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original research

Interday Reliability of Peak Muscular Power Outputs on an Isotonic Dynamometer and Assessment of Active Trunk Control Using the Chop and Lift Tests

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Context: Assessment techniques used to measure functional tasks involving active trunk control are restricted to linear movements that lack the explosive movements and dynamic tasks associated with activities of daily living and sport. Reliable clinical methods used to assess the diagonal and ballistic movements about the trunk are lacking.

Objective: To assess the interday reliability of peak muscular power outputs while participants performed diagonal chop and lift tests and maintained a stable trunk.

Design: Controlled laboratory study.

Setting: University research laboratory.

Patients or Other Participants: Eighteen healthy individuals (10 men and 8 women; age = 32 ± 11 years, height = 168 ± 12 cm, mass = 80 ± 19 kg) from the general population participated.

Intervention(s): Participants performed 2 power tests (chop, lift) using an isotonic dynamometer and 3 endurance tests (Biering-Sørensen, side-plank left, side-plank right) to assess active trunk control. Testing was performed on 3 different days separated by at least 1 week. Reliability was compared between days 1 and 2 and between days 2 and 3. Correlations between the power and endurance tests were evaluated to determine the degree of similarity.

Main Outcome Measure(s): Peak muscular power outputs (watts) derived from a 1-repetition maximum protocol for the chop and lift tests were collected for both the right and left sides.

Results: Intraclass correlation coefficients for peak muscular power were highly reliable for the chop (range, 0.87–0.98), lift (range, 0.83–0.96), and endurance (range, 0.80–0.98) tests between test sessions. The correlations between the power assessments and the Biering-Sørensen test (r range, −0.008 to 0.017) were low. The side-plank tests were moderately correlated with the chop (r range, 0.528–0.590) and the lift (r range, 0.359–0.467) tests.

Conclusions: The diagonal chop and lift power protocol generated reliable data and appears to be a dynamic test that simulates functional tasks, which require dynamic trunk control.

Key Words: trunk stability, anaerobic peak muscular power, assessment, diagonal movement patterns

Key Points

- Peak muscular power outputs (measured in watts) obtained from the chop and lift tests were highly reliable across different test days separated by at least 1 week.
- The chop and lift tests were novel but reliable measurements for dynamic, multiplanar functional activities that have low to moderate correlation with traditional muscular endurance tests, indicating that these tests provide unique information about function compared with traditional measures.
- Performing diagonal power movements about a stable trunk can offer clinicians alternate tests that simulate activities of daily living and sport in a dynamic nature.

Functional tasks in activities of daily living and sport require some dynamic trunk activity.[1,2] The trunk musculature absorbs, produces, and transports multidirectional forces to and from the upper and lower extremities by maintaining a balance of stability and mobility.[3–5] The importance of maintaining and controlling different positions of the trunk during physical activity has been well established in the functional performance and injury literature.[6–12] Researchers have hypothesized that deficits in muscular capabilities (power, strength, endurance) and motor control (amplitude, timing) lead to poor trunk stabilization and can alter performance or increase injury susceptibility.[10,13–17] As a result, several different assessment techniques have emerged to evaluate trunk musculature. Unfortunately, most of these assessment techniques focus on muscular endurance tasks and evaluate static postures[18–20] or linear movements.[21] Recently, investigators[22,23] identified muscular power as a critical element in the development and evaluation of proximal stability for dynamic trunk activity. Power movements, such as lifting a heavy bag of pet food out of the car or throwing or kicking a ball, rely on a proximal foundation.[5,24,25] Some researchers[16,17] consider diagonal and forceful movement patterns that simulate motions associated with activities of daily living or sport to be more functionally appropriate in assessing the capabilities of the trunk stabilizers. To date, limited reliable assessment tests are available to evaluate active trunk control with diagonal and forceful movements similar to activities of daily living and sport.

