Journal of Spine Care

Research Article

ISSN: 2399-6862

Inter-day session reliability of a novel assessment for rotational power of the pelvis, spine and trunk

Thomas G. Palmer[1*]

[1]Department of Rehabilitation Sciences, University of Cincinnati, College of Allied Health Sciences, USA

Abstract

Purpose: The proximal musculature of the pelvis, spine and trunk play a key role in modulating forces to and from the extremities and the environment. Many field tests are designed to assess isometric muscular endurance tasks but are limited in assessing inter-day session reliability of rotational muscular power at the proximal segments.

Methods: Inter-session reliability was assessed over three separate test sessions 7 days apart using the inline lunge ball toss (ILBT), isometric muscular endurance prone (IMEP) and side (IMES) plank tests in twenty-one females and twenty-two male college aged recreational athletic volunteers, (N=43).

Results: Intraclass correlation coefficients were highly reliable for the ILBT (range, 0.72–0.99), the IMEP (range, 0.60–0.96) and moderate to high for the IMES (range, 0.62–0.88) between test sessions. Correlations relationships between the ILBT, IMEP and IMES were low to moderate (r range, 0.268 to 0.587).

Conclusions: The ILBT was reliable and appeared to have a limited intersession learning effect over two weeks of testing. The stability and power component of the ILBT offer a reliable and comprehensive assessment protocol.

Introduction

Maximizing force production in a safe manner during sport is greatly predicated upon by the incremental stability and mobility of the proximal muscles that support the pelvis, spine and trunk. These muscles play a critical role in creating and transferring forces to and from the body and the environment. The unique motor control patterns between the deep and superficial proximal musculature supporting the pelvis, spine and trunk make it possible for athletes to perform skills at various intensities with diverse movement patterns [1-3]. The deep spinal muscles, such as the transverse abdominis or the quadratus lumborum, act in an anticipatory nature to support and prepare the lumbar spine to absorb and transfer forces milliseconds prior to distal muscle activations about the trunk and pelvis [4]. These spinal muscles have an intimate relationship with the vertebral segments and act as riggers to provide a proximal foundation for movement and force distribution to and from the proximal and distal segments. Deficits in motor control patterns or muscle weakness have been reported to disrupt the efficiency of force distribution, sport performance and contribute to injurious mechanisms [5]. As a result, health care professionals often implement assessment techniques designed to test the functional integrity of the proximal segments.

Low levels of deep spinal muscle activation have been reported to stabilize and maintain postures of the lumbar spine regardless of the intensity or movement pattern performed [3,6]. Identified predominately as endurance based muscles the assessment techniques used to test the spinal stabilizers have been isometric endurance tasks, such as, static planks or the Biering-Sorensen test [7]. Despite a sequential learning effect over time static plank tests are reliable following a familiarization period and offer good insight as to the muscular endurance characteristics of the spinal stabilizers. However, the proximal musculature has recently been identified to have task specific characteristics regarding the mobility and bioenergetics demands necessary to complete a given task [3,8]. Plank tests offer limited insight to rotational and/or power movements common to acts of daily living and sport [8]. As a result, various ball toss tasks with different seated and standing positions have been proposed to assess the rotational power of the proximal segments. However, recent literature has struggled to find a field test with consistency in testing protocols, psychometric properties and inter-session reliability [3,6,9]. A primary contributor to these inconsistencies are the seated and standing positions that lack control of extremities and/or various degrees of freedom throughout the kinetic chain that allow for a variety of compensatory patterns.

