Original Article

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Reliability of a novel method assessing muscle power and velocity during seated trunk rotations

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Abstract

Introduction: Isometric and isokinetic dynamometers are mainly used for assessment of strength and endurance of core muscles. However, muscle power represents a more appropriate variable for evaluating of athlete performance that involve dynamic movements of the trunk. This study estimates test-retest reliability of trunk rotational power and velocity over a 1-week interval using the FiTRO Torso Isoinertial Dynamometer. *Material and Methods:* A group of 32 physically active men performed 5 trunk rotations to each side while seated with a barbell of 1 kg or 20 kg placed on their shoulders. *Results:* Results showed that assessment of peak and mean velocity in the acceleration phase of trunk rotations with 1 kg provides reliable results (ICC = 0.94 and 0.92 respectively, SEM = 7.0% and 7.3% respectively). However, peak and mean values of velocity and power obtained during trunk rotations with a weight of 20 kg should be interpreted with caution (ICC < 0.80, SEM > 10%). *Conclusions:* Such an assessment of trunk rotational power and velocity can be used in practice, however with a limitation of performing trunk rotations in a seated position and using lower loads.

Keywords: core muscles, testing, trunk rotational power and velocity

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INTRODUCTION

The importance of the role of the central core of the body for stabilization and force generation in sports and daily activities is being increasingly recognized. Core stabilization and core strengthening exercises have been promoted as a preventive regimen, a form of rehabilitation, and a performance-enhancing program for various lumbar spine and musculoskeletal injuries. However, there is a limited and conflicting scientific evidence on their efficiency for the enhancement of athletic performance or the prevention and rehabilitation of injuries. This is mainly due to the lack of a standard evaluation system for core stability and core strength. Evidence is based on the biomechanical analysis of technique, the experience of conditioning specialists or cross-sectional training evidence. Moreover, the low reliability and sensitivity of current diagnostic methods evaluating the stability and strength of core muscles limits their practical application. Another drawback is that these methods do not target major stabilizers of the spine in spite of the fact that studies have shown that the most important stabilizers are task specific.

Core stability tests evaluate the endurance of trunk muscles (e.g., trunk flexor and extensor endurance tests and a lateral bridge test) or the ability of the lumbopelvic-hip structures and musculature to withstand compressive forces on the spine and return the body to equilibrium after perturbation. Core strength is measured in terms of how much weight can be lifted, how many repetitions can be performed, or how long a neutral stable position can be maintained [1]. Implements, such as the medicine ball and cable pulleys, that allow motion in all three planes, can be also useful in the evaluation of muscle strength and power. Both medicine ball throws (side, overhead, scoop) and the chop and lift have shown high reliability (ICC = 0.84-0.99 and 0.87-0.98, respectively) [2-5]. Also Andre et al. [6] reported that a pulley system and an external dynamometer can be used together as a reliable research tool for assessing power during a rotational exercise of the axial skeleton in the transverse plane while seated on a box. Similarly, evaluation of the maximal power and endurance of core muscles during the standing cable wood chop exercise on a weight stack machine is both a reliable method and sensitive to differences among physically active individuals [7]. In addition to these field testing methods, in the laboratory isometric and isokinetic dynamometers that allow assessment of strength and endurance of trunk muscles are frequently used.

However, the external validity of these tests for physical tasks is ambiguous. Whilst some authors have shown that measures of core strength and sports performance are related [8, 9], others have not [10-12]. The synergistic relationship between the muscles of the core and limbs has been documented for a variety of sports specific tasks, such as overhead throwing in baseball, forehand and backhand strokes in tennis, cycling, and various lifting tasks [13-19]. For instance, Rivilla-Garcia et al. [4] reported a high correlation (r = 0.90) between a light overhead medicine ball throw (0.8 kg) and handball-throwing velocity. Conversely, Kohmura et al. [2] reported that the scoop medicine ball throw has very little shared variance with baseball fielding (throwing distance, standing long jump, and agility T-test) (~7%) compared with batting (~14%). Talukdar et al. [20] suggest that rotational power measured during the chop and lift using a linear position transducer attached to the weight stack of a cable pulley system may not be an important contributor to throwing velocity in cricket. These discrepancies may be ascribed to the task specificity and weight of the medicine ball or amount of load used during the chop and lift.

