Effect of Core Strength on the Measure of Power in the Extremities

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EFFECT OF CORE STRENGTH ON THE MEASURE OF POWER IN THE EXTREMITIES

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ABSTRACT

Shinkle, J, Nesser, TW, Demchak, TJ, and McMannus, DM. Effect of core strength on the measure of power in the extremities. J Strength Cond Res 26(2): 373–380, 2012—The purpose of this study was to (a) develop a functional field test to assess the role of the core musculature and its impact on sport performance in an athletic population and (b) develop a functional field test to determine how well the core can transfer forces from the lower to the upper extremities. Twenty-five DI collegiate football players performed medicine ball throws (forward, reverse, right, and left) in static and dynamic positions. The results of the medicine ball throws were compared with several athletic performance measurements: 1 repetition maximum (1RM) squat, squat kg/bw, 1RM bench press, bench kg/bw, countermovement vertical jump (CMJ), 40-yd dash (40 yd), and proagility (PrA). Push press power (PWR) was used to measure the transfer of forces through the body. Several correlations were found in both the static and dynamic medicine ball throws when compared with the performance measures. Static reverse correlated with CMJ (r = 0.44), 40 yd (r = 0.5), and PrA (r = 0.46). Static left correlated with bench kg/bw (0.42), CMJ (0.44), 40 yd (0.62), and PrA (0.59). Static right also correlated with bench kg/bw (0.41), 40 yd (0.44), and PrA (0.65). Dynamic forward (DyFw) correlated with the 1RM squat (r = 0.45) and 1RM bench (0.41). Dynamic left and Dynamic right correlated with CMJ, r = 0.48 and r = 0.40, respectively. Push press power correlated with bench kg/bw (0.50), CMJ (0.48), and PrA (0.48). A stepwise regression for PWR prediction identified 1RM squat as the best predictor. The results indicate that core strength does have a significant effect on an athlete’s ability to create and transfer forces to the extremities. Currently, plank exercises are considered an adequate method of training the core for athletes to improve core strength and stability. This is a problem because it puts the athletes in a nonfunctional static position that is very rarely replicated in the demands of sport-related activities. The core is the center of most kinetic chains in the body and should be trained accordingly.

KEY WORDS dynamic core assessment, muscular power, trunk strength, athletic performance, trunk muscles

INTRODUCTION

By definition, the core is considered a box with the abdominals as the front, paraspinals and gluteals in back, the diaphragm as the roof, obliques as the sides, and the pelvic girdle and hip girdle musculature serving as the bottom (2,10). It has been theorized that a strong core will allow a transfer of forces from the lower body to the upper body with a minimal dissipation of energy in the torso (6,17). If power is created but not transferred, performance (i.e., running, jumping, throwing, etc.) will be negatively affected. The current literature shows the importance of having a strong core in relation to static and isokinetic endurance times and the prevention of injury (3,5,8,9,16), and researchers even make claims for improved performance (2,12,13,18,21). However, when attempts have been made to determine the significance of the core in sport performance with an athletic population, the results are not as promising (10,19,20,23,24,26). One possible reason for this discrepancy is the lack of core testing specificity to athletic performance. McGill’s (18) core assessment is one such test commonly used to measure core strength and stability. With this assessment, individuals are required to maintain a static muscle contraction for an extended period of time in 4 different positions. Originally, this test was developed to assess individuals with low back pain. Ultimately, this is a static muscle endurance test. Considering athletic performance is primarily dynamic and intermittent, a static muscle endurance test is not an accurate assessment of the role of the core in a healthy athletic population.

Currently, there are no means to dynamically assess the core and its potential role in athletic performance nor is there a test to determine how well the core transfers forces.
from the lower extremities to the upper extremities. Therefore, the purpose of this study was to (a) develop a functional field test to assess the role of the core musculature and its impact on sport performance in an athletic population and (b) develop a functional field test to determine how well the core can transfer forces from the lower to the upper extremities.