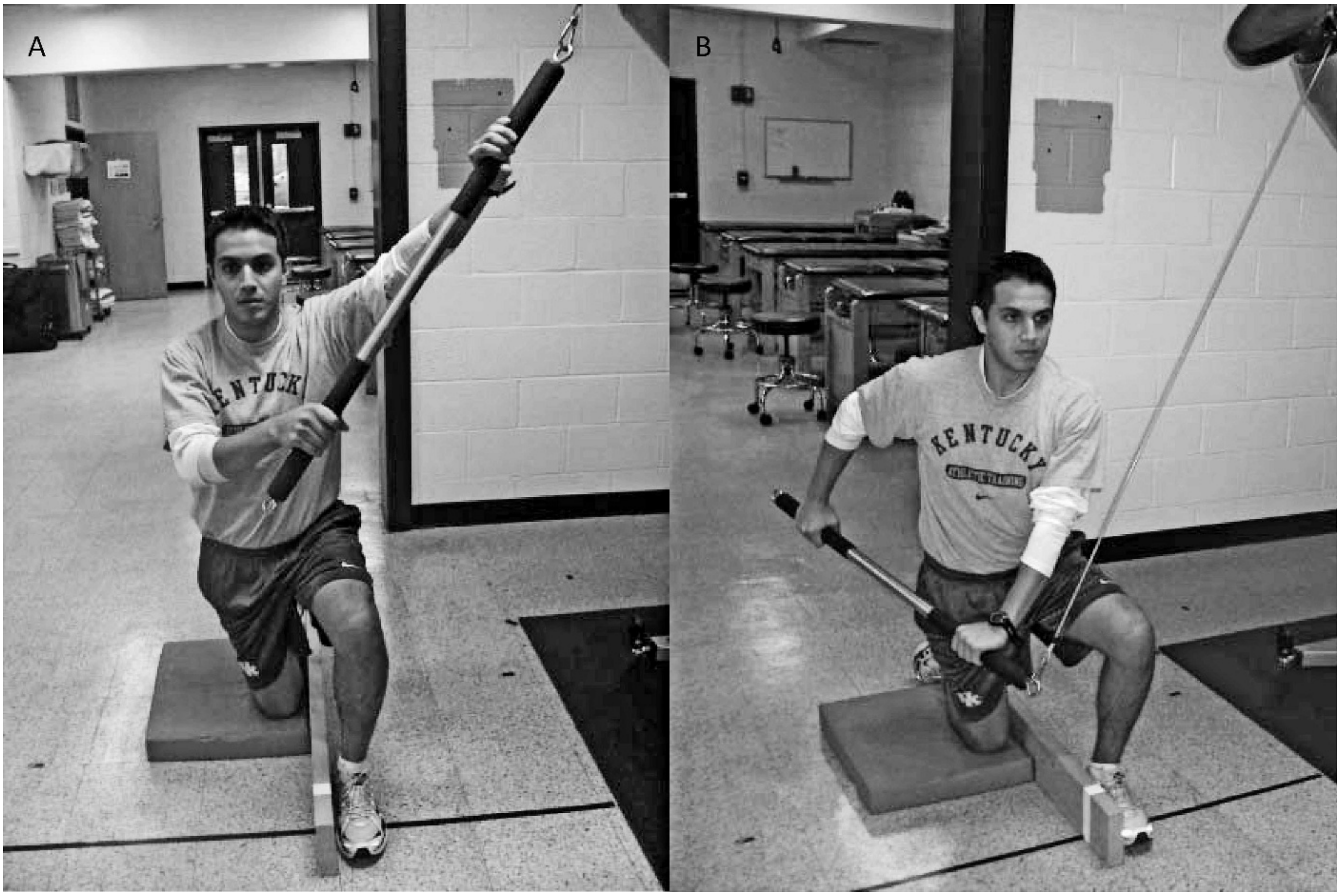

Figure 1. Chop test, right. The diagonal chopping motion moves across the torso in a downward direction from left to right. A, Beginning position. B, Ending position.

Described as bilateral modified proprioceptive neuromuscular facilitation exercises, the half-kneeling chop and lift tests use upper extremity multiplanar motions to assess or train shoulder and trunk musculature (Figures 1 and 2).[4,17] Combined with an explosive-power output measure, these maneuvers could provide a novel way to assess diagonal forceful movement that mimics the activities of daily living and demands seen in some sports. No researchers have assessed the repeatability of the chop and lift tests to measure peak muscular power capabilities. Therefore, the primary purpose of our study was to evaluate the interday reliability of peak muscular power output measures using diagonal chop and lift tests among the general population. We hypothesized that 1-repetition maximum (1RM) peak muscular power outputs produced during the chop and lift tests would be reliable between days. Our secondary purpose was to examine the relationship between the chop and lift tests and the traditional plank endurance tests. Because of the dynamic and static nature of the tests, we anticipated that the correlations between the tests would be low to moderate (<0.75).[26]

METHODS

Participants

Eighteen healthy volunteers from a general population (10 men and 8 women; age = 32 ± 11 years, height = 168 ± 12 cm, mass = 80 ± 19 kg) took part in the trunk-stability assessment sessions. Inclusion criteria were set to anyone between ages 18 and 65 years. Individuals reporting (1) any major orthopaedic injury (upper or lower extremity, torso, spine) 3 months before the study that resulted in dysfunction or time missed from performing daily activities or (2) cardiovascular or neurologic diseases, infections, tumors, osteoporosis, spondylolysis, spondylolithesis, or injury to the vertebrae or discs were excluded from the study. Participants provided their current physical activity levels using a modified Tegner activity scale (range, 1–10), with 1 representing *low activity level* and 10 representing *high activity level*.[27] The study population represented a wide cross section of activity levels on the Tegner scale (mean, 5 ± 2; range, 2–9). All participants were instructed to maintain the same activity level until the completion of the study. They provided written informed consent, and the study was approved by the institutional review board of the University of Kentucky.

Testing Procedures

Testing was performed in the Musculoskeletal Laboratory at the University of Kentucky. All testing sessions included both power and endurance tests performed on the same day and were completed in approximately 1 hour. Each set of tests required approximately 20 minutes to complete. Participants performed a 5-minute to 10-minute warm-up at 60 revolutions/minute on a stationary bicycle. A general flexibility routine involving the trunk and the