Therefore, there is a need for new robust tests that assess multiple aspects of core function and correlate well to physical tasks. However, most current tests evaluate the endurance and strength of core muscles rather than the power component of core stability. Given that rotational power is a better predictor of physical performance, the test that measures this component of the core may be more useful, especially because it may better mimic the demands imposed by many sports or occupational tasks. One of the alternatives is equipment that allows the monitoring of basic biomechanical parameters during rotational movement of the trunk. This study estimates test-retest reliability of a novel method assessing muscle power and velocity during trunk rotations in a seated position with weights of 1 kg and 20 kg in physically active individuals.

METHODS

A group of 32 physically active men (age 21.7 ± 2.1 y, height 179.6 ± 8.3 cm, body mass 83.3 ± 9.9 kg) volunteered to participate in the study. All participants had experience with resistance training including exercises strengthening the trunk muscles. They were included in the study only if they did not subjectively report back pain. Individuals who had previously undergone surgery or other medically invasive procedures for low back pain were excluded from participation in the study. All of them were informed of the procedures and the main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation and in compliance with the Helsinki Declaration.

Participants were requested to avoid any strenuous exercises during the study. Before testing, they were given a visual demonstration of the proper exercise technique and were informed of the instructions during testing. Following the warm-up, participants were exposed to a familiarization trial during which they performed seated trunk rotations in a slow and controlled manner, while keeping the back straight. They were then required to complete five repetitions of trunk rotations to each side, in the seated position with a barbell of 1 kg or 20 kg placed on their shoulders behind the neck. They were instructed to perform trunk rotations with maximal effort in the acceleration phase. Emphasis was placed on the proper position of the body while seated on a chair and holding a barbell on the shoulders with the hands. Their legs were fastened to the chair via straps crossed over the thighs and their feet inserted into board bindings to prevent movement. They began with trunk rotations to the right (or the left) side, then rotated their torso forcefully from the right (or the left) towards the opposite side until the body reached the end position, and then they slowly returned to the starting position. The test was then repeated for the opposite side of the body. They had to engage their core muscles to stiffen the torso and stabilize the spine. A laboratory assistant ensured that participants remained upright throughout the movement and that the head, chest and torso were aligned over their hips. The same experienced researchers conducted the measurements during two testing sessions with 7 days in-between.

Basic biomechanical parameters throughout the trunk rotational movement were monitored using the FiTRO Torso Isoinertial Dynamometer (FiTRONiC, Slovakia). The construction of this system allows the height of the seat to be adjusted for each individual with the lower limbs being fixed in place. The system monitors rotational movement of the barbell by means of the mechanically coupled precise angular velocity sensor. Angular acceleration was obtained by derivation of angular velocity. Angular displacement was calculated as an integral of angular velocity over time. Instantaneous force was calculated from acceleration and known rotating mass. Instantaneous power was calculated as a product of instantaneous values of force and velocity.

Data analyses were performed using the statistical program SPSS for Windows, version 18.0 (SPSS, Inc., Chicago, IL, USA). Homogeneity of variance was evaluated using Mauchly's test of sphericity and the Greenhouse-Geisser adjustment was used if assumptions of homogeneity were violated.

A one-way analysis of variance (ANOVA) with repeated measures was used to investigate whether differences exist between the outcomes of ten trials (5 of them on the left side and 5 of them on the right side of trunk rotations). The level for statistical significance was set at $p < 0.05$. Where significant F values were obtained, Scheffe *post hoc* analysis was performed.

The test-retest reliability of parameters registered during trunk rotations over two testing sessions was estimated using intraclass correlation coefficients (ICCs) (model 2,1) with 95% confidence intervals (CI). A value above 0.80 was considered acceptable. The error associated with testing was calculated using the standard error of measurement (SEM). Also the coefficient of variations (CV) derived from a two-way ANOVA were calculated.

Figure 1. Assessment of trunk rotational power and velocity using the FiTRO Torso Isoinertial Dynamometer.