**METHODS**

**Experimental Approach to the Problem**
To date, there has been no attempt to investigate the effect of dynamic core strength on extremity function and performance. Therefore, this study was a multivariate correlation design. The independent variables of core strength included various medicine ball throws: Static Forward (StF), Static Reverse (StR), Static Left (StL), Static Right (StRi), Dynamic Forward (DyF), Dynamic Reverse (DyR), Dynamic Left (DyL), and Dynamic Right (DyRi), and a push press for power (PP). The dependent variables used were measurements of athletic performance: 1 repetition maximum (1RM) squat maximum (absolute and relative to body mass), 1RM bench press maximum (absolute and relative to body mass), countermovement vertical jump (CMJ), 40-yd dash (40 yd), and a proagility run (PrA).

**Subjects**
Twenty-five National Collegiate Athletic Association Division I football players (weight 106.2 ± 20.9 kg; height 184 ± 4.6 cm; age 19.0 ± 1.1 years) were tested. All testing was completed as part of the off-season strength and performance assessment just before the start of spring ball. All the participants were free of injury at the time of data collection. All the participants signed the informed consent. The university institutional review board approved this study.

**Procedures**
All the subjects were educated on the procedures and expectations of the research study and familiarized to the tests. Before data collection, all the subjects performed a dynamic warm-up administered by the university strength and conditioning staff. The warm-up took approximately 15 minutes to complete.

The seated medicine ball throw has been identified as a valid measure of upper body power (22,25). The back is stabilized for this test eliminating the need for core stabilization; however, it only measures throws in a forward direction and does not have the option to mobilize the upper body allowing use of the torso. For this reason, 2 side throws and a reverse throw were added to assess the anterior, posterior, and lateral aspects of the core with the torso stabilized and not stabilized. The BOMB throw exists as a valid backward medicine ball throw (15), but it is executed from a standing position. For this study, all medicine ball throws were completed from a seated position to eliminate any force production from the lower extremities. For this reason, the feet were not secured. Medicine ball throws were performed twice; the best throw for distance was used for analysis. The throws were marked at first contact with the ground and were measured in meters. After completion of the first throw in each position, the ball was returned, and the second throw was performed. A 1-minute rest period was given between each throw.

**Static Forward Throw.** The subject sat on a standard adjustable weightlifting bench with the back inclined to 90°. Feet remained flat on the floor. A strap was placed across the chest and secured to the back of the bench to limit the involvement of the core musculature in the throw. The subject maintained 90° of hip flexion and a fully erect spine from the beginning of the test until the medicine ball was released forward. A 2.7-kg medicine ball was placed in both hands, the arms were then raised just above the head with the shoulders abducted and elbows flexed. The throw was then performed with a powerful contraction of the arms to throw the ball forward.

**Dynamic Forward Throw.** The subjects sat on a standard adjustable weightlifting bench in a flat position with their feet flat on the floor. The 2.7-kg medicine ball was raised overhead, and the subject extended at the hips and spine in an attempt to lean back as far as possible while maintaining foot contact with the floor. The throw was completed with flexion of the spine and hips as the subject propelled the ball forward to release it.

**Static Reverse Throw.** The subject sat on a standard adjustable weightlifting bench with the back inclined to 90°. The feet remained flat on the floor. A strap was placed across the chest and secured to the back of the bench to limit the involvement of the core musculature in the throw. The subject maintained 90° of hip flexion and a fully erect spine from beginning of the test until the medicine ball was released backward. The throw was initiated from the lap to a release point throwing the ball behind the subject. The throw was repeated if the subject attempted to use the muscles of the core.

**Dynamic Reverse Throw.** The subjects sat on a standard adjustable weightlifting bench in a flat position with their feet flat on the floor. To initiate the throwing position the subject flexed at the spine and hips toward the knees. The 2.7-kg medicine ball was placed in the subject's hands and placed just distal to the knees. The subject then extended at the hips and abdomen while extending the arms overhead to release the ball in a pattern directly behind them. The momentum from this throw caused the subjects to lay flat on the bench upon completion.

**Static Lateral Throws.** The subject sat on a standard adjustable weightlifting bench with the back inclined to 90°. The feet remained flat on the floor. A strap was placed across the chest to secure the back to the bench. The starting position for the throw was in 90° of hip flexion with a fully erect spine; this position was maintained throughout. The subjects held the medicine ball to the side of their leg in a comfortable position.
To throw the ball, a maximal contraction was initiated in a direction that is contralateral to the starting point without involving the trunk musculature. If the subject attempted to rotate the spine, the throw was not counted. This throw was completed to both the left and right sides.

