Validity and reliability of a medicine ball explosive power test.

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Validity and Reliability of a Medicine Ball Explosive Power Test

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ABSTRACT

The purpose of this study was to evaluate the validity and reliability of a medicine ball throw test to assess explosive power. Twenty competitive sand volleyball players (10 male players, 10 female players) performed a medicine ball throw and a standard countermovement vertical jump. The subjects attended 2 sessions; at each session, 3 attempts of each test were completed. The movement pattern for the medicine ball throw was a backward overhead toss. To standardize for body weight, a power index was calculated for the countermovement vertical jump using the Lewis formula. Validity was assessed using the best score for both the throw and the jump, and reliability was assessed using the best score from each session. There was a strong correlation between the distance of the medicine ball throw and the power index for the countermovement vertical jump ($r = 0.906$, $p < 0.01$). For the countermovement vertical jump, the test-retest reliability was 0.993 ($p < 0.01$), and for the medicine ball throw, the test-retest reliability was 0.996 ($p < 0.01$). These findings suggest that the medicine ball throw test is a valid and reliable test for assessing explosive power for an analogous total-body movement pattern and general athletic ability.

Key Words: vertical jump, volleyball, plyometric, testing

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Introduction

The ability to generate or transfer explosive muscle power is a key element to the success of many athletic activities. In many of these activities, explosive power is generated by the legs and hips, which have collectively been referred to as the ''power zone'' (1). However, many athletic skills also involve generating or transferring explosive power through the upper extremities and trunk musculature.

Numerous tests have been designed to assess the explosive power generated by the lower body or power zone. Some commonly used tests include the vertical jump (8, 9, 12, 13, 27), the Margaria-Kalamen anaerobic power test (19), the standing long jump, and repeated bounding (10). All of these tests have demonstrated good reliability and have been widely used as field tests to assess overall athletic ability or the effects of specific training programs. Tests of explosive power involving the upper extremity or trunk musculature are not as readily available. Some tests that have been used to assess upper-body explosive power include those using the seated shot put (5, 16–18), medicine ball throws (23), isokinetic testing instruments (23), force plate (8), and more recently the Plyometric Power System (PPS) (Plyopower Technologies, Lismore, Australia) (20–22).

The use of medicine balls in sports training is growing as practitioners see the wide range of skills that can be trained or simulated. In an attempt to make training programs more sport specific, strength and conditioning coaches are continuously exploring new ways of using medicine balls to train the specific physiologic or biomechanical variables required for success in their particular sport.

Explosive power generation during athletic activities is often integrated, multidirectional movement involving high levels of neuromuscular activation (4). It usually demands high levels of proprioception and coordination, with movement often occurring through multiple planes (14). To assess athletic ability during this type of activity, testing must also involve integrated, multidirectional movement that simulates as closely as possible the activities required for success in a particular sport. Therefore, the purpose of this study was twofold: first, to evaluate the reliability of a field test that was designed to assess explosive power in a movement that involved integrating the upper body, trunk, and lower extremities in its execution; and second, to examine the similarity of this movement to a specific task common in many sports such as the vertical jump.

Methods

Experimental Design and Approach to the Problem

This study was designed to examine the validity and reliability of a medicine ball throw as a practical tool for assessing explosive power in a field setting. To accomplish this, subjects completed both the medicine ball throw and the countermovement vertical jump. By comparing a commonly used test of explosive power (i.e., countermovement vertical jump) that has established validity (9, 12), the commonality of performance scores for an analogous movement pattern would support the ability of the medicine ball throw to assess explosive power. The study used a within-group test-retest format in an attempt to examine the test-retest reliability of the medicine ball throw. Power calculation for this study indicated that a sample size of 20 would be necessary and that with the chosen sample size of 20 subjects, the statistical power for this study is 0.99 ($p < 0.01$) (28).

