[Athletic Training]

CEU

Functional Performance Testing for Power and Return to Sports

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Context: Functional performance testing of athletes can determine physical limitations that may affect sporting activities. Optimal functional performance testing simulates the athlete's activity.

Evidence Acquisition: A Medline search from 1960 to 2012 was implemented with the keywords *functional testing, functional impairment testing,* and *functional performance testing* in the English language. Each author also undertook independent searches of article references.

Conclusion: Functional performance tests can bridge the gap between general physical tests and full, unrestricted athletic activity.

Keywords: functional performance tests; physical performance; power

Safe execution of athletics requires multiple components of physical performance.[41,48] Physical attributes required for high-level activities include muscular strength, power, endurance, flexibility, balance, proprioception, speed, agility, and functional movement patterns (Figure 1). When athletes are injured, these physical components are less than optimal.[8] A safe and expedient return to full recreational or competitive sports requires a nearly complete return of these attributes. Each component can be measured using standardized clinical testing: manual muscle, endurance, and goniometry.

One of the most commonly lost physical attributes following injury is muscular power.[58] Power is "the time rate of doing work," and work is "the product of force exerted on an object and the distance the object moves in the direction in which force is exerted."[47] A powerful athlete generates force quickly.

Functional performance testing (FPT) may objectively measure progress and determine rehabilitation effectiveness as well as whether the athlete is safe to return to full sports participation.

FUNCTIONAL PERFORMANCE TESTING

A clear distinction must be made between clinical testing and FPT. FPT has multiple purposes. It can provide quantitative and qualitative information on specialized movements in sport, exercise, and occupations.[58] Clinical testing is at the level of impairment, not the assessment of overall functional ability.[59] It may involve anthropometric measurements of a knee joint effusion.

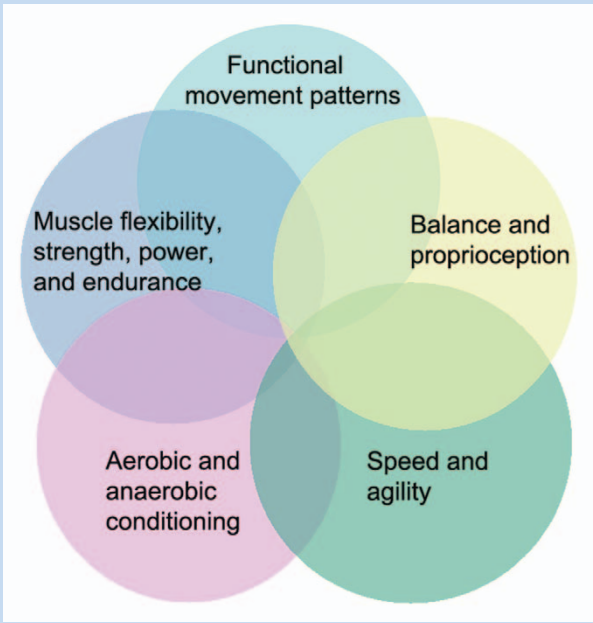

Figure 1. The essential components of functional testing. Reprinted with permission from Reiman and Manske.[58]

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Test Administration

The best test of ability to return to sport is one that closely mimics that activity. For example, functional testing of a long jumper with a recently sprained ankle may involve a single-leg hop or double-leg jump test.[11]

Why Use Functional Performance Tests?

The controlled rehabilitation setting is ideal for FPT progression, allowing easier to harder tests.[11,41-43] Inability to properly perform a single-leg hop may indicate poor static and dynamic balance, requiring impairment assessments (joint stability, strength, range of motion).

Selection of appropriate FPT requires careful consideration of safety, relevance, specificity, and practicality.[58] FPT must be appropriate for the athlete's condition, stage of injury, and abilities. In general, approximately 12 to 16 weeks is needed following soft tissue repairs before aggressive loading FPT to injured shoulders or knees.[11] Therefore, a maximum single-leg hop test would not be appropriate 6 weeks following bone–patellar tendon–bone anterior cruciate ligament reconstruction.

Relevance should account for the injury, region, and sport. Closely related to relevance is specificity: muscle action, energy system, and velocity.

Sequence and Timing

In general, the most fatiguing (aerobic) FPT should be performed last, with the most explosive tests first.[26,58] Aerobic or endurance exercises decrease isotonic and isokinetic muscle performance.[1,39] Tests for power (vertical jump) require an energy system with a larger work-to-rest ratio.[26] The phosphagen energy system is utilized in short-term, high-intensity activities.[26] A work-to-rest ratio of 1:12 to 1:20 provides maximal effort using the phosphagen system of muscle recovery.[26] A vertical jump takes only 2 to 3 seconds, but adequate rest is 24 to 36 seconds. A 1-mile run requires a shorter work-to-rest ratio but takes at least 4 to 5 minutes for complete recovery to occur.

Functional Testing Implementation

Before the performance of functional testing implementation, several activities should occur. Considerable debate exists as to which form of stretching is better—static or dynamic. To reduce the risk of injury, decrease postactivity muscle soreness, and create a warm-up effect before activity, some form of stretching, either static or dynamic, is recommended before maximal effort testing.

To decrease the risk of testing results improving owing to a learning effect, we recommend performance of a practice trial of functional tests. Practice sessions to familiarize athletes with the procedures aid in reproducibility and maximum effort.[23,58,68,72]

There are multiple ways to perform a single test. A single-leg hop for distance can be performed with hands on the hips, with hands clasped behind the back, or with hands and arms to gain momentum while hopping. Each method may allow the athlete to hop a different distance. A compensatory pattern may occur with FPT when the athlete exhibits a weakness. Using the single-leg hop, the athlete may flex excessively at the waist and hips during the eccentric phase preceding the actual hop in an effort to utilize the stronger gluteal muscles rather than the quadriceps muscles.[55]

Figure 2. Backward overhead medicine ball throw.