**Dynamic Lateral Throws.** The subject sat on the end of a standard adjustable weightlifting bench in a flat position with their feet flat on the floor. The starting position for the throw required the subject to forward flex at the hips and abdomen while rotating to either the left or right side. The increased forward flexion and rotation allowed a more powerful movement as a 2.7-kg medicine ball was thrown to the contralateral side. The throw was performed on the left and right sides.

**Push Press Power.** The push press is a weightlifting technique that requires forces created in the lower extremities to be transferred into the hands as the bar is propelled overhead. This test was performed with 50% of the subject’s bodyweight. The standing push press started with the bar positioned on the upper portion of the chest resting on the clavicles. A Myotest (Myotest SA, Scion, Switzerland) was attached to the barbell at the midpoint between the hands. The weight was then unracked, and the Myotest was started. On the first beep, the subject performed a maximal repetition by bending at the hips and knees to obtain a countermovement, the subject then maximally exerted the legs, hips, and arms upward to drive the weight into a fully extended position. This position was held until the Myotest beeped. After the beep, the bar was lowered, and the procedure was repeated for the remaining repetitions. A total of 5 repetitions were performed, and the average power was recorded.

**Other Performance Variables.** The strength and conditioning staff performed an off-season testing session at the time of this study, and access to the results of their testing was provided to the researchers upon consent from the subjects. The variables that were accessed included CMJ, proagility shuttle run, 40-yd dash, and 1RM bench press and squat.

### Table 1. Descriptive statistics for medicine ball throws.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Covariation</th>
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</thead>
<tbody>
<tr>
<td>Static forward (m)</td>
<td>7.5 ± 0.9</td>
<td>11.6</td>
</tr>
<tr>
<td>Static reverse (m)</td>
<td>8.7 ± 1.0</td>
<td>11.6</td>
</tr>
<tr>
<td>Static left (m)</td>
<td>8.2 ± 1.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Static right (m)</td>
<td>8.0 ± 1.0</td>
<td>12.2</td>
</tr>
<tr>
<td>Dynamic forward (m)</td>
<td>8.0 ± 0.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Dynamic reverse (m)</td>
<td>15.0 ± 2.4</td>
<td>15.8</td>
</tr>
<tr>
<td>Dynamic left (m)</td>
<td>10.5 ± 1.5</td>
<td>14.4</td>
</tr>
<tr>
<td>Dynamic right (m)</td>
<td>10.7 ± 1.3</td>
<td>12.2</td>
</tr>
</tbody>
</table>

### Table 2. Descriptive statistics of performance variables and push press power.*

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Covariation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RM squat (kg)</td>
<td>188.26 ± 24.43</td>
<td>13.0</td>
</tr>
<tr>
<td>Squat (kg·bw⁻¹)</td>
<td>1.8 ± 0.22</td>
<td>11.9</td>
</tr>
<tr>
<td>1RM bench press (kg)</td>
<td>134.19 ± 18.65</td>
<td>13.9</td>
</tr>
<tr>
<td>Bench (kg·bw⁻¹)</td>
<td>1.29 ± 0.21</td>
<td>16.1</td>
</tr>
<tr>
<td>Countermovement jump (cm)</td>
<td>65.79 ± 8.85</td>
<td>13.5</td>
</tr>
<tr>
<td>40-yd Dash (s)</td>
<td>5.10 ± 0.38</td>
<td>7.3</td>
</tr>
<tr>
<td>Proagility (s)</td>
<td>4.53 ± 0.33</td>
<td>7.4</td>
</tr>
<tr>
<td>Push press power (w·kg⁻¹)</td>
<td>37.6 ± 6.0</td>
<td>16.0</td>
</tr>
</tbody>
</table>

*1RM = 1 repetition maximum.