The inline lunge chop and lift test on a dynamometer is one technique that has been identified as a reliable and valid measure of rotational power involving the proximal segments and appears to control for compensatory movements [6,10]. The strict upright inline lunge position mandates that participants maintain hip and trunk alignment and control while forcefully rotating the trunk and arms [6,8]. It has been proposed that the incremental stability and mobility required to perform the movement is more sport specific and capitalizes on the static stability of the deep proximal musculature while integrating the rotational power of the superficial musculature [3,8]. However, measures using a dynamometer requires expensive and uncommon equipment. It seems reasonable that combining the inline-

Correspondence to: Thomas G. Palmer, PhD, ATC, CSCS*D, University of Cincinnati, Assistant Professor, College of Allied Health Sciences, Department of Rehabilitation Sciences, Room 275 French Hall East, 3202 Eden Ave., Cincinnati, OH 45267-0394, USA; Tel: 513-558-3766; E-mail: rehabsci@ucmail.uc.edu

Received: May 12, 2017; **Accepted:** June 05, 2017; **Published:** June 08, 2017

lunge position with a ball toss movement will produce a field test that can assess inter-session reliability of rotational power for the proximal segments with good to excellent consistency. Therefore, the purpose of this project was to assess the long-term inter-session reliability of a novel inline lunge ball toss (ILBT) using a randomized control trial study. Based on previous literature we hypothesize that this test would have a limited learning effect and reveal good to excellent inter-session reliability over time.

Methods

Design

This was a controlled laboratory repeated measures reliability study performed on a random college age recreational athletic population. The aim of the study was to evaluate the consistency of a novel inline lunge ball toss test over three separate testing sessions. Secondary analysis was performed to evaluate the relationship between the ball toss and traditional prone and side-plank measures. The independent variables were the volunteers, and the inline lunge ball toss, prone plank and side-plank tests. The dependent variables were the distance of the inline lunge ball toss (ILBT) in cm, the time in seconds for the prone (IMEP) and side (IMES) planks.

Following IRB approval, testing procedures and consent forms were thoroughly reviewed and explained to all potential participants prior to signing acceptance into the study. Demographic information regarding height, weight and sex were collected prior to each testing session. Following the information session three consecutive testing sessions were conducted seven days apart. All participants were asked to maintain normal activities of daily living during the study.

The inclusion criteria was aimed at college age students that participated in recreational activities a minimum of three times per week, such as recreational sports, weight lifting, and/or aerobic fitness training or running. Subjects were prohibited to join the study if they had suffered an injury or related ailment that had not allowed them to maintain an exercise regimen 6 months prior to testing.

Testing

The *in-line lunge ball toss* (ILBT) illustrated in Figure 1 was conducted from a half- kneeling in-line lunge stance, where the feet and knee of the kneeling leg are lined up. Participants performed 3 power throws with a 3 Kg medicine ball toward the opposite leg while maintaining and upright trunk and hip position and rotating the arms and trunk. To assure appropriate technique each participant was given an opportunity to practice the testing motion prior to data collection [11]. Testing occurred on days 1, 7, and 14 of the study and results on each test were not revealed to the participants at any time. The average distance of three throws for the left and right sides were recorded in a straight line. If a throw did not fall within a 45 degree angle of the test position the participant was given an additional throw. No participant was allowed more than 5 total throws.

The *isometric muscular endurance prone plank* (IMEP) [8] illustrated in Figure 2 was initiated from a prone-erect posture supported on the elbows and feet flexed to approximately 90 degrees. Participants attempted to maintain the erect posture while the examiner provided verbal feedback to correct observed position faults. The examiner assured the prone-erect position was maintained throughout the test and did not provide motivation or encouragement. The examiner monitored the midpoint of the participants' iliac crest to assure an erect neutral posture. The examiner would notify and assist in correcting any

Figure 1. In-line Lunge Ball Toss

Figure 2. Isometric Muscular Endurance Prone Plank

deviation one half inch above or below the midpoint. More than three adjustments or an inability to maintain or comply with the desired erect position, the test was terminated, and the time was recorded in seconds. Hold times were not reported to the participants. The *isometric muscular endurance side-plank* (IMES) illustrated in Figure 3 was initiated for the left and right sides from an erect side lying position with the torso, hips and legs fully extended and suspended on a flexed elbow and the lateral aspect of the foot. The supporting shoulder was abducted at approximately 85 degrees in the frontal plane with the opposite arm placed across the chest. Participants were instructed to hold the test position for a long as possible. A 1:5 work-to-rest ratio was used between endurance measures.