Subjects

The subject population for this study consisted of 20 competitive outdoor sand volleyball players (10 male subjects and 10 female subjects). The subjects had an age range of 16–30 years, with a mean ± *SD* age of 22.8 ± 3.7 years, and a mean body weight of 75.7 ± 14.8 kg. This study was approved by the University of Regina Research Ethics Board, and all subjects gave written informed consent before participating.

Testing Procedures

On the first day of testing, the protocol was explained to the subjects, and they then watched a demonstration of the medicine ball throw. This was followed by a practice session. Subjects were given as many practice throws as they desired until they were able to make 3 consecutive throws to within 0.50 m of their longest practice throw. This was followed by a rest period (typically 20 minutes) before completing the test protocol. Subjects performed their initial testing at least 5 days before their retesting, and all testing was conducted over a 21-day span. Testing consisted of a medicine ball throw that involved a movement pattern similar to that of a standard countermovement vertical jump. The medicine ball throws were performed using a 3-kg rubber medicine ball. For comparative purposes, subjects also completed a standard countermovement vertical jump.

Before each session, the subjects performed their normal warm-up. They were also given several warm-up throws, followed by 3 measured trials in which they attempted to throw a medicine ball as far as possible. Each throw was measured for distance (meters), and each jump was measured for height (meters). The subjects were also measured for their standing reach height (meters) and body weight (kilograms). Each trial was followed by approximately 45 seconds of passive rest before the subsequent trial. Testing was conducted so that each subject performed 3 medicine ball throws and 3 vertical jumps at each session. According to the test order, the subjects completed the jump trials first and the medicine ball throws second.

Assessment of Explosive Power

The standing backward overhead medicine ball throw consisted of starting with the feet shoulder width apart, heels on the zero measurement line, and the medicine ball held with arms straight out front at shoulder height. The countermovement consisted of the subjects flexing the hips and knees. At the same time, they also flexed forward at the trunk, lowering the medicine ball to just below waist or hip height. After the countermovement, the subjects began to thrust the hips forward and to extend the knees and trunk. They flexed the shoulders, elevating the ball back up to shoulder height and beyond as they threw it back over their head. The arms were maintained in an extended manner. The finishing point was with the ankles plantar flexed; the knees, hips, and trunk extended; and the shoulders flexed to above the head. During the countermovement, the subjects were asked not to bend the knees or hips any more than they normally would for a standard countermovement vertical jump. The shoulders maintained at least 45° of shoulder flexion in relation to the trunk. At the end of the throw, the subjects' feet were allowed to leave the ground, as would happen with a jumping motion, to minimize any deceleration component of the vertical ground reaction forces (Figure 1). The subjects were also asked to keep their arms as straight as possible as they threw the ball back over their head with a pendulum action. This instruction was meant to force the legs, trunk, and shoulders to generate the power, as would be the case in a vertical jump.

The vertical jump was a standard countermovement jump. To perform the jump, subjects started with the feet shoulder width apart, standing approximately 30 cm from the wall with their arms straight out front at shoulder height. The countermovement consisted of the subjects flexing the hips and knees while at the same time they also flexed forward at the trunk, lowering the arms to approximately waist or hip height. After the countermovement, the subjects began to extend the hips, knees, and trunk. They flexed the shoulders, elevating them back up over shoulder height as they reached as high as possible to touch the wall with the hand nearest to the wall. During the counter-

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Figure 1. Backward overhead medicine ball throw. Reprinted, by permission from Radcliffe, J., and R. Farentinos. *High-Powered Plyometrics.* Champaign, IL: Human Kinetics, 1999. p. 107.