### Table 3. Mean comparisons for medicine ball throws.

<table>
<thead>
<tr>
<th></th>
<th>Static (M ± SD)</th>
<th>Dynamic (M ± SD)</th>
<th>Cohen’s d</th>
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</thead>
<tbody>
<tr>
<td>Forward (m)</td>
<td>7.5 ± 0.9</td>
<td>8.0 ± 0.9</td>
<td>0.56</td>
</tr>
<tr>
<td>Reverse (m)</td>
<td>8.7 ± 1.0</td>
<td>15.0 ± 2.4*</td>
<td>3.43</td>
</tr>
<tr>
<td>Left (m)</td>
<td>8.2 ± 1.0</td>
<td>10.5 ± 1.5*</td>
<td>1.80</td>
</tr>
<tr>
<td>Right (m)</td>
<td>8.0 ± 1.0</td>
<td>10.7 ± 1.3*</td>
<td>2.33</td>
</tr>
</tbody>
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*p ≤ 0.05.

**Countermovement Vertical Jump.** Reach height was measured for all the participants before vertical jump testing. The subjects stood flatfooted and reached as high as possible with 1 arm. The highest point reached on the Vertec™ was considered reach height. Individuals were allowed 1 arm swing down and up while jumping off both feet and reaching as high as possible with 1 arm to displace the highest possible vane on the Vertec™. The CMJ was calculated as the distance from the highest point reached during the reach height and the highest point reached during the jump. Individuals were only allowed 1 attempt unless the previous attempt was not performed properly. In that case, 3–5 minutes of rest was allowed between attempts.

**Proagility Shuttle Run.** The proagility shuttle run was used to determine agility performance. A distance of 10 yds was measured with a line in the middle at the 5-yd point. The participants straddled the middle line and ran to their right to the end of the 10-yd marker, then to their left to the opposite 10-yd mark, and back to the middle 5-yd point. Time began with initial movement and ended when the individual crossed the 5-yd point a second time covering a total distance of 20 yds.
Two timers were used with the average of the 2 recorded to 0.01 seconds. The individuals were only allowed 1 attempt unless the previous attempt was not performed properly. In that case, a 3- to 5-minute rest was allowed between attempts.

Forty-yd Sprint. Forty-yard sprints were used to determine quickness. A distance of 40 yds was measured. Individuals started in a 3-point stance with their fingers on a touch and release starter for the electronic timer. As soon as the athlete released pressure from the touch pad, the timer began. A speed trap II electronic timer was used to measure time for the 40-yd sprint. The individuals were only allowed 1 attempt unless the previous attempt was not performed properly. In that case, 3–5 minutes of rest was allowed between attempts.

One Repetition Maximum Bench Press and Squat. The individuals started each lift with 50% of their previous 1RM and increased weight by 10–20 kg until their 1RM was determined. All the participants attempted to achieve their 1RM within 5 sets. All lifts were observed by the head strength coach to determine if they were acceptable lifts (i.e., proper depth, technique, etc.).

Statistical Analyses

Descriptive statistics were performed on all data. Relationships between test variables were determined using multiple bivariate correlations, represented by the Pearson correlation coefficient. A stepwise multiple regression was used to determine the best predictor(s) of power. Statistical significance was set at \( p \leq 0.05 \). SPSS 16.0 software (SPSS Inc., Chicago, IL, USA) was used for all analyses.

Results

The means and SDs of the medicine ball throws and push press, and performance variables are shown in Tables 1 and 2, respectively. Independent sample \( T \)-tests (with Cohen’s \( d \) identified significant differences between the respective static and dynamic throws, with the exception of the forward throw (Table 3). Correlation coefficients (and \( r^2 \)) between the static and dynamic medicine ball throws are listed in Table 4. Correlation coefficients (and \( r^2 \)) between the medicine ball throws, push press power, and performance values are listed in Tables 5 and 6. The stepwise regression equation is provided in Table 7. The Myotest has an intraclass correlation coefficient (ICC) of 0.96 (14), whereas the ICCs for the medicine ball throws ranged from 0.85 to 0.95.

Several significant correlations were identified between the static medicine ball throws and the performance variables. Static reverse correlated with CMJ (\( r = 0.44 \)), 40yd (0.50), and PrA (0.46). Static left correlated with Bench kg/bw (0.42), CMJ (0.44), 40yd (0.62), and PrA (0.59). Static right correlated with Bench kg/bw (0.41), 40yd (0.44), and PrA (0.65). Static forward did not correlate with any of the performance variables. Fewer dynamic throws correlated significantly with the performance variables. Dynamic forward correlated with the IRM squat (\( r = 0.45 \)) and IRM bench (0.41). Dynamic left and right correlated with CMJ (0.48 and 0.40, respectively). Dynamic reverse did not correlate with any of the performance variables.