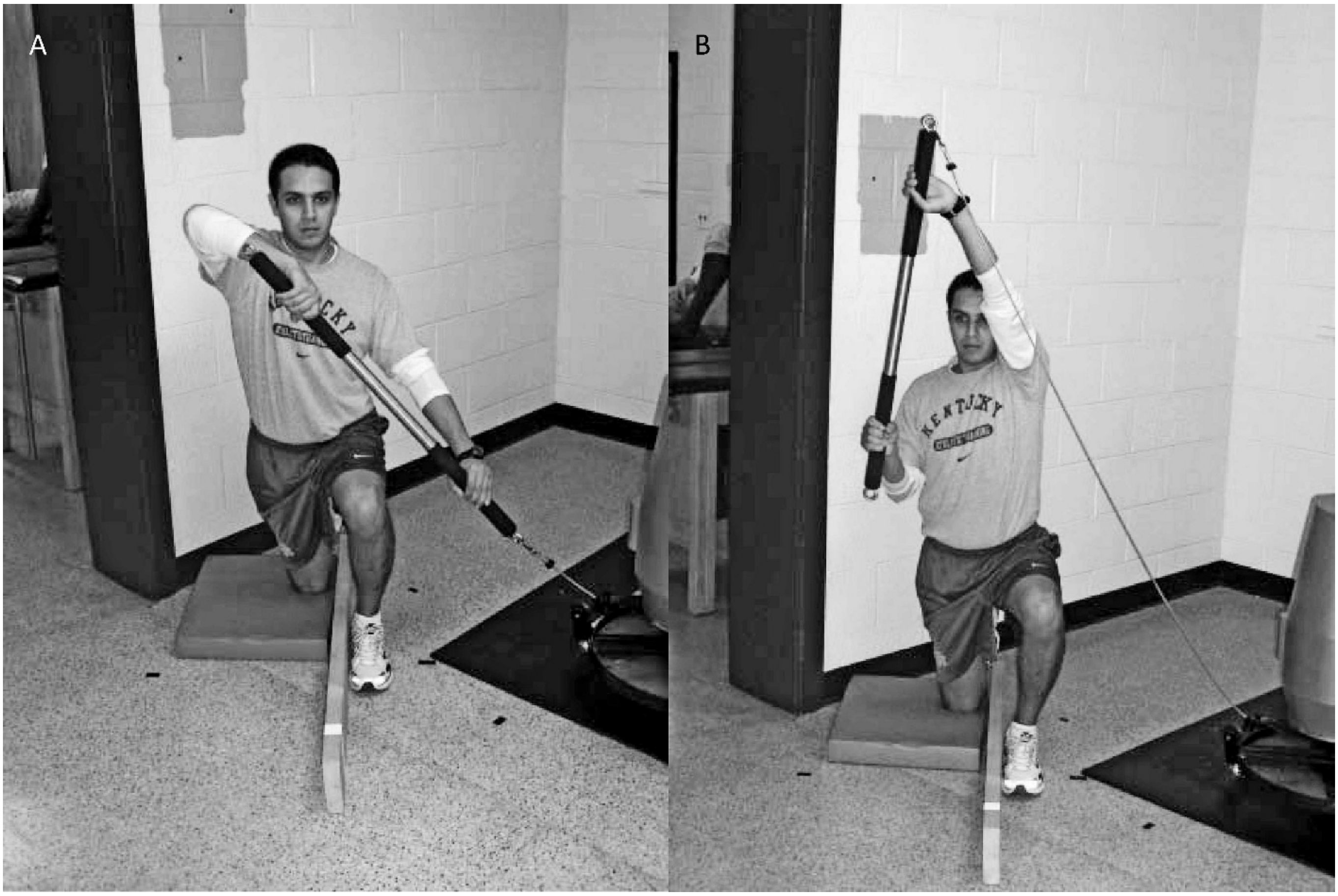

Figure 2. Lift test, right. The diagonal lifting motion moves across the torso in an upward direction from left to right. A, Beginning position. B, Ending position.

upper and lower extremities was used to prepare the participants for rotational and stability forces. All testing sessions were initiated with the power tests, followed by a 5-minute rest period and then the endurance tests.[28] The order of power tests (chop left, chop right, lift left, lift right) and endurance tests (Biering-Sørensen, side-plank left, side-plank right) were counterbalanced using a Latin-square design. All participants were instructed to produce a maximal effort for each test. Three separate testing sessions were performed at least 7 days apart.

Power Testing Protocol

Before all testing sessions, participants viewed a video demonstrating the proper chop and lift techniques. Each participant practiced the maneuvers while viewing the video and received feedback to ensure proper technique. During the first testing session, one investigator (T.G.P.) placed the participants into a half-kneeling position and instructed them for approximately 5 to 10 minutes on maintaining an erect trunk while performing the tests. Proper test position was reviewed before each testing session. The half-kneeling position was standardized to a 90° hip-flexion and knee-flexion position with a 2 × 6 × 60-in (5.08 × 15.24 × 152.4-cm) wooden plank placed between the legs. The knee and foot maintained flush contact with the board to keep the base of support narrow and to maintain a consistent challenge to the trunk stabilizers.[29] A standard 46 × 43 × 13-cm^3 block of medium-density foam pad (Airex AG, Sins, Switzerland) was used to support the weight-bearing knee for the comfort of the participant. The PrimusRS dynamometer (BTE Technologies, Inc, Hanover, MA) was used to perform the chop and lift tests. The sport package for the PrimusRS is equipped with a 1.9-lb (0.86-kg), 36-in (91.44-cm) metal dowel rod that can be secured to a 9-ft (2.75-m), 3-dimensional cable motion system (Figure 3A). Participants were instructed to look at a fixed point while maintaining a stable torso and a half-kneeling position during all chop and lift repetitions. Initially, participants received instruction on maintaining proper form and test performance for approximately 5 to 10 practice repetitions with a submaximal weight. Based on pilot data, initial testing resistance was standardized to approximately 12% and 15% of the individual's body mass for the lift and chop tests, respectively. The weight of the dowel rod (1.9 lb [0.86 kg]) was calculated as part of the test resistance provided by the PrimusRS system. Resistance was increased by 3 lb (1.35 kg) for the lift and 5 lb (2.25 kg) for the chop after a successful 1RM. Inability to produce an equal or greater peak power output value from the previous test trial resulted in a reduction in resistance by 1 lb (0.45 kg) for the lift and by 3 lb (1.35 kg) for the chop. Further adjustments were made to the resistance in 1-lb (0.45-kg) increments (increase or decrease) until maximal peak muscular power was achieved. Participants performed