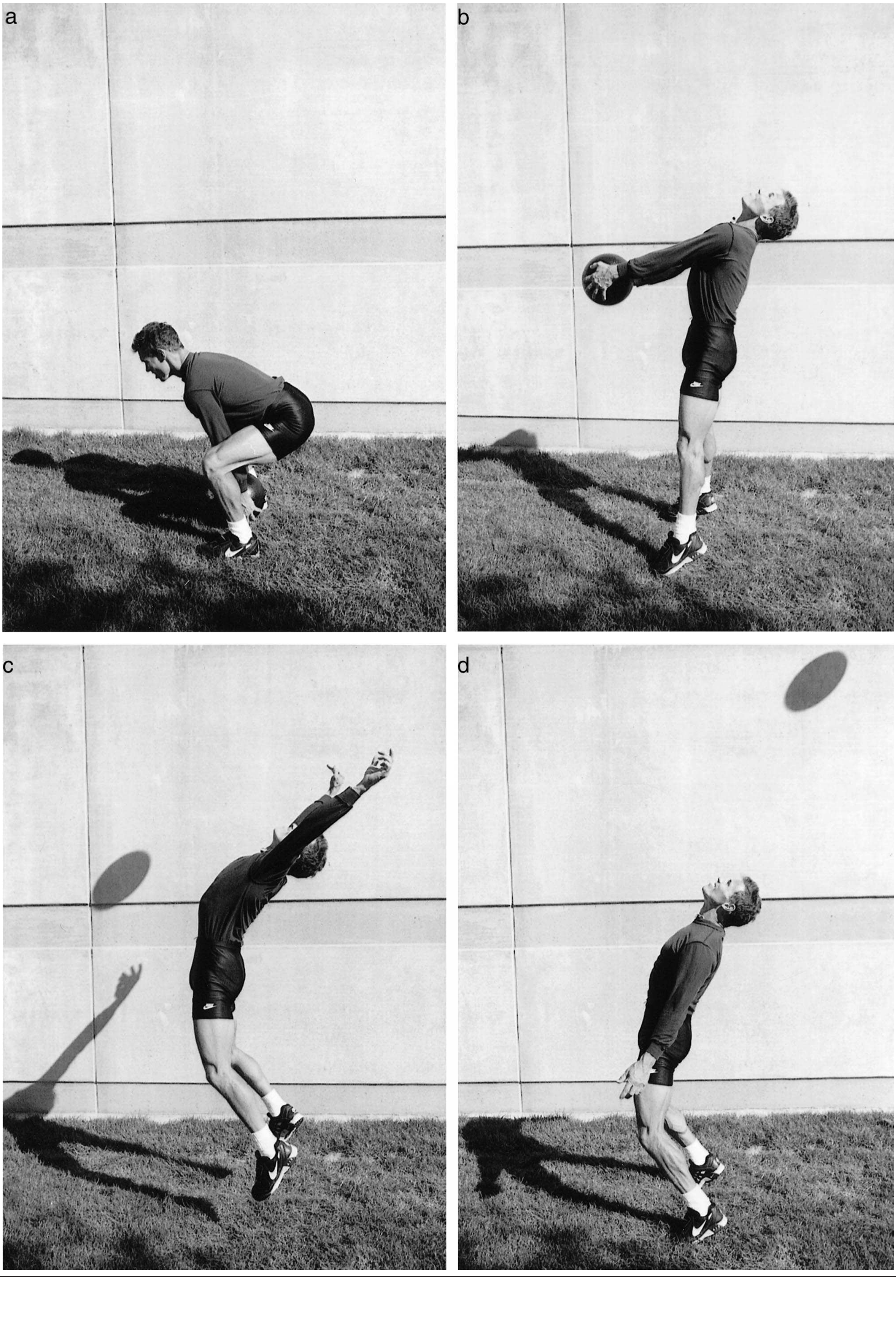
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Table 1. Comparison of the test and retest scores for the medicine ball throw distance, vertical jump height, and vertical jump power index.*

	Mean	*SD*	Minimum	Maximum	*p*
MedBall 1, m	12.5	3.24	7.1	18.2	0.881
MedBall 2, m	12.5	3.33	6.8	18.3	
Jump Ht 1, m	0.51	0.10	0.34	0.68	1.000
Jump Ht 2, m	0.51	0.10	0.34	0.69	
Power 1, $kg \cdot s^{-1}$	120.0	31.67	79.9	199.9	0.968
Power 2, $kg \cdot s^{-1}$	120.1	31.75	79.7	198.3	

* MedBall = medicine ball throw distance; Jump Ht = vertical jump height; Power = vertical jump power index.

movement, the subjects were allowed to flex the knees and hips to the angle that they were comfortable with.