Statistical analysis

Intraclass correlation coefficients were assessed using a 1-way, random-effects, repeated-measures analysis for each dependent variable between testing days 1 and 7 and again between test days 7 and 14. Raw data was collected for each dependent variable with the ball toss scores normalized by body weight. (Table 1) A standard error of measurement was used to assess test precision. The responsiveness of a meaningful change between test days was estimated using the minimal detectable change (MDC) [12]. The relationship between the ILBT and the plank tests was assessed using a bivariate Pearson product moment correlation (2 tailed). Precision and correlation calculations were performed on session 3 data to account for a potential learning effect for the endurance tests across days. All statistical analyses were performed using SPSS/PAW v23.0 (SPSS, IMB Inc., Chicago, IL) with an a priori significance level of $p \leq .05$.

Results

Forty-three college recreation athletes (mean age=21, height=178cm, weight=66kg) had highly reliable intraclass correlation coefficients (Table 2) for the ILBT (range, 0.72–0.99), the IMEP (range, 0.60–0.96) and moderate to high for the IMES (range, 0.62–0.88) between test sessions. The correlations (Table 3)

Table 1. Inline Lunge Ball Toss Raw Data, Inline Lunge Ball Toss Normalized by Body Weight and Endurance Test Outputs Means, standard deviations (SD), and range are reported for average thrown distance (cm) and endurance time outputs (seconds) for test days 1, 7, and 14.

	Day 1		Day 7		Day 14	Range
Test	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	
ILBT Left Raw Data (cm)	679 ± 166	425 - 931	699.9 ± 185	418 – 1022	703 ± 188	424 – 1059
ILBT Left Normalized (cm)	9.9 ± 1.5	7.2-11.9	10.2 ± 1.8	7.1 -13.4	10.6 ± 1.8	7.2 – 12.9
ILBT Right Raw Data (cm)	693.1 ± 160	392-934	683.9 ± 165	405 – 961	708.5 ± 166	432.3 – 999.7
ILBT Right Normalized (cm)	10.1 ± 1.7	13.1 – 6.6	10.3± 1.6	6.9 -13.6	10.6± 1.6	7.8 - 13.1
IMEP (seconds)	115 ± 49	44 - 225	139 ± 54	63 - 222	130 ± 54	53 –234
IMES Left (seconds)	79 ± 26	49 - 126	94 ± 20	57 – 154	96 ± 29	54 – 169
IMES Right (seconds)	74 ± 40	44 - 156	91 ± 33	56 – 174	95 ± 21	42 - 176

ILBT= Inline Lunge Ball Toss
IMEP= Isometric Endurance Prone Plank
IMES= Isometric Endurance Side Plank
Normalized= divided raw data by Kg per body weight

Table 2. Inter-day Session Reliability of the Inline Lunge Ball Toss, Isometric Prone and Side Planks. The inter-day session reliability between test day 1 to day 7 and days 7 to 14 are presented with the intraclass correlation coefficient (ICC) with associated lower and upper boundary of 95% confidence interval (95% CI). The standard error of a single measurement (SEM) is presented using testing sessions day 7 to 14. Meaningful change was estimated with the minimal detectable change (MDC) from the SEM.

Test	Day1 to 7			Day 7 to 14			Day 7 to 14	
	ICC	95% CI low	95% CI up	ICC	95% CI low	95% CI up	SEM	MDC
ILBT Left	.91	.79	.98	.91	.84	.99	8 cm	24 cm
ILBT Right	.94	.72	.95	.96	.83	.97	7 cm	19 cm
IMEP	.82	.60	.93	.94	.88	.96	12 sec	33 sec
IMES Left	.66	.63	.81	.72	.67	.88	16 sec	37 sec
IMES Right	.79	.71	.84	.78	.62	.88	14 sec	45 sec

Day 1 to 7 = test relationship between data from day 1 to day 7.
Day 7 to 14 = test relationship between data from day 7 to day 14.
SD = standard deviation
Low = lower boundary of 95% confidence interval
Up = upper boundary of 95% confidence interval
SEM = Standard Error of Measure, calculated using the pooled standard deviation [30]
MDC = Minimal Detectable Change [26]

Table 3. Bivariate Pearson correlation coefficient for day 14 of testing is listed for the inline lunge ball toss (left and right) and isometric endurance tests (Prone and side-planks, left and right). The two-tailed significance for each correlation is reported (P-value).