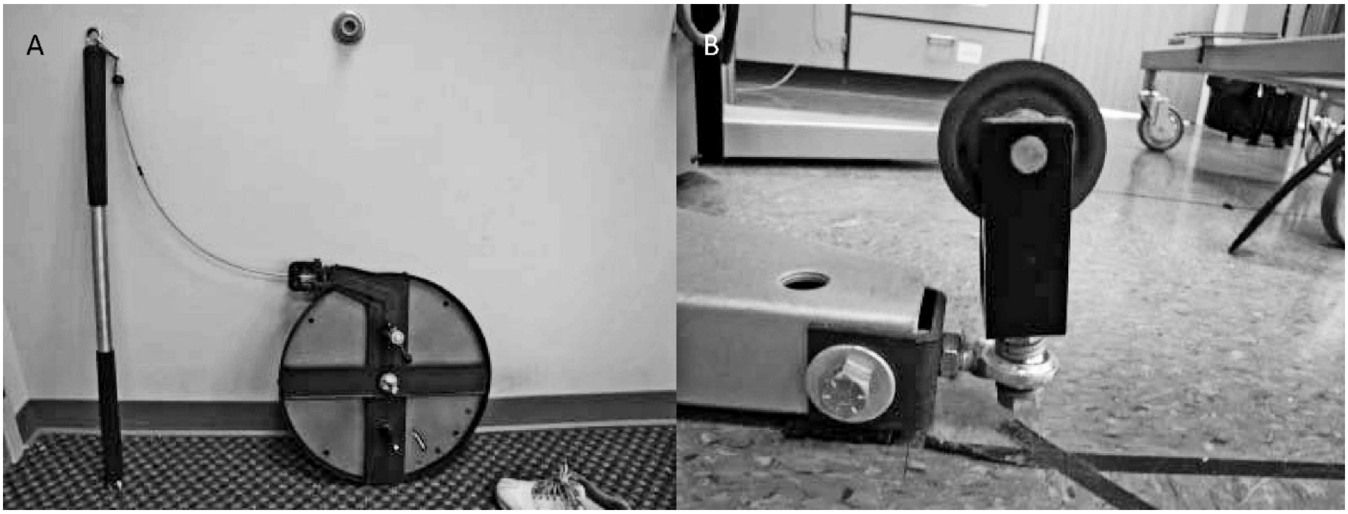

Figure 3. The PrimusRS 3-dimensional motion system (BTE Technologies, Inc, Hanover, MD) consists of a rotating head attaching a 9-ft (2.75-m) cable through a grounded pulley to a 36-in (91.44-cm), 1.9-lb (0.86-kg) dowel rod to allow for linear displacement. A, BTE PrimusRS 3-dimensional motion system. B, Grounded pulley.

a series of 1RM efforts for each test with a minimum rest period of 30 seconds between attempts. Peak muscular power (watts) and the number of repetitions (mean, 4 repetitions; range, 2–7 repetitions) used to achieve this level were recorded for each of the 4 power tests for each participant.

Chop Test. In a half-kneeling stance, the hand on the same side of the kneeling limb was placed at the bottom of the metal dowel rod, and the opposite hand was placed in an overhead position at the top of the dowel rod (Figure 1). The metal dowel rod was pulled or pushed diagonally downward across the torso by both arms in a chopping motion.[17] The test was called *right* when the dowel rod was chopped from an overhead position toward the kneeling right limb and was called *left* when the chop was toward the kneeling left limb.

Lift Test. From a half-kneeling stance, the hand on the kneeling side was placed at the bottom of the metal dowel rod at the level of the hip, the opposite elbow was flexed, and the opposite hand was placed at chest height (Figure 2). The metal cable traveled through a grounded pulley during the lift tests, which allowed for redirection of the linear displacement from the floor (Figure 3B). The metal dowel rod was pulled or pushed diagonally across the torso in an upward lifting motion.[17] The test was called *right* when the metal dowel rod was lifted across the trunk from a downward position toward the right side of the body in a more upward position. It was called *left* when the dowel rod was lifted across the torso toward the left side of the body and away from the supported right limb.[4]

The PrimusRS system calculated isotonic peak muscular power outputs in watts using the traditional equation of dividing work by time, with work equaling force × distance. Power was a product of force (Newtons) placed on the cable by the dynamometer multiplied by the distance (meters) that the cable was displaced divided by time (seconds). Instantaneous power was determined at 5-millisecond intervals based on the sampling frequency of 200 Hz. Peak muscular power was the highest power output recorded during a single repetition of the chop or lift test.

Endurance Testing Protocol

Participants were shown a photograph of the endurance tests and were able to practice the test position 1 to 2 times for approximately 5 seconds before testing. Participants focused on a fixed point while holding the static posture for as many seconds as possible. Endurance tests were terminated if the neutral position was disrupted because of fatigue or pain or because a 5° deviation occurred and could not be corrected after oral encouragement. The examiner (T.G.P.) provided oral feedback to correct observed position faults but did not provide motivation or encouragement. When a participant was unable to comply with the desired position, the test was terminated, and the time was recorded. Hold times were not reported after each test session to blind participants to the results until all 3 data collections were completed. A 1:5 work-to-rest ratio was used between endurance measures.[19,28]

Biering-Sørensen Test. Participants were positioned prone on a padded treatment table, and their legs were secured with inelastic straps at the ankles, knees, and hips below the anterosuperior iliac spine. With their arms across their chests, participants were instructed to extend and hold an erect neutral position for as long as possible. No participant exceeded 3 minutes, 54 seconds (Figure 4).

Side-Plank Test. Participants were positioned side lying on a padded table with the body straight. Each participant was instructed to suspend his or her torso and hips on a flexed elbow and the lateral surface of the foot nearest the table with the legs fully extended. The supporting shoulder was abducted to approximately 80° to 85° in the frontal plane with 90° of elbow flexion. The opposite arm was placed across the chest with the hand on the shoulder. Side planks were performed for the left and right sides. We instructed the participants to hold the test position for a long as possible. No participant exceeded 2 minutes, 56 seconds (Figure 5).