Before the vertical jump test, the subjects stood beside the wall with feet flat on the floor as they reached as high as possible. This height was measured to the nearest centimeter and was used as the standing reach height. Vertical jump height and body weight were entered into the Lewis formula for calculating power output (12) or power index (13).

Statistical Analyses

For the vertical jump and medicine ball throwing tests, intraclass correlation coefficient (r_I) were used to examine the test-retest reliability (28), and Pearson product correlations (r) were used to compare the medicine ball throw distance, vertical jump height, power index from the vertical jump, and body weight (28). Paired *t*-tests were used to determine if there were any significant differences between the test and retest. Pearson product correlations were also used to evaluate the variability of scores among the groups. A significance level of $p \leq 0.01$ was chosen for all tests. Data are expressed as mean ± *SD*.

Results

Descriptive statistics for the test and retest of the medicine ball throw distance, vertical jump height, and power index are summarized in Table 1. There were no significant differences between the test-retest scores for the vertical jump height, medicine ball throw distances, or the power index calculated from body weight and jump height.

Intraclass correlation coefficients (r_I) were used to examine the relationship between the test-retest scores (Table 2). All 3 measures (medicine ball distance, vertical jump height, and vertical jump power index) demonstrated significant intraclass correlation coefficients ($p < 0.01$). The range of correlations was 0.993–0.999. The range of the coefficient of determination (r^2) was 0.986–0.998, indicating that the original test scores

Table 2. Intraclass reliability of the medicine ball throw distance, vertical jump height, and vertical jump power index.†

	MedBall	Jump Ht	Power
r	0.996*	0.993*	0.999*
r^2	0.993	0.986	0.998
SEE	0.293	0.012	1.381

† SEE = standard error of estimate; MedBall = medicine ball throw distance; Jump Ht = vertical jump height; Power = vertical jump power index.
* Statistically significant intraclass correlations ($p < 0.01$).

Table 3. Best results for the medicine ball throw distance, vertical jump height, and vertical jump power index calculations.

	Mean	*SD*	Minimum	Maximum
MedBall, m	12.59	3.31	7.1	18.3
Jump Ht, m	0.51	0.10	0.35	0.69
Power, $kg \cdot s^{-1}$	120.56	31.72	79.9	199.9

* MedBall = medicine ball throw distance; Jump Ht = vertical jump height; Power = vertical jump power index.

account for 98.6–99.8% of the retest score variance. The standard errors of estimate (*SEE*s) were ±0.293 m, ±0.012 cm, and ±1.381 kg per second (Table 2) for the medicine ball throw distance, the vertical jump height, and the power index, respectively.

After establishing that there was a significant intraclass correlation and low *SEE* for the test-retest scores, the highest of the 2 scores was chosen for further analysis and for comparison between the medicine ball throw distances, vertical jump heights, and vertical jump power indexes. Descriptive statistics for these measurements are summarized in Table 3.

Comparisons were made between the medicine ball throw distance, vertical jump height, body weight, and power index (calculated from body weight and vertical jump height). The r values showed significant correlation ($p < 0.01$) for all comparisons, with the exception of the jump height vs. body weight ($p < 0.041$). The coefficients (r values) ranged from 0.461 to 0.943, and coefficients of determination (r^2 values) ranged from 0.212 to 0.889 (Table 4). Of the 3 variables (throw distance, jump height, and body weight), the variable with strongest correlation to the vertical jump power index was body weight ($r = 0.943$). This finding indicates that the weight of the subject accounted for 89% of the variance and could have a significant effect on the power output. The variable with the weakest relationship was jump height, which accounted for only 52.6% of the variance.