Peak and mean power and velocity in the acceleration phase of trunk rotations, as the most used parameters allowing the evaluation of physical performance, showed good to excellent reliability when the weight of 1 kg was used (Table 3). However, lower coefficients of variation for trunk rotational velocity rather than power indicate that the former represents a more reliable parameter and should be used for data analysis. Furthermore, peak and mean values of power and velocity obtained during trunk rotations with the weight of 20 kg should be interpreted with caution, taking into account the ICC < 0.80 and SEM > 10% (Table 4). Similarly, poor to moderate reliability was observed for these parameters registered during whole rotational phase of the trunk.

Table 1. Peak and mean values (SD - standard deviation) of parameters registered during seated trunk rotations with 1 kg.

Parameters of trunk rotations with 1 kg	Whole rotational phase		Acceleration phase	
	Session 1 Mean (SD)	Session 2 Mean (SD)	Session 1 Mean (SD)	Session 2 Mean (SD)
Mean angular velocity [º/s]	409.6 (88.8)	423.6 (82.9)	391.7 (59.7)	397.1 (68.6)
Mean power [W]	118.7 (41.4)	125.4 (45.4)	115.6 (43.7)	119.5 (41.4)
Mean force [N]	32.1 (8.1)	33.3 (8.0)	32.1 (7.7)	32.3 (7.4)
Mean angular displacement [º]	184.2 (36.5)	187.7 (37.6)	101.8 (28.5)	104.1 (29.8)
Peak angular velocity [º/s]	702.4 (104.4)	705.3 (117.3)	-	-
Peak power [W]	234.6 (88.6)	236.7 (86.5)	-	-
Peak force [N]	56.4 (18.8)	57.0 (19.4)	-	-

Table 2. Peak and mean values (SD - standard deviation) of parameters registered during seated trunk rotations with 20 kg.

Parameters of trunk rotations with 1 kg	Whole rotational phase		Acceleration phase	
	Session 1 Mean (SD)	Session 2 Mean (SD)	Session 1 Mean (SD)	Session 2 Mean (SD)
Mean angular velocity [º/s]	140.8 (32.2)	150.5 (36.5)	151.4 (29.2)	157.3 (32.2)
Mean power [W]	139.8 (74.5)	150.9 (80.2)	174.5 (91.9)	181.9 (96.8)
Mean force [N]	98.5 (33.6)	104.7 (35.2)	114.3 (36.3)	117.3 (38.5)
Mean angular displacement [º]	166.6 (28.6)	170.3 (30.2)	81.9 (18.1)	84.6 (18.3)
Peak angular velocity [º/s]	267.2 (58.0)	280.0 (57.1)	-	-
Peak power [W]	344.9 (181.1)	358.6 (178.7)	-	-
Peak force [N]	321.2 (100.3)	328.1 (100.7)	-	-

Table 3. Measures of reliability for parameters registered during seated trunk rotations with 1 kg.

	Whole rotational phase		Acceleration phase	
Parameters of trunk rotations with 1 kg	ICC (95% CI)	SEM% (95% CI)	ICC (95% CI)	SEM% (95% CI)
Mean angular velocity	0.70 (0.67-0.74)	11.8 (10.7-12.4)	0.92 (0.90-0.94)	7.3 (7.1-7.7)
Mean power	0.66 (0.62-0.69)	14.0 (12.9-15.2)	0.91 (0.87-0.93)	7.6 (7.4-7.9)
Mean force	0.97 (0.95-0.98)	3.3 (2.9-3.5)	0.99 (0.98-0.99)	2.1 (1.8-2.3)
Mean angular displacement	0.87 (0.85-0.91)	8.0 (7.7-8.2)	0.90 (0.87-0.93)	7.7 (7.5-8.0)
Peak angular velocity	0.94 (0.90-0.96)	7.0 (6.7-7.3)	-	-
Peak power	0.92 (0.88-0.94)	7.4 (7.2-7.7)	-	-
Peak force	0.98 (0.96-0.99)	2.5 (2.3-2.7)	-	-

Table 4. Measures of reliability for parameters registered during seated trunk rotations with 20 kg.

