliability for S1 and S2, and between-day reliability was assessed using the mean of all three trials for S1 and S2. ICCs and corresponding 95% confidence intervals (CIs) were calculated using a two-way random effect model, with absolute agreement and a single measure. 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 > 0.90 = excellent reliability. Pearson's correlations were used to assess the relationship between strength, Body Mass Index, height, weight. A p-value equal to or less than 0.05 was accepted as significant.

Results

Demographic data are summarized in Table 1. A total of 79 healthy participants (33 males, 46 females) aged 25–63 years participated in S1. Of these 79 subjects, 60 (24 males and 36 females) were available and had second sessions (S2) 1–14 days later (average 3 days). The mean force recorded for the three trials at S1 and S2 was consistent, with a mean of 314.6 ± 118.3 N (range: 120.8–728.02) for S1 and 318.6 ± 123.6 N (range: 143.2.–710.4) for S2.

Table 1: Demographics Data

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

*All data are expressed in mean \pm standard deviation.

Within-day reliability for S1 and S2 was good to excellent (Table 2). In addition, between-day reliability between S1 and S2 (average measure of 3 trials) was good to excellent (Table 3). There was a strong correlation between the average measures of S1 and S2 ($r = 0.80$; $p < 0.001$; $R^2 = 0.62$) (Fig. 2).

Table 2
Within-day reliability (mean±standard deviation)

	Trial 1	Trial 2	Trial 3	ICC (95% CI)
S1 (N)	298.2±111.1	319.8±128.5	325.8±126.9	0.89 (0.83, 0.92)
S2 (N)	311.2±124.8	321.4±127.0	323.2±125.3	0.94 (0.92, 0.96)

Table 3
Between-day reliability (mean±standard deviation)

Mean Strength S1 (N)	Mean Strength S2 (N)	ICC (95% CI)
314.59±118.31	318.55±123.62	0.88 (0.81–0.93)

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 in a 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 limbs. However, few studies have investigated trunk extensor strength using HHD^{15,16} or established the reliability of trunk extensor strength measurement 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 measurement with 39 subjects.¹⁵ The authors conducted their trials with a 30-second rest period between consecutive measurements. However, their test had several weak points. The dynamometer was stabilized by the examiner, which made it an open chain and highly

dependent on the examiner's strength. In addition, the dynamometer fixation was affected by grip strength, gender and lean body mass.¹⁸ Further, the Biering–Sørensen test has significant inter-individual variation because it is 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 their chest from the examination table because of muscle weakness, and another patient terminated testing due to dyspnoea in the prone position. These findings illustrated that inducing pain is an important discouragement for clinical testing.¹⁹

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

A limited number of studies have examined lumbar spine extensor strength in a comfortable seated position to overcome all the previously mentioned concerns. Park *et al.* designed a similar chair with an attached HHD to measure lumbar spine extensor strength. The chair test–retest results were reliable, with an ICC of 0.82 (0.65–0.91 CI 95%). Additionally, when they compared the chair with the isokinetic dynamometer machine PrimusRS, it showed good validity. However, their study only included a few patients (30 patients in total).¹² Yang *et al.* examined lumbar spine extensor strength in three different postures, prone, standing and sitting, using HHD. For the sitting position, they used a chair without a back support that was fixed to the wall, and they fixed the HHD device to the wall separately. They compared the results of the test with an isokinetic dynamometer for validation. The test in the sitting position was reliable, with an ICC of 0.90 (0.83–0.94 CI 95%), but it had a low validity.¹⁷

Our protocol involves testing subjects in a secured seated position with a seat belt, which helps eliminate the activation of other muscles while isolating the extensor muscles. In addition, this technique maximizes the comfort and safety of the test subjects, especially for elderly, post-operative patient or individuals with poor balance.

The HHD was fixed on the chair, and the chair was stabilized against the wall to eliminate examiner-based variability, making the test feasible for all patients, including kyphotic patients. The test was also not influenced by upper body mass and did not induce pain during or after testing in any of the subjects

included in our sample. Further, in comparison to other machines, our novel chair/technique is cost effective, and the simplicity of its design and portable size makes it easy to access and transport in a clinic setting.

The novel chair showed excellent reliability in measuring lumbar extensor muscle strength, both within-day and between-day. These promising results with healthy adults without a history of spine disease or LBP is a first step in investigating the changes in spinal extensor muscle power following spine surgery.

Limitations

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

Conclusion

Our novel chair showed excellent reliability in testing back-extensor muscle strength. It is a safe and comfortable option for all patients. Further research on this novel technique is needed, especially in post-operative patients.