Of specific interest in this study was the finding of

Table 4. Comparison of the medicine ball throw distance, vertical jump height, vertical jump power index, and body weight.*

	MedBall/Power	Jump Ht/Power	Weight/Power	Weight/ MedBall	MedBall/ Jump Ht	Weight/ Jump Ht
r	0.906	0.725	0.943	0.794	0.808	0.461
r^2	0.821	0.526	0.889	0.631	0.653	0.212
SEE	13.785	22.435	10.855	2.068	0.060	0.090
p	0.01	0.01	0.01	0.01	0.01	0.041

* *SEE* = standard error of estimate; MedBall = medicine ball throw distance; Power = vertical jump power index; Jump Ht = vertical jump height; Weight = body weight.

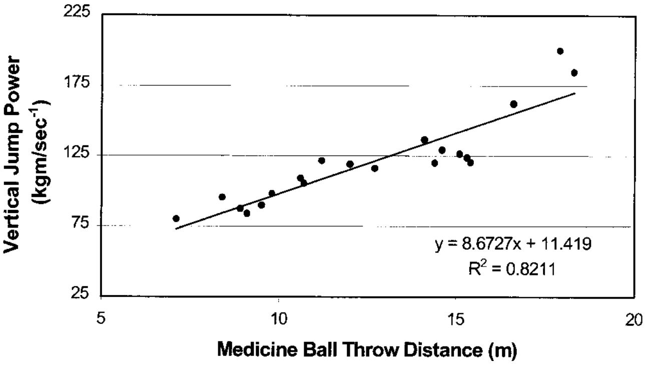

Figure 2. Comparison of the medicine ball throw to the power index generated during a vertical jump ($r = 0.906$; $p < 0.01$).

a strong relationship between vertical jump power index and the distance that the subjects could throw the medicine ball, which had a correlation coefficient of 0.906. This value gave a coefficient of determination of 0.821, which indicated that the medicine ball throw distances accounted for 82.1% of the variance in the power index from the vertical jump. There was also a low *SEE* (±13.785 kg per second), which supports the "goodness" of the regression line (11) (Figure 2). The medicine ball throw distance accounted for 65.3% of the variance in jump height, whereas body weight accounted for only 21.2%. For the relationship between body weight and medicine ball throw distance, body weight accounted for 63.1% of the variance in the medicine ball throw distance, supporting the rationale for converting jump height and body weight into power index to standardize for body weight.

Discussion

The medicine ball throw test was designed to assess explosive power of the upper body, trunk, and lower extremities using a general movement pattern common to many sports skills. To evaluate the reliability and validity of this test, competitive volleyball players were tested using a movement pattern regularly performed in volleyball. The medicine ball test was designed to generate forces in the same musculature and movement sequence used during the vertical jump. It was hoped that this could provide coaches with another reliable field test for assessing explosive power and shed light on the ability of the medicine ball throw to be used as a training technique to help improve vertical jump performance.

A number of tests have been designed to assess either upper-body (5, 6, 16–18, 23) or lower-body (6–10, 12, 13, 19–22, 26, 27) explosiveness. For instance, the seated shot put test has been one of the more commonly used field tests to evaluate explosive upper-body power (5, 16–18). The reported intraclass reliability coefficients for seated shot put tests range from 0.95 to 0.98 (5, 17). In the present study, the intraclass correlation coefficient for the medicine ball throw indicates excellent reliability, comparable to that found previously for seated shot put tests. The advantage of the medicine ball throw test over other test modalities, such as the seated shot put test, is that it uses an integrated total-body movement to simultaneously test the explosive power of the upper body, trunk, and lower extremities during the execution of key movement patterns important to success in a particular sport (6, 23).