Statistical Analysis

We used an interday repeated-measures study design. The independent variables were the chop and lift tests for

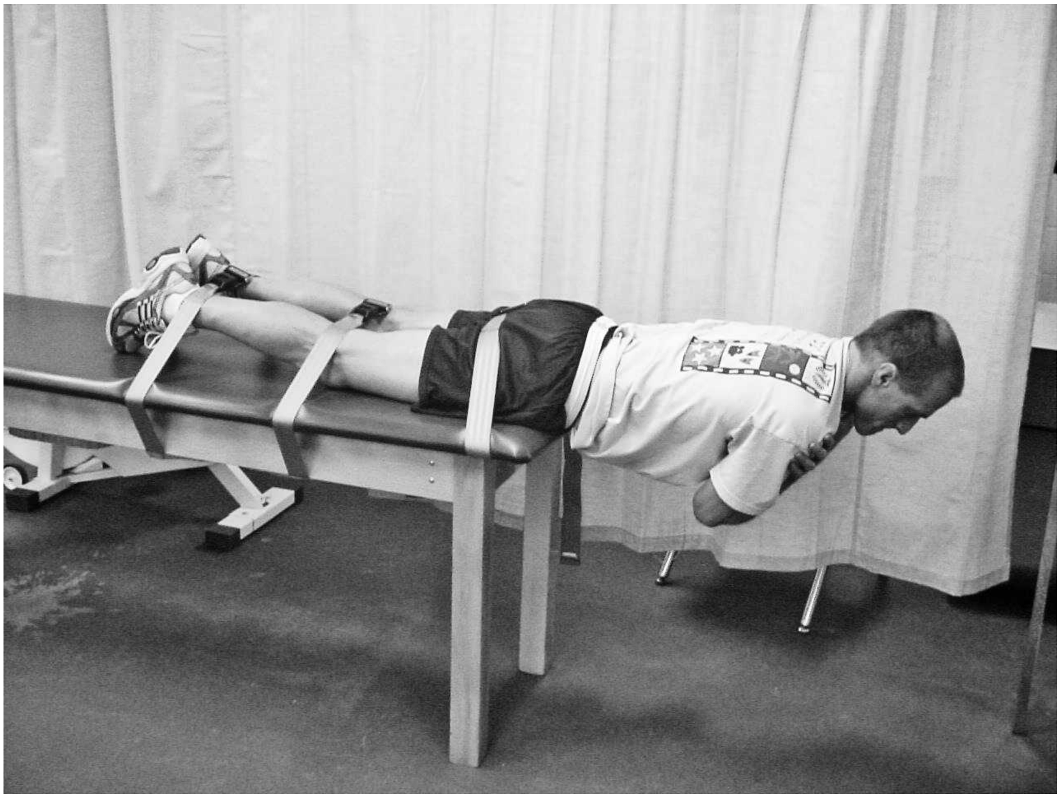

Figure 4. Biering-Sørensen isometric endurance test. Participants were instructed to stabilize and maintain an erect torso with their legs secured to a treatment table.

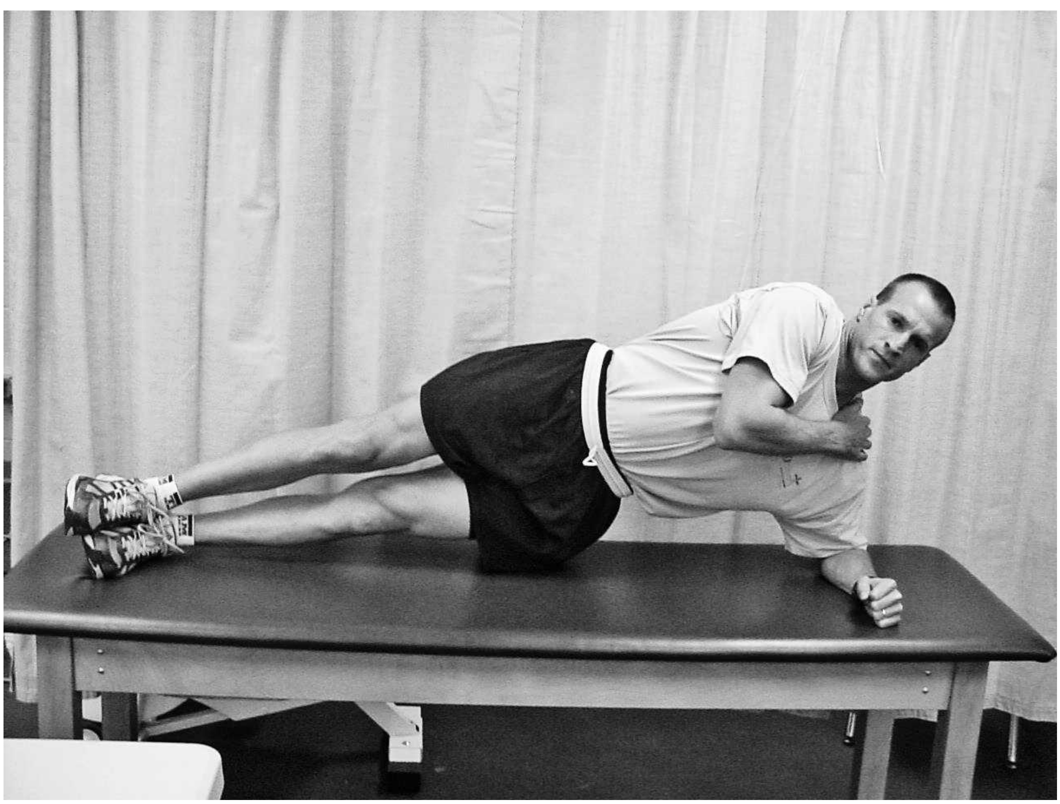

Figure 5. Side-plank isometric endurance test performed to the left side. The erect torso and lumbopelvic area were supported over the elbow and the feet. During performance, a visual target was provided to help the participant maintain focus and balance.