	Whole rotational phase		Acceleration phase	
Parameters of trunk rotations with 20 kg	ICC (95% CI)	SEM% (95% CI)	ICC (95% CI)	SEM% (95% CI)
Mean angular velocity	0.63 (0.61-0.66)	14.7 (13.6-15.0)	0.73 (0.70-0.75)	10.9 (10.6-11.3)
Mean power	0.59 (0.55-0.63)	15.1 (13.9-15.4)	0.69 (0.67-0.73)	12.7 (12.4-13.0)
Mean force	0.84 (0.81-0.87)	8.3 (7.8-8.5)	0.89 (0.85-0.92)	7.7 (7.4-7.9)
Mean angular displacement	0.82 (0.79-0.85)	8.6 (8.2-8.9)	0.86 (0.83-0.90)	8.1 (7.7-8.4)
Peak angular velocity	0.76 (0.72-0.79)	10.6 (10.1-10.8)	-	-
Peak power	0.71 (0.68-0.74)	11.3 (10.9-11.5)	-	-
Peak force	0.87 (0.84-0.89)	8.0 (7.8-8.3)	-	-

DISCUSSION

Assessment of peak and mean power and velocity in the acceleration phase of trunk rotations using the FiTRO Torso Isoinertial Dynamometer provides reliable results. However, the reliability of measures obtained from the whole rotational phase, which includes the acceleration and deceleration phase, is insufficient for their use in practice. Participants were required to perform trunk rotations with maximal effort in the acceleration phase, which means that they were allowed to break the movement in the deceleration phase. This could contribute to the low reliability of data obtained from the whole rotational phase.

The limitation of this measurement is that trunk rotations were performed in a seated and fixed position with a maximum weight of 20 kg. Seated trunk rotations reduce the involvement of the legs and the contribution of thoracic/hip mobility to the upper-body rotational power. Reduced range of motion of the hips and the thoracic spine, which allow the greatest rotation because of the orientation of the joints [21], could contribute to lower movement velocity of the trunk and consequently influence ball velocity in throwing and striking sports. These sports that involve throwing motions require the production of explosive movement in either the transverse or oblique planes [22]. The force is transferred sequentially from the proximal segments, such as the hips, toward the more distal segments, such as the shoulders and arms. Because of the kinetic linkage of the proximal to distal sequence in throwing [23], rotational mobility may play an important role in the production of trunk rotational power. This power transference from the proximal segments, such as the hips and upper trunk, may be crucial to throwing velocity.

Therefore in sports involving loaded trunk rotations, standing posture should be preferred when testing an athlete´s specific performance as opposed to the rotations performed while sitting on a chair with straps around the back and legs. However, standing rotational movement that allows more involvement of the lower body is less confined to the trunk. Additionally, such movement of the whole body may increase the data variability and influence the reliability of measurements. On the contrary, standing trunk rotations are much more effective for power production than those performed in the seated position [24]. As shown, peak and mean values of power were significantly higher during standing than seated trunk rotations, with more pronounced differences at higher weights (≥ 10.5 kg). This may be ascribed to a greater range of trunk motion while standing as compared to sitting, which allowed participants to accelerate the movement more forcefully at the beginning of rotation. As a result a greater trunk rotational velocity and overall power outputs were observed.

When comparing trunk rotational power at different weights while standing and sitting in athletes of various sports [25], the values were significantly higher in a standing compared to a sitting position with weights ≥ 10.5 kg in a group of athletes that are used to performing standing trunk rotational movements in their sports (boxers, hockey players, judo practitioners, karate practitioners, tennis players, and wrestlers). However, mean power in the acceleration phase of trunk rotations did not differ significantly during standing and seated trunk rotations in canoeists and kayakers at all weights used. In other words, there were no significant differences in the trunk rotational power between these groups of athletes when trunk rotations were performed in a standing position. However, when trunk rotations were performed in a sitting position, the values were significantly higher with weights ≥ 10.5 kg in athletes performing seated rather than standing trunk rotational movements in their sports. Although the respective angular displacement during trunk rotations showed a similar tendency, its values only moderately correlated with trunk rotational power in both the standing and sitting positions. This indicates that athletes were able to produce forceful movement, regardless of their range of trunk rotational motion. Greater trunk rotational power in either a standing or a seated position is undoubtedly due to the predominant exercise mode used during their training and competition. Therefore, the exercise that most closely replicates the upper/lower body rotation movements should be preferred in testing in order to assess sport-specific power.