The nature of the medicine ball throw test is such that athletes must coordinate movement at the involved joints in order to summate the forces generated for an integrated total-body movement (4), leading to higher power outputs and improved athletic performance. It has been documented that a learning effect may be demonstrated, as subjects learn to coordinate and activate the involved musculature, improving overall muscle performance during certain activities (24).

Among elite junior tennis players (age, 15.0 ± 1.3 years) tested with a 6-lb medicine ball throw, male players are able to throw the ball 7.8 ± 2.0 m and 11.9 ± 3.1 m, and female players are able to throw the ball 6.0 ± 1.4 m and 8.3 ± 1.8 m using test protocols for forward overhead and backward overhead throws, respectively (23). Using a similar movement pattern, the present study demonstrated a mean of 12.6 ± 3.3 m for the backward overhead throw. The results of the medicine ball throw have been positively correlated with power output of the trunk musculature. Using an isokinetic flexion-extension test protocol, researchers have found that peak power and work for trunk extensors are positively correlated with throw distance for a backward overhead medicine ball throw (23). This finding may provide a link between the musculature of the trunk and lower back and its contribution to functional activities that involve the lower-body musculature, but which are of a total-body nature, such as the backward overhead medicine ball throw.

The trunk and upper-body musculature may contribute more significantly to overall performance during a total-body activity such as the backward overhead medicine ball throw as compared with the vertical jump. The use of the medicine ball will increase physical demand on the upper body and trunk, which may facilitate a higher neural activation of the area. The vertical jump is a very common activity in many sports, either as a required skill, or as a training tool as in its use for various plyometric training activities (i.e., depth jumps). As a result, the present study attempted to use the vertical jump power index as a measuring stick for determining how well the medicine ball throw distance would correlate with the power index. Both activities involve similar movement patterns of flexing the ankles, knees, and hips for the countermovement, followed by a powerful extension of the lower back, hips, knees, and ankles to generate vertical ground reaction forces. Both activities also involve an extension followed by a powerful flexion of the shoulders. The angles achieved during the countermovement of both activities were very similar, while both movements also required full extension to summate the forces and propel the body weight or medicine ball as explosively as possible. Use of the medicine ball as a training tool may elicit better performance in the vertical jump because the medicine ball throw specifically targets the lower back and shoulder musculature, creating a better overload on the area than the load created by lower-body plyometrics and jump training alone. Traditionally, plyometrics and jump training have been the standard protocol for increasing vertical jump height. We suggest that incorporating medicine ball training will elicit even better overall performance.

It was demonstrated here that the body weight of subjects correlated highly with the distance that they could throw the medicine ball. The comparison to the Lewis formula for power index was meant simply to standardize the subjects' scores accounting for body weight. This was done because jump height alone cannot reveal the power output generated during the vertical jump, and because increased body weight will have a negative effect on jump height. For example, for 2 subjects who can jump the same height, the heavier of the 2 would need to generate higher power output to elevate his or her body mass to any given height. This helps explain the relationship between body weight and throw distance. The subjects who could generate the most power could also throw the medicine ball the farthest. This finding may lead to an ability to evaluate medicine ball training and its contribution to a total-body activity such as jumping. Further, the medicine ball test used in this study may allow for the evaluation of training programs aimed at improving explosive power and may help predict performance of certain sport-specific skills (i.e., vertical jump).

There are several available tests that have been used to assess the different aspects of athletic ability involving explosive lower-body power (7–9, 12, 13, 19, 27). For the medicine ball throw test, the information gathered would relate specifically to the skill or activity that it simulated. This is important because medicine ball training is one of the fastest growing methods used for developing specific aspects of athletic ability or training specific movement patterns. Other test procedures can be used to evaluate specific aspects of the movement (i.e., vertical jump) or muscle function (e.g., the Plyometric Power System). A system of this nature will provide information on specific aspects of muscle function, such as the stretch shortening cycle and power output, because it allows the subject to accelerate through the end range of a movement. This is important as many explosive athletic activities involve high rates of force development (25) and minimal deceleration, or deceleration as a set-up for another explosive movement (i.e., during agility movements). In many athletic skills or activities, the lower body is used as a base of support. The explosive power is generated in the hips and lower extremities and must be transferred through the trunk and upper-body musculature to successfully execute a skill.