Test	ILBT Left	ILBT Right	IMEP	IMES Left	IMES Right
ILBT Left	1	.915	.268	.698	.517
P-value		.007	.014	.017	.002
ILBT Right		1	.372	.518	.687
P-value			.000	.024	.019
IMEP			1	.784	.690
P-value				.011	.010
IMES Left				1	.975
P-value					.000
IMES Right					1

ILBT= Inline Lunge Ball Toss
IMEP= Isometric Endurance Prone Plank
IMES= Isometric Endurance Side Plank
Normalized= divided raw data by Kg per body weight
1= perfect correlation
Significant difference at p ≤.05

between the ILBT and IMEP assessments (r range, 0.268 to 0.372) were low while the IMES tests correlated moderate with the ILBT (r range, 0.517–0.698) and moderate to high with the IMEP (r range, 0.690 - 0.784) tests.

Figure 3. Isometric Muscular Endurance Side Plank

Discussion

The ILBT was reliable with very little evidence of an intersession learning effect over two weeks of testing. This is the first test to challenge both the integrated nature of the deep spinal stabilizers and the superficial power/strength muscles of the proximal segments [8,13]. The excellent reliability and novelty of the test appears to enhance the overall outcomes of the test. In addition, the correlation and shared variance between ILBT and the planks suggest each test evaluates similar aspects of the proximal segments, while also testing separate attributes.

The unique inline lunge position of the ILBT creates a perturbation state which necessitates static stability and control of the proximal segments. The deep muscles of the spine, pelvis and trunk act to sequentially provide a base of support for the superficial muscles to facilitate a ballistic throw [8]. Theoretically without the proximal stability of the deep stabilizing muscles the force distribution of the distal segments would be limited [13,14]. Thus, it seems reasonable that the challenges in maintaining an inline lunge position enhances the test's ability to assess true spinal stability, as well as the ability to transmit the forces distally [15]. Mcgill and others have reported the proximal segments work collectively to create incremental stability and mobility mechanics which are essential for maximizing force distribution [3,14]. Test positions on stable surfaces appear to require less proximal stabilization and integration of the proximal muscle groups [15]. Variations of the ball toss have used relatively stable standing, seated or double kneeling positions [9,16]. While many of these tests have reported fair to good reliability the testing positions are stable and potentially create a false measure of stability or control at the proximal segments. Thus, the novel tall-kneeling inline lunge position increases the integrity of the test.

Perturbation sling and unstable surface training has been hypothesized to stimulate increases in motor unit recruitment rate and frequency to stabilize the proximal segment, thus creating a stable base for the distal musculature and extremities. Further, perturbation sling training, such as, TRX have been reported as one of the few intervention techniques associated with improvements in higher velocities associated with golf club and ball throwing speeds [17,18]. The act of having to stabilize the proximal segments of the spine, pelvis and trunk prior to initiating a ballistic strength or power movement appears to maximize and simulate motor control patterns that integrate the deep and superficial muscles of the proximal segments [18]. These integrated motor control patterns enhance sport performance and reduce time lost from participation [19]. Therefore the inline lunge position offers a novel component that other ball toss tests do not. The incremental stability and mobility required by the inline lunge position inherently challenges and initiates deep spinal stabilizers in lieu of controlling the pelvis and trunk. The ballistic power throw predominately challenges the superficial musculature while also challenging a power element of the spinal stabilizers. The integrated fashion of the novel inline lunge position and a ballistic power throw mimic much of the integrated patterns necessary to compete in sport or related activities [3]. Thus, the face validity of the ILBT appears to be enhanced. The functional characteristics of the ILBT appear to offer additional insight not previous reported regarding intersession reliability of a test for the proximal segments [8].