Abbreviations

Proximal junctional kyphosis (PJK), Handheld dynamometry (HHD), initial session (S1), follow-up session (S2), Intra-class correlation (ICC), confidence interval (CI), bone mineral density (BMD), lower back pain (LBP), Newton (N).

Declarations

Acknowledgements

The authors would like to thank the Deanship of Scientific Research, King Saud University and the Research Chair of Spine Deformities, Riyadh, Saudi Arabia.

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Data collection: Abdullah Alshammari, Nizar Algarni

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Project management: Abdullah Alshammari, Nizar Algarni, Peter Jarzem

Consultation (including review of manuscript before submitting): Abdullah Alshammari, Nizar Algarni, Peter Jarzem, Maryse Fortin.

Funding

Not applicable.

Availability of data and materials

The data used to support the findings 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 conflict of interest to declare.

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Figures

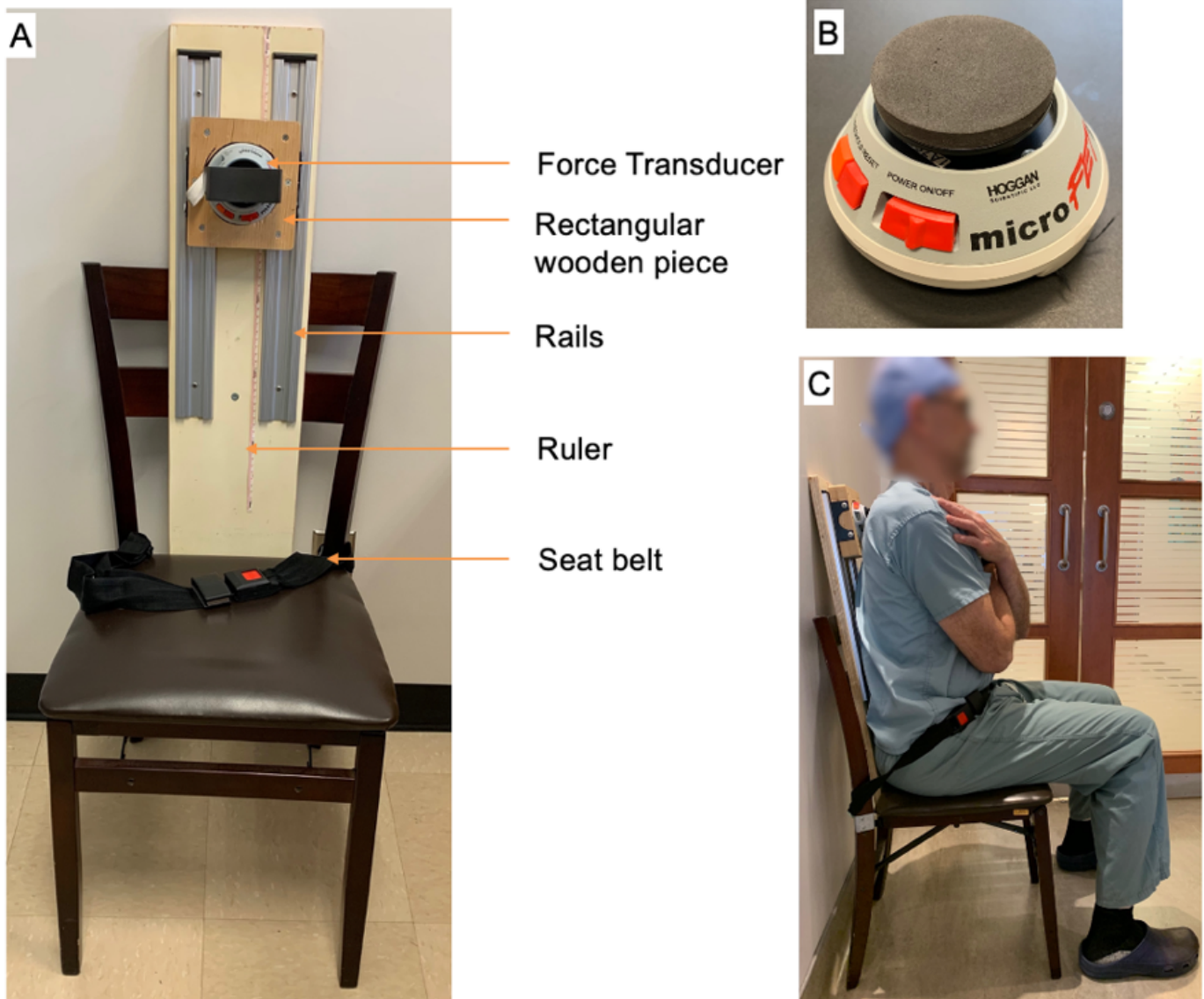


Figure 1

(A) The dynamometer static chair and its components. (B) Force transducer using a portable digital HHD (microFET®2, Hoggan Scientific, Salt Lake City, UT). (C) Subject demonstrating the proper position for chair use, crossing their arms over their chest and placing their legs at a 90-degree angle with their feet resting on the floor.