The results of this study suggest that the backward overhead medicine ball throw is an excellent total-body activity that may be used for testing and possibly for training. This may be especially important for those sports that require a combination of upper- and lower-body explosive power and involve integrated, multidirectional movement (4). Many of the ground-based sports involve generating power in the lower extremities and transferring it through the hips, trunk, and upper extremities and then to an implement, such as a baseball bat, a tennis racket, or a hockey stick. Other sports such as volleyball may require the generation of explosive power from an airborne position, as with an attack or spike (3). Using a technique such as medicine ball training may help to improve performance by integrating both lower-body and upper-body training.

A limitation of the present study was the method used to calculate the power index from the vertical jump. Some have questioned the validity of the Lewis formula and what it actually measures (i.e., peak power, average power) (9, 12). Future research might examine the medicine ball throws by having the subjects perform the throws while standing on a force plate so that the actual forces can be measured. The purpose of using the Lewis formula was simply to try to standardize the vertical jump score accounting for body weight.

A further limitation of this study was that it used competitive outdoor volleyball players. Future research could examine the use of other skill-related tests compared with medicine ball throws involving similar movement patterns and physiologic attributes. Examples of this may be comparing the speed of a volleyball serve, as measured with a radar gun, with the distance of a forward overhead medicine ball throw or comparing bat speed with a sideways rotational throw. It would also be interesting to look at other levels of athletes, including adolescent or prepubertal athletes, to see if these groups demonstrate similar reliability.

It should also be noted that varying physical dimensions and throwing styles may also influence individual performance. The protocol was established and monitored closely for all throws. Any throws that deviated from the established protocol were disregarded, and the attempt was repeated. However, there was a certain amount of individuality in the depth of the countermovement and the follow-through, for example, that would be inherent in any performance-related field test. The physical dimensions of the subjects (i.e., height, weight, limb length) may also play a role in their individual performances; however, this limitation would also be the same for any performance-related field test, including vertical jumping.

Practical Applications

Any athletic activity that involves a combination of strength and speed will generally have explosive power as a key element to the successful execution of its required skills (25). To enhance the performance of these skills, the athlete needs to train in an explosive manner (15, 25, 26). Explosive power can be developed in numerous ways, such as using body weight exercises (e.g., power push-ups or lower-body plyometrics); performing free weight exercises such as power cleans; or performing movement-specific medicine ball training (2).

It is important to evaluate the effectiveness of any training program. When doing so, coaches need to have available to them tests that will assess the particular components of athletic ability that are important for the sport in question. Medicine balls can be used to test or train certain movement patterns (6, 23). The medicine ball throw test used in this study may add to the test protocols available to coaches requiring tests that simulate specific skills or assess specific physiologic characteristics. Medicine ball tests have several advantages: they are inexpensive field tests, they offer a great degree of testing flexibility, and they can provide the coach with valuable information regarding the efficacy of the current training programs.

Further research into the use of medicine ball throws for assessing explosive upper-body power may be able to shed more light on the contribution of the upper-body and trunk in other total-body activities. Whether such tests are appropriate for sport-specific movement patterns or whether they are better suited to assess general athletic ability is a topic for future investigation. One advantage of medicine ball throw tests is that they are flexible in the type of movement patterns that they can be used to simulate; this attribute suggests that they could be used to train specific muscular actions such as those involved in the vertical jump or other sport-specific skills. They may also provide a training method that can develop the explosiveness required in activities such as the vertical jump without requiring athletes to undergo training that continuously involves the impact forces of landing. This can be especially important during in-season maintenance training for sports such as volleyball, in which athletes are subjected to a lot of landings during practice and competition that can lead to injury.

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