The correlates for the ILBT and the endurance plank tests are similar to previous reports. In a similar study, power tests and isometric endurance static plank maneuvers both had favorable inter-session reliability [6,8]. In most cases plank maneuvers have lower intersession ICCs among the first two testing sessions, indicating a testing learning effect. General improvements from a learning effect for isometric plank hold times are about 5-15% between test one and test two [20]. Our data was very similar and had a steady increase in all plank tests with the largest improvements between the first two test sessions. The increased ICC values between data from day 7 to 14 indicates the participants' performance started to plateau between test sessions 2 and 3. However, the ILBT had excellent ICC values between all testing sessions indicating there was very little learning effect. Previous literature using a dynamic power chop and lift similar to a ball toss reported similar reliability and correlative values to the current study [6,8]. The ballistic nature of the ILBT is a similar power movement to the chop and lift, thus it seems reasonable the current study has similar reliability measures. In addition, the plank tests appear to have the greatest number of variability and are less agreeable overall. Anecdotally, the IMES is more difficult to control and is often subject to be difficult to evaluate consistently due to a variety of incorrect body positions and/or compensatory patterns [18]. Thus, if not tested stringently data could be misrepresented. Further, plank assessment techniques throughout the literature lack consistency regarding test termination and objectifying outcomes making it difficult to compare various outcomes. Our data reinforces indications to initiate several familiarization sessions prior to recording baseline data with isometric endurance plank tests, but not with the ILBT. The lack of agreeability between day 1 and the remaining sessions could create false baseline data, thus inflating improvements.

Previous literature has highlighted the low correlations between muscular endurance and power tests designed to isolate the proximal segments [16, 21]. Linear static isometric assessments verse power, multidirectional sport skills movements or assessments appear to measure different muscle characteristics [8]. Sells et al reported good reliability measures (r=.7 - .9) using a double leg kneeling medicine ball toss, yet had a negative correlation with isokinetic strength of the proximal segments [16]. These and others have noted that the power throw involved in a ball toss requires different muscle mechanics, thus the low correlation with isometric plank tests in the current study are not surprising. Our data supports this notion that a power ball toss test and/or an isometric endurance test are likely limited in isolation [8]. As a result, previous literature has suggested using a variety of sport specific assessment techniques that target specific strength, power and endurance characteristics [3,8]. Thus, combining power/strength tests and isometric endurance tests have been reported to illustrate a better profile of one's proximal segments. The ILBT seems to offer both a stability component regarding maintained test upright position and an explosive multi-directional power movement pattern. In addition, the shared variance between the ILBT and the IMES indicate that nearly 50% of each test can be explained by the other. The rotational movement of the ILBT and the lateral position of the IMES suggest perhaps the oblique muscles have a more active role with the flexors and extensors of the trunk, when compared to a prone plank or a linear ball toss without rotation [6]. This is likely the reason the ILBT had higher correlations with the plank tests in the current study when compared to linear ball toss tests [16,22]. Overall, the ILBT does appear to offer further insight then previously reported ball test protocols, however further outcomes research is needed to explore the comparisons.

Conclusion

The multitude of forces and mobility patterns occurring at the proximal segments mandates a comprehensive testing protocol that assesses both stability and mobility muscle characteristics of the proximal segments. The ILBT is the first test to attempt to challenge a static stability position while performing a power movement. Further research is need to explore the utility of the ILBT.