The push press correlated moderately well with IRM squat (kg/bw) (0.50), IRM bench (kg/bw) (0.50), CMJ (0.48), and PrA (0.48).

A stepwise regression was run in an attempt to determine which dependent variable(s) best predict push press power. Analysis identified IRM squat as the only predictor (\( r = 0.53 \)).
The demands that athletic performance places on the body cannot be created or dissipated locally; it takes the entire body reacting on a surface to create aspects of performance (velocity, power, strength, displacement). The muscles of the core are responsible for providing the stable base for extremity function and force transfer. There are very few athletic activities that do not require a transfer of forces. The primary intent of this research was to gain an insight into any effect that the muscles of the core have on the transfer of forces through the body. By developing and implementing a dynamic core test, several indices of the effect that the core has on forces in the body have been shown.

The medicine ball throws used in this study were designed to test upper extremity power generation with and without the use of the core musculature to measure the effect of the core on throw distance. The theory behind this is that in a static throw with the chest secured to a bench, the core musculature would not be able to aid in propulsion. The dynamic throw thus would allow the subjects to obtain a posture that would enable them to use the muscles of the core to improve the distance of the throw.

The StF, StL, and StR medicine ball throws correlated at least moderately with their corresponding dynamic throws (Table 3). When the static throws were compared with the dynamic throws for differences, all throws were significantly different with the exception of the forward throw. This indicates that the rectus abdominis has little to do with the dynamic function of the core. Likewise, the lack of a significant correlation between the reverse throws suggests that the erector spinae is not only dynamically active but that other muscular assistance is provided to further increase the propulsion of the medicine ball during the dynamic throw. An assumption is then made suggesting that the lateral aspects of the core musculature provide equal assistance to the dynamic lateral throws with no additional assistance from other musculature.

The push press with 50% bodyweight was used to assess the transfer of forces generated with the lower extremities, through the torso to the upper extremities, and ultimately to a weighted barbell with the use of a Myotest (Myotest SA). The Myotest had been previously validated to a force plate in its capacity to measure force output (14). In this situation, the Myotest was attached to the barbell while each...
participant completed the push press. The weight on the bar was programmed into the Myotest. The Myotest then calculated power by knowing the mass of the barbell and measuring velocity. Theoretically, those individuals with greater power output have stronger core musculature and superior force transfer. When the push press was correlated with the medicine ball throws, significant correlations were identified between the StR, StL, and StRi throws, and the DyL and DyRi throws. The lack of a significant correlation with the forward throws suggests the anterior portion of the core musculature has little to do with the transfer of forces when it comes to overhead pressing movements. The push press did correlate significantly with the StR throw but not with the DyR throw. This may indicate the superior dynamic capacity of the posterior aspect of the core in comparison to the anterior. Both the anterior and posterior aspects maintain static stability, though the extra musculature related to the posterior aspect does not allow direct comparison.

Significant correlations were identified between the push press and both the static and dynamic left and right throws. It is believed that this further supports the idea of the symmetry of the lateral aspects of the core musculature and their dynamic properties.

The correlations between the medicine ball throws and the performance variables suggest that the core does have some relationship with performance. All of the medicine ball throws except the StF and DyRi throws correlated with at least 1 performance variable.

The reverse static throw correlated moderately with the CMJ, 40 yd, and PrA. These correlations may come from the similarity in the motions of the throw and the 3 performance measurements. The throw mimics the action of the upper extremities in the performance measurements because they are rapidly and forcefully moved upward to enhance the momentum created by the lower extremity action. The relationships shown for this throw are most likely a result of extremity power and function to include the core musculature’s ability to provide lateral stability.

A complete lack of relationship with the DyR throw to the performance measures reinforces the idea that the relationship of the StRi throw is primarily driven by the function and power of the extremities. The incorporation of the core in the DyR throw altered the effect of the arm and shoulder musculature because they were no longer the primary movers for the action. The subjects relied more on the momentum from the rapid extension of the spine to throw the ball rather than on extremity strength alone, and this altered the relationship to the goal of functional performance. Dynamically, it became a nonfunctional test in relation to the selected measurements of performance. There are very few functional activities within athletics that would require an individual to extend the spine backward to complete a task, and the data reinforce this observation. If the posterior musculature functioned as anything more than stabilizers, there would be some indication of the effect within the relationship between medicine ball throws and performance measures.