Table 1. Interday Reliability of Chop and Lift Power Tests

Test	Day 1 to Day 2[a] Intraclass Correlation Coefficient	95% Confidence Interval Lower Limit	95% Confidence Interval Upper Limit	Day 2 to Day 3[b] Intraclass Correlation Coefficient	95% Confidence Interval Lower Limit	95% Confidence Interval Upper Limit	Standard Error of Measurement, W[c]	Minimal Detectable Change, W[d]
Chop left	0.93	0.91	0.98	0.97	0.93	0.99	34	48
Chop right	0.87	0.68	0.95	0.98	0.95	0.99	28	39
Lift left	0.96	0.92	0.98	0.83	0.60	0.93	52	73
Lift right	0.91	0.79	0.96	0.86	0.67	0.94	41	48

[a] Indicates tests between day 1 and day 2.
[b] Indicates tests between day 2 and day 3.
[c] Calculated using the pooled SD.[30]
[d] Calculated using standard error of measurement values from all testing days.[26]

the left and right sides, the Biering-Sørensen test, and the side-plank tests for the left and right sides. The dependent variables of interest were peak muscular power output (watts) and seconds during the endurance tests (Biering-Sørensen, side-plank left, side-plank right). A 1-way, random-effects, repeated-measures analysis was used to determine intraclass correlation coefficients for each dependent variable between test days 1 and 2 and again between days 2 and 3. The precision of these tests was determined with standard error of measurement, and the responsiveness of meaningful change between 2 test days was estimated using the minimal detectable change (MDC).[30] A bivariate Pearson product moment correlation (2 tailed) was performed on the day 2 test values to determine the degree of relationship between the 4 power tests and the 3 endurance tests. Day 3 was selected for the precision and correlation calculations to account for the observed learning effect for the endurance tests across days. All statistical analyses were performed using SPSS (version 17.0; SPSS Inc, Chicago, IL).

RESULTS

Peak muscular power tests exhibited moderate to high reliability (range, 0.83–0.98) (Table 1). Peak muscular power (watts) and endurance test outputs (seconds) for test days 1, 2, and 3 are reported in Table 2. Repeatability among all the endurance tests had high reliability (range, 0.80–0.98) (Table 3). Correlations between the Biering-Sørensen and the power tests were low (range, −0.135 to 0.017) (Table 4). We observed high correlations between power tests (r range, 0.768–0.975) and moderate to high correlations among all endurance tests (r range, 0.568–0.972). The side-plank endurance tests were moderately correlated with the chop test (r range, 0.528–0.590) and to a lesser degree with the lift test (r range, 0.359–0.467) (Table 4).

DISCUSSION

We hypothesized that the peak muscular power output measures from the chop and lift tests would be reliable between days. Our results supported this hypothesis with relatively high reliability across all 3 test days. We also hypothesized that the correlation between the power and endurance tests would be low. The results of the Biering-Sørensen test supported this hypothesis; however, the side-plank tests generated moderate to low correlations with the power outputs from the chop and the lift tests. Our results indicated that the diagonal chop and lift tests are novel quantitative assessments of functional tasks compared with the static linear measures.

The peak muscular power data generated by the chop and lift tests were difficult to compare with data from other studies because these were novel tests. However, the power outputs appeared reasonable when compared with previously reported peak and average power values (range, 200–800 W) of anaerobic power tests (Wingate).[31] The muscular power from the chop (mean, 373 ± 44 W; range, 43–890 W) and the lift (mean, 216 ± 34 W; range, 25–435 W) tests was based on 1RM efforts. Tests such as the Wingate test are derived from short-burst anaerobic energy with multiple repetitions. Upper body ergometer Wingate tests for the general population average approximately 300 to 400 W, whereas lower body Wingate tests average 500 to 800 W.[31] A degree of face validity is evident because our anaerobic power outputs were relatively comparable with those previously reported. The power outputs were reasonable values but differed slightly because the 1RM peak muscular power outputs were attained from an "immediate" anaerobic energy source, whereas the Wingate test values typically are considered short-term anaerobic power efforts, usually lasting 6 to 30 seconds.[32]

Power training and explosive activities have been reported to improve function of daily tasks and promote

Table 2. Peak Muscular Power and Endurance Test Outputs

Test	Day 1 Mean ± SD	Day 1 Range	Day 2 Mean ± SD	Day 2 Range	Day 3 Mean ± SD	Day 3 Range
Chop left, W	348 ± 194	54–890	375 ± 199	53–800	387 ± 198	70–786
Chop right, W	346 ± 184	43–761	387 ± 196	56–778	395 ± 212	66–835
Lift left, W	195 ± 124	41–435	191 ± 116	37–422	223 ± 140	46–470
Lift right, W	181 ± 106	25–425	196 ± 106	31–428	215 ± 112	45–437
Biering-Sørensen, s	115 ± 49	44–225	129 ± 54	63–222	130 ± 54	63–234
Side-plank left, s	69 ± 36	23–166	74 ± 36	37–154	76 ± 39	24–169
Side-plank right, s	64 ± 40	16–156	71 ± 43	16–174	75 ± 41	22–176