Furthermore, there are low correlations between the power achieved during standing and seated trunk rotations with weights ≥10.5 kg [24], suggesting that these tests measure distinct qualities. This is because the core muscles better facilitate the movement of the trunk when the body is in an upright position. On the contrary, there is a strong relationship between the power produced during standing and seated trunk rotations with a lower weight of 5.5 kg. This indicates that these exercises are similar in terms of power production. Taking these findings into account, measurement of the velocity of trunk rotations in a seated position with 1 kg could lead to similar results as those obtained while standing. Moreover, laboratory conditions provide standardized conditions and permit comparisons to be made on repeated measurements.

This test can also be applied for middle-aged individuals who practice sports such as canoeing, golf, table tennis or tennis that require rotational movements of the trunk under unloading or loading conditions. Older adults produce significantly lower peak and mean velocity in the acceleration phase of trunk rotation and respective angular displacement when compared to young adults [26]. These values of the velocity of trunk rotations correlate significantly with trunk angular displacement in both groups. It is therefore most likely that the slower velocity of trunk rotations is due to a limited range of trunk rotational motion, which is more evident in older adults.

Another application of this method relates to wheelchair athletes, whose core musculature is the foundation for efficient movement and maximum power production. Similarly to the previous study, peak and mean velocity of trunk rotations strongly correlated with respective angular displacement in para table tennis players [27], indicating that their slower velocity of trunk rotations when compared with able-bodied athletes is due to their limited range of trunk motion. However, within-subject variation in angular acceleration and velocity was unaffected by angular displacement of the trunk. It is therefore likely that the performance level plays a role in the underlying variation within these individuals. Both peak and mean velocity and acceleration during trunk rotations with 1 kg were found to be sensitive parameters able to discriminate between individuals with different performance levels.

Other studies have also documented that mean power and velocity in the acceleration phase of trunk rotation are sensitive parameters able to identify group and individual differences [28, 29]. More specifically, mean power produced with a weight of 20 kg was significantly higher in tennis players than golfers, in rock & roll dancers than ballroom dancers, and in judoists than wrestlers. Also mean velocity in the acceleration phase of trunk rotation was significantly higher in tennis players than golfers; however only when the weight of 1 kg was used. Significantly higher trunk rotational velocity with both 1 kg and 20 kg was also found in rock & roll dancers as compared to ballroom dancers. On the other hand, its values did not differ significantly between judoists and wrestlers with weights of 1 kg and 20 kg. Comparison of trunk rotational power with 20 kg and velocity with 1 kg and 20 kg between individuals showed higher values in the ice-hockey player than in the karate competitor, in the canoeist than in the rower, and in the weightlifter than in the bodybuilder. These within and between groups differences in trunk rotational power and velocity may be attributed to the specificity of training involving trunk movements of different velocities under different load conditions.

These findings indicate that the measurement of trunk rotational power and velocity using the FiTRO Torso Isoinertial Dynamometer provides reliable data and is also sensitive to within and between group differences. Hence, it may be implemented in the functional diagnostics for physically active individuals and so complement existing testing methods.

CONCLUSION

Test-retest reliability of peak and mean velocity in the acceleration phase of trunk rotations with 1 kg is good to excellent, with high values of ICC (> 0.90) and low SEM (approximately 7%). However, peak and mean values of velocity and power obtained during trunk rotations with a weight of 20 kg should be interpreted with caution (ICC < 0.80, SEM > 10%). It is recommended to use the testing protocol that consists of three trials to each side of trunk rotations, following 2-3 practice trials. In such a case, the stability of the same-day and the reliability of day-to-day measures is sufficient for using this method in practice. Such an assessment of trunk rotational power and velocity may be considered to be a suitable and practical alternative for fitness-oriented testing of physically active populations.

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