The dynamic forward throw correlated with 2 strength measurements, the 1RM squat and 1RM bench. The throwing position of this task required the subject to lean back as far as possible while maintaining foot contact with the floor, while holding the medicine ball directly overhead. Just obtaining the starting position puts a great deal of stress on the anterior trunk musculature because the feet had to remain in contact with the floor. From that starting position, the participants were asked to throw the ball as far forward as possible. This throwing position required the subject to forward flex the spine while moving the extremities forward. For the subject to move the extremities forward, a stable base was necessary, but if the core is also dynamically forward flexing while trying to provide a stable base the actions seem to be contradictory. The duality of this motion really tests the true function of the anterior core. According to the results of the static and dynamic t-tests, the forward throws were the only throws that did not have a significant difference in the distance thrown. Because of the starting position of the throw, the subject had to choose to either forward flex and then throw or throw and then forward flex. In this manner, the core is not designed to explosively flex while the extremities are in motion, so 1 action has to take place at a time. In a sense, both forward throws appear to be a test of extremity strength, with the dynamic throw requiring stabilization of the core.

The anatomy of the rectus abdominus provides minimal forward movement when contracted. This leads to the assumption that if it can only move a short distance, its main function has to be to provide stability and on occasion provide small amounts of trunk flexion. The relationship of the dynamic forward throw to the 1RM squat and bench press comes from the individual’s ability to provide anterior stability while resisting forces of an external load and extremity action.

The lateral medicine ball throws show relationships with performance measurements in both the static and dynamic positions. Both statically and dynamically to the left and right the medicine ball throws correlated with the CMJ. The 40 yd and PrA correlated with the static throws only. These are interesting correlations in that the 40 yd and PrA are both running activities requiring the core’s ability to resist rotational forces, yet both measures did not correlate to the dynamic throws to the left or right.

For push press, there were no relationships with the forward throws. Its relationships with the other static throws are most likely a result of the subject’s ability to generate force in the upper extremity, which would be an expected relationship. A person with strong extremities should be able to throw the medicine ball further and have a better push press power output. However, when the core became involved in the throw, the relationship to the push press remained with the left and right throws but not the reverse. The lack of significance in the dynamic forward and reverse
accomplish these demands. All of the local muscles function base. The core has to be complex in design and function to requires a stable base and transfer of force through the body of running. For instance, pitching or batting in baseball rotational forces of the activity and keep all motion moving in properly. The function of the core as a unit is to resist the base created by the core allowing movement of the subject. Therefore, a strong external oblique would lead to less disruptive forces altering the core allowing better force transfer. This is a big difference in the anatomical function of the 4 sides of the core. The rectus abdominus and erector spinae are both global muscles in nature and functional in a lot of daily activities, but when it comes to athletic performance, they in a sense become the primary stabilizers of the spine and help to control the motion of the external obliques. The main difference between the lateral aspects of the core when compared with the anterior and posterior is that in a dynamic function the main movers of the anterior and posterior have to provide stability, but laterally the external oblique can rely on other core muscles to provide stability.

The effect not only comes from external oblique strength but it also appears to be the ability of the athlete to activate the external oblique and use that strength for improved performance. In a study on throwing athletes, Ikeda et al. (11) found that subjects who performed better in a side medicine ball throw had a higher external oblique activation. They also suggest that isometric trunk rotation to 1 side has a significant effect on the dynamic trunk rotation of the opposite side. This would indicate that although 1 side of the core creates a rotational force, the opposite side must control the motion and provide stability for extremity function. The possible relationship of the dynamic throw to push press power comes from the ability of the subject to effectively activate the external oblique for both rotation and stability in conjunction with the other muscles of the core.