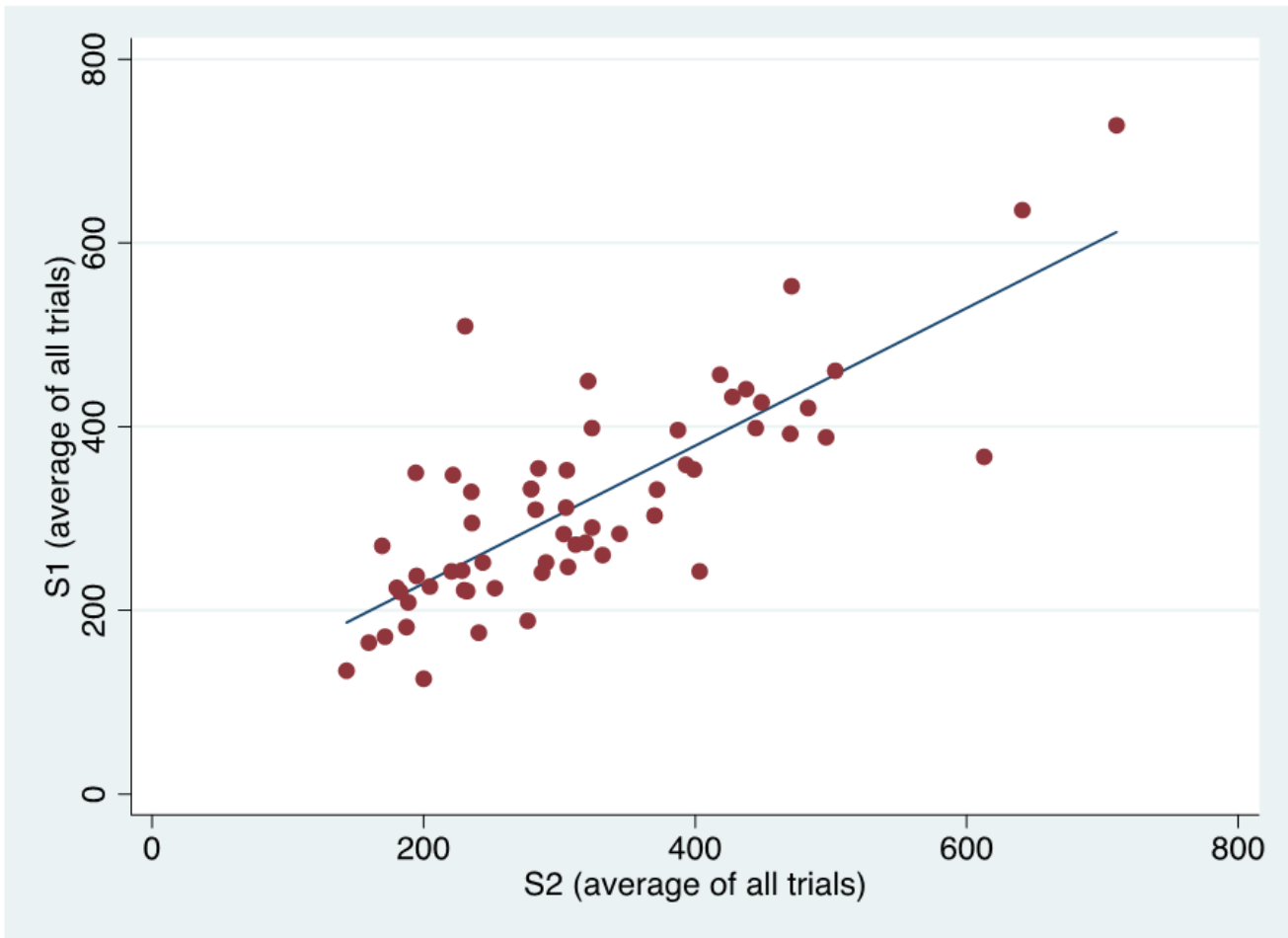


Figure 2

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