Table 3. Interday Reliability of Muscular Endurance Tests

Test	Day 1 to Day 2[a]			Day 2 to Day 3[b]			Standard Error of Measurement, s[c,d]	Minimal Detectable Change, s[c,e]
	Intraclass Correlation Coefficient	95% Confidence Interval		Intraclass Correlation Coefficient	95% Confidence Interval			
		Lower Limit	Upper Limit		Lower Limit	Upper Limit		
Biering-Sørensen	0.80	0.65	0.97	0.98	0.95	0.99	7	10
Side-plank left	0.89	0.81	0.97	0.96	0.91	0.98	7	10
Side-plank right	0.91	0.80	0.97	0.98	0.95	0.99	6	8

[a] Indicates tests between day 1 and day 2.
[b] Indicates tests between day 2 and day 3.
[c] Time in seconds is the average amount of seconds for each endurance test for all sessions.
[d] Calculated using the pooled SD.[30]
[e] Calculated using standard error of measurement values from all testing days.[26]

muscle hypertrophy at a more efficient rate than does slow-velocity resistance training.[33–37] Activities that produce higher force at high velocities at the distal segments (kicking, throwing, landing) depend on moments created in the proximal segments.[24,25,38] Therefore, it is reasonable to combine diagonal patterns using the extremities with a 1RM protocol to determine the power capacity of the upper extremity and trunk functioning together. Several authors[14,22,25,29,39,40] have recognized the importance of active trunk control during power movements but have not fully explored the use of peak muscular power and trunk control. These results indicate that the dynamic power test might be a reliable method with which to further explore these systems and how they change in response to injury or training.

Nesser et al[41] and Nesser and Lee[42] studied the correlation between power performance measures and tests that challenge dynamic trunk activity. In both studies, the authors reported very low to moderate correlations (r range, 0.099–0.6) between trunk muscular measures (planks, trunk flexion-extension repetitions) and power performance measures (20-yd [18.3-m] and 40-yd [36.6-m] sprints, vertical jump) among football players and female soccer players.[41,42] They concluded the assessment tests used had very little to do with athletic performance measures in these sports and the assessment techniques used possibly were not specific enough to evaluate athletic performance.[41,42] The measures used in these studies were primarily static linear tests and static muscular-endurance tests and not explosive anaerobic tasks commonly associated with sport performance. The low to moderate correlations (r range, 0.099–0.6) between the static/linear tests and sport performance measures were similar to the correlations between the power and endurance assessment tests used in our study (r range, −0.008 to 0.590). Our results offer further evidence that trunk stability during dynamic arm movements might function along a muscular performance continuum (power–strength–endurance), as suggested by McGill et al.[22] The moderate correlations between the power and side-plank tests (r range, 0.359–0.590) revealed that approximately 33% of the variance is explained by the static measures. The fact that approximately 66% of the variance is unexplained between these measures indicates that the chop and lift protocol might provide another method with which to further investigate activities of daily living and sport by requiring the distal extremities to exert a maximal effort on a stable proximal base.

Recently, McGill et al[22] hypothesized that the hip and trunk stabilizers can develop sport-specific anaerobic capabilities that assist in the performance of explosive tasks. Some authors[22,23,29,40,43,44] have suggested these muscular characteristics are directly related to sport specificity, the bioenergetics of an individual, and the range of motion needed to successfully complete a given task. McGill et al[22] evaluated electromyography of the lumbopelvic-trunk musculature along a stability continuum and concluded that different levels of trunk muscular activation and stiffness are required for different activities and should be trained according to the mobility and stability needs of a specific task. In addition, traditional linear and static measures commonly used for patients with low back conditions or lower levels of trunk stabilization likely are less appropriate for monitoring trunk control at higher levels of activity.[3,45] Therefore, clinicians should consider assessing dynamic trunk control on a continuum that progresses from low to high levels of muscular activity. The chop and lift tests might be good alternative tests when

Table 4. Bivariate Pearson Product Moment Correlation Coefficients (*P* Values) for Day 3 of Testing

Test	Endurance Test			Power Test			
	Biering-Sørensen	Side-Plank Left	Side-Plank Right	Chop Left	Chop Right	Lift Left	Lift Right
Biering-Sørensen	1[a]	0.615 (.007[b])	0.568 (.01[b])	−0.027 (.92)	0.017 (.95)	−0.008 (.97)	−0.135 (.59)
Side-plank left		1[a]	0.972 (<.001[b])	0.528 (.02[b])	0.547 (.03[b])	0.451 (.06)	0.367 (.13)
Side-plank right			1[a]	0.584 (.01[b])	0.590 (.01[b])	0.467 (.05)	0.359 (.14)
Chop left				1[a]	0.975 (<.001[b])	0.768 (<.001[b])	0.860 (<.001[b])
Chop right					1[a]	0.783 (<.001[b])	0.857 (<.001[b])
Lift left						1[a]	0.769 (<.001[b])
Lift right							1[a]

[a] Indicates perfect correlation.
[b] Indicates difference ($P < .05$).

assessing movements involving the trunk. The combination of ballistic arm movements and the narrow base of support in the half-kneeling stance creates a different state from that associated with the static plank test, which offers an alternative challenge to the proximal stabilizers.[23,29] Sport-specific training and assessments have been implemented for decades; these tests might provide another method to evaluate active extremity and trunk function. Further research is needed to investigate the performance capabilities as they pertain to specific tasks that require muscular power rather than muscular endurance.