In athletics, nearly every activity is based on some sort of rotational axis. “Running is a series of unilateral hip flexion and extension movements that can place considerable amounts of destabilizing torques on the trunk” (4). More simply stated, the hips and pelvis rotate on the stable base created by the core allowing movement of the subject. If the core is weak, the forces created will not be used properly. The function of the core as a unit is to resist the rotational forces of the activity and keep all motion moving in the desired direction, but not all activities mimic the demands of running. For instance, pitching or batting in baseball requires a stable base and transfer of force through the body into the arms, and it also requires rotation of that same stable base. The core has to be complex in design and function to accomplish these demands. All of the local muscles function as the main stabilizers of the spine, and several of the global muscles do as well. The lower abdominals (rectus abdominus, internal oblique, and transverse abdominus) function to provide anterior stability to aid in spinal stabilization and the erector spinae act on the posterior to keep the upper body erect. Those muscular actions function as the stable base. The external oblique along with the muscles of the hip and upper back function to create the rotation needed to complete these tasks and to control the rotation. In regards to running, rotation disrupts the function of the kinetic chain. The most efficient method of moving from point A to point B is a straight line, and any rotation occurring between those 2 points adds distance. Rotation equals lost energy, and lost energy equates to decreased performance. Therefore, it is the responsibility of the lateral core musculature to not only facilitate a rotational action in several activities but to also resist rotational forces in other activities.

The stepwise regression revealed that the 1RM squat is the only predictor of push press power. The push press was chosen as the dependent variable for this analysis because of the way it uses the forces generated in the lower extremities to the upper extremities driving the weight upward. This link shows that the lower body has an effect of the transfer of forces to the upper body. A strong lower extremity creates forces that are transferred to the upper body via the core musculature. Although the medicine ball throws did not test the function of the core on forces created within the lower body, the throws still help to understand how the forces created at the feet are transferred to the hands. If a lower body exercise is the best predictor of an upper body strength measurement, there has to be a significant transfer of forces occurring through the core. This transfer can be seen in the relationship between the dynamic front throw and 1RM squat and bench and also between the lateral throws and push press power. The stability created by the anterior and posterior core musculature in conjunction with the stability provided by the lateral musculature resisting rotation allows the forces created by the bigger movers of the lower extremity to transfer into the arms. If the core is too weak to handle the forces, rotation is likely to occur causing an energy leak and a breakdown in technique ultimately lowering performance. A strong core will transfer the forces with minimal rotation and minimal energy loss.

The core has a very demanding job providing a control system on forces within the body. This demand has to be met with not only an adequate amount of strength as discussed previously but also precise control and timing. When forces are created in the lower extremity and are transferred into the extremities, the core has to react and perform with proper timing and control. For example in the baseball pitch, if the core reacts to early, the forces are dissipated and the arm has to create more forces placing it at a higher risk of injury (1). Borghuis et al. (7) state that motion at 1 segment will influence that of all other segments in the chain. The core is the central component to most athletic activities; if it fails so
does the effectiveness of the forces being created and transferred. An increase or decrease of forces created from the improper distribution from the core can be detrimental to performance and possibly lead to injury.

In previous studies attempting to determine an effect of core strength and stability on athletic performance little support had been identified (10,19,20,23,24,26). The difference between these studies and the current study is that the measurements of core function were static and endurance based. The functionality of the tests used in this study more accurately assessed the core musculatures effect on performance. Our results indicate that core strength does have an effect on performance in an athletic population. However, its extent is yet to be determined.

To completely understand how the core transfers forces to and from the extremities, it will be necessary to include the lower body in the core assessment. Several authors state that the core includes several of the muscles in the hips and thighs (2,10,12). The core assessment used in this study did not assess those muscles. However, the relationship to the transfer of forces has been seen in the results of this study and should not be altered with the addition of the hips. It is still necessary to include these muscles to completely understand the force transfer within the body.

PRACTICAL APPLICATIONS

In sports, muscular demands vary greatly from athlete to athlete. This makes it very difficult to have 1 statement that will address all superiorities or inadequacies of the core. Currently, plank exercises are considered an adequate method of training the core for athletes to improve core strength and stability. The problem with these exercises is that they put the athletes in a nonfunctional static position that is very rarely replicated in the demands of sport-related activities. To train for the majority of sports, it requires a dynamic motion. According to the results of this study, it is recommended to train the lateral aspects of the core with specific dynamic exercises. The anterior and posterior aspects of the core are likely to be trained in conjunction with other sport-specific training—particularly closed chain kinetic exercises. Athletes play dynamically and should be trained dynamically.

REFERENCES