References

1. Akuthota V1, Ferreiro A, Moore T, Fredericson M (2008) Core stability exercise principles. *Curr Sports Med Rep* 7: 39-44. [Crossref]

2. Hirashima M, Yamane K, Nakamura Y, Ohtsuki T (2008) Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. *J Biomech* 41: 2874-2883. [Crossref]

3. McGill SM, Karpowicz AMY, Fenwick CMJ (2009) Ballistic abdominal exercises: muscle activation patterns during three activities along the stability/mobility continuum *J Strength Cond Res* 23: 898-905. [Crossref]

4. Hodges PW, Richardson CA (1997) Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. Experimental Brain Research. Experimentelle Hirnforschung. *Expérimentation Cérébrale* 114: 362-370.

5. Baker JS, Davies B (2004) Resistive force selection during brief cycle ergometer exercise: implications for power assessment in international rugby union players. *J Exerc Physiol Online* 7: 68-74.

6. Palmer TG, Uhl TL (2011) Interday reliability of peak muscular power outputs on an isotonic dynamometer and assessment of active trunk control using the chop and lift tests. *Journal of Athletic Training* 46: 150-159. [Crossref]

7. Biering-Sørensen F (1984) Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine (Phila Pa 1976)* 9: 106-119. [Crossref]

8. Palmer T, Uhl TL, Howell D, Hewett TE, Viele K et al. (2015) Sport-Specific Training Targeting the Proximal Segments and Throwing Velocity in Collegiate Throwing Athletes. *Journal Of Athletic Training* 50: 567-577. [Crossref]

9. Stockbrugger BA, Haennel RG (2001) Validity and reliability of a medicine ball explosive power test. *J Strength Cond Res* 15: 431-438. [Crossref]

10. Voight M (2008) The chop and lift reconsidered: integrating neuromuscular principles into orthopedic and sports rehabilitation. *N Am J Sports Phys Ther* 3: 151-159. [Crossref]

11. Latimer J, Maher CG, Refshauge K, Colaco I (1999) The reliability and validity of the Biering-Sorensen test in asymptomatic subjects and subjects reporting current or previous nonspecific low back pain. *Spine (Phila Pa 1976)* 24: 2085-2089. [Crossref]

12. Haley SM, Fragala-Pinkham MA (2006) Interpreting change scores of tests and measures used in physical therapy. *Phys. Ther* 86: 735-743. [Crossref]

13. Bergmark A (1989) Stability of the lumbar spine. A study in mechanical engineering. *Acta Orthop Scand Suppl* 230: 1-54. [Crossref]

14. Panjabi MM (1992) The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord* 5: 383-389. [Crossref]

15. Vera-Garcia FJ, Elvira JLL, Brown SHM, McGill SM (2007) Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. *J Electromyogr Kinesiol.* 17: 556-567. [Crossref]

16. Sell MA, Abt JP, Sell TC et al. (2015) Reliability and validity of medicine ball toss tests as clinical measures of core strength. *Isokinet Exerc Sci* 23: 151-160.

17. Seiler S, Skaanes P, Kirkesola G (2006) Effects of sling exercise training on manimal clubhead velocity in junior golfers. *Med Sci Sports Exercise.* 38: 286-292.

18. Pedersen J, Magnussen R, Kuffel E, Seiler S (2006) Sling exercise training improves balance, kicking velocity and torso stabilization. *Med Science and Sport Exercise* 38: 243.

19. Peate WF, Bates G, Lunda K, Francis S, Bellamy K (2007) Core strength: a new model for injury prediction and prevention. *Journal Of Occupational Medicine And Toxicology (London, England*). 2: 3-3.

20. Schellenberg KL, Lang JM, Chan KM, Burnham RS (2007) A clinical tool for office assessment of lumbar spine stabilization endurance: prone and supine bridge maneuvers. *Am J Phys Med. Rehabil* 86: 380-386. [Crossref]

21. Nesser TW, Lee WL (2009) The relationship between core strength performance in division I female soccer players. *J Exerc Physiol Online.* 12: 21-28.

22. Everett R, Strutton PH, McGregor AH (2008) Do asymmetries exist in the trunk muscles and is this influenced by sporting task? *Isokinet Exerc Sci* 16: 255-262.