Muscular endurance characteristics of the hip and trunk stabilizers traditionally have been recognized as primary contributors in maintaining a stable lumbopelvic area.[6,8,11] As a result, the Biering-Sørensen and side-plank tests have become 2 of the most common clinical tests used to assess the isometric endurance capabilities of the hip and trunk musculature to identify individuals with potential dysfunction.[18,19,46] Therefore, we investigated the relationship between the traditional measures and a novel test with the expectation that the correlation between them would be low, per our hypothesis. The moderate correlation (r range, 0.359–0.590; P range, .01–.14) between the side-plank tests and the power maneuvers indicated that both tests challenge the lateral stabilizers (oblique musculature, transverse abdominus) but conceivably through the use of different muscle bioenergetics.[22,46] Although not quantified in our study, the correlations between the chop test and the side-plank tests are likely due to similarities in the muscular activation of the lateral trunk and abdominal obliques necessary to complete these movements.[47] The low to moderate correlations between the different assessment protocols support the divergent validity of the power test outputs. Both the power and endurance assessment protocols appear to be measuring different characteristics, perhaps on a performance continuum.[22]

Diagonal movements, such as those used in the chop and lift tests, are likely to promote sequential muscle activation on multiple planes between the proximal and distal body segments. The muscular endurance tests tend to isolate a select group of muscles while functioning on a single plane.[1,16,17,20,25] The erector spine, gluteal, or hamstrings muscles have been reported[20] to be active predominantly during a supine-plank position and Biering-Sørensen prone position. The anterior musculatures of the torso and pelvis are active predominately during a prone-plank position, whereas the lateral trunk stabilizers are isolated with the side-plank positions.[20,47–49] The trunk stabilizers seldomly are isolated in this manner[22]; rather, they function collectively on multiple planes to provide different degrees of stability and mobility.[50–52] As such, researchers[39,48,53–55] have reported that static and 1-dimensional muscular endurance tests are poorly correlated with tasks associated with daily function and sport. In part, this is likely due to the limited multidimensional and diagonal movements commonly used in sport. McGill et al[22] identified the potential importance of incorporating diagonal movement patterns because greater electromyographic peak torque activation among a variety of trunk musculature was evident when compared with linear stability tasks. Furthermore, the use of diagonal movement patterns has been reported[16] to promote a balance between agonist and antagonist muscle activation of multiple muscle groups. Thus, diagonal movement patterns of the extremities should be considered because they promote a comprehensive integration of active trunk stability on multiple planes. The results of our study provide a foundation for further investigations involving diagonal movements and functional tasks.

To have clinical meaningfulness, a new clinical test needs to demonstrate high reliability, validity, and responsiveness to change.[30] The primary purpose of our study was to evaluate interday reliability of peak muscular output measures using diagonal chop and lift tests; the reliability was found to be good to excellent (intraclass correlation coefficient range, 0.83–0.98). However, a gradual increase in the peak power outputs from day 1 to day 3 for each testing session indicated that learning might have been occurring (Table 2). In previous studies,[18,19] investigators have identified a learning effect between testing sessions for muscular endurance tests involving the trunk and pelvic musculature. Based on our study and previous reports, we suggest that a familiarization period be included. At least 1 day of testing or training is recommended to ensure that measurable changes are true and are not due to learning.[48]

We did not specifically evaluate responsiveness because it would have required either an intervention or 2 separate populations. However, the calculation of standard error of measurement and MDC describes the potential change that would be needed to determine a true change in performance (Tables 1 and 2). The MDC values represent the minimal amount of change necessary to determine a true change has occurred beyond the measurement error. The average MDCs for the 4 power tests were about 20% of their respective mean values. An approximate increase in performance of 20% would represent a meaningful clinical change for the power tests. This percentage is similar to that found with traditional static measures within a general population.[18] This percentage of change seems reasonable because other measures, such as numeric pain rating scales, require a 2 out of 10 change to indicate a meaningful change.[56]

The initial test resistance of 12% and 15% body mass for the lift and chop tests, respectively, appears to be a relatively good recommendation when testing the general population for 1RM. The average number of repetitions needed to reach maximal peak power outputs was 3 for the lift tests and 4 for the chop tests. Testing resistance that is closer to an individual's 1RM makes the testing process more efficient.[57] Although not different, a trend of more trials for the chop test was evident among participants scoring "high" (>7) on the Tegner activity scale. Our results indicated that individuals with a higher activity level or those competing in sport might benefit from using a higher starting resistance, such as 20% to 25% of the total body mass, especially with the chop test.

Limitations

Although the values gained from the chop and lift tests were reliable and attainable in approximately 30 minutes (mean = 26 ± 3.9 minutes), the test techniques did have some limitations. The diagonal patterns required the participant to create forceful movements of the upper body while maintaining a stable proximal base from a half-kneeling position. This required individuals to have adequate upper body strength and coordination to perform these movements. It is impossible to not consider the contributions made by the upper extremity to the testing procedure and, therefore, the contribution to the peak power generated. This test does not isolate the specific trunk musculature but evaluates contributions of dynamic trunk control while an individual performs a functional task with the lower and upper extremity as a single forceful unit. The lift motion is a slightly awkward movement; compared with the chop test, it requires more time to practice, to instruct the participant in use, and to complete testing. Improvements in the testing protocol might be needed to refine the overall efficiency of the assessment techniques.

CONCLUSIONS

The chop and lift tests performed on the PrimusRS dynamometer provided repeatable measures of power output from week to week in the general population. This novel test appeared to measure a different construct than muscular endurance because correlations with the Biering-Sørensen and side-plank tests were low to moderate. The frequent use of power movements on multiple planes in athletics and in daily tasks requires clinicians and researchers to identify testing techniques that evaluate these effects. We believe the chop and lift 1RM protocol has good potential to serve this purpose because it appears to measure functional tasks that require dynamic trunk control. Further testing and modification of this protocol might provide additional evidence to support the potential roles that muscular power might play during specific activities.

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