FUNCTIONAL PERFORMANCE TESTS FOR POWER

Rationale for Trunk Performance Tests

The most important trunk muscle (local and global muscles) function is providing dynamic stability.[32,35] A lack of core strength and stability may predispose the athlete to injury.[33] Trunk endurance is generally more important than strength for preventing low back pain. Balance of anterior, posterior, and lateral local and global trunk muscles is necessary to maintain neutral spine alignment necessary for dynamic stability.[24]

Figure 3. Sidearm medicine ball throw.

Trunk Power Tests

Backward Overhead Medicine Ball Throw

The athlete holds a medicine ball with arms straight in front of the body and, following a countermovement, flexes at the hips and knees before extending forcefully backward to throw the ball over the head (Figure 2). There is a strong correlation between the distance of the throw and the power index for a countermovement vertical jump ($r = 0.91$, $P < 0.01$).[65] This test demonstrates high test-retest reliability ($r = 0.996$).[65] Five to 6 trials before actual testing is best.[15] The mean distance thrown by 40 intercollegiate football players was 10.41 ± 1.45 m (range, 8.17-13.85 m; test-retest reliability, 0.86).[50] The absolute values were higher in male volleyball players (mean, 15.4 ± 1.1 m; range, 13.4-17.4 m) versus male wrestlers (mean, 14.2 ± 1.8 m; range, 12.2-18.8 m).[65] The test results correlated with the countermovement vertical jump.[65] This test is ideal to compare right to left. Ideally, right-to-left differences should be no greater than 10% to 15%.[58]

Sidearm Medicine Ball Throw

A functional test of trunk power is the sidearm medicine ball throw (Figure 3), which correlates with isometric trunk rotation torque ($r = 0.60$-0.74, $P < 0.05$-0.01) and 1-repetition maximum bench press ($r = 0.68$-0.73, $P < 0.01$).[30] In elite tennis players, symmetric isokinetic trunk rotation strength correlated with trunk rotation throw based on a 2.7-kg medicine ball ($r = 0.79$-0.84, $P < 0.01$). Normative values for various groups are known.[16,30]

Lower Extremity Power Tests

Power is work divided by time,[47] making the velocity important. The vertical jump test can assess overall lower extremity power, bilaterally or unilaterally.

Vertical Jump

The vertical jump[9,19,20,27,44,60,64] test can be done with a piece of chalk and a wall or the Vertec Vertical Jump System (Senoh, Columbus, Ohio) (Figure 4). The vertical jump test is considered a measure of explosive anaerobic power.[12,66] To begin, the athlete stands with equal weight on both limbs while reaching as high as possible with a single arm. The athlete jumps or hops as high as possible (Figure 5). Taking a counterstep is the most reliable and valid field test for estimation of explosive leg power.[40] The score is the distance between the first reach and the second.

Power tests for the lower extremities should be kinematic chain tests rather than isolated tests of the hip, knee, or ankle. The vertical jump test is not an isolated assessment of knee function. The propulsive phase of vertical jump on a force plate shows that the hip contributes 40% of the total jump force; the knee, 24%; and the ankle, 36%.[60] Arm swing consistently increases vertical jump height.[27,40,64] Reliability of the vertical jump ranges between 0.93 and 0.99.[9,19,44] In sequencing FPT, the vertical jump should be performed before standing long jump.

Vertical jump correlates well with maximal isometric peak force, 1-repetition maximum squat (recreationally trained men),[46] kinematic data from ground reaction forces in eccentric

Figure 4. Starting position for vertical jump. Reprinted with permission from Reiman and Manske.[58]

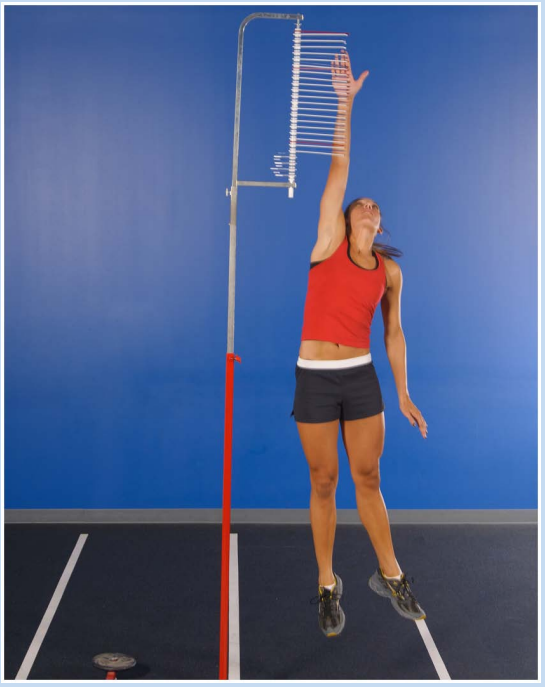

Figure 5. Maximum height of vertical jump. Reprinted with permission from Reiman and Manske.[58]

and concentric phases (trained track athletes),[20] knee extensor muscle strength at 40° and 90° (female athletes),[62] and relative quadriceps strength (children 7-12 years old).[28]

Standing Long Jump

Regarding the standing long jump,[13,20,43,44,69] because vertical and horizontal forces are active during takeoff and landing, this test may be more stressful than the vertical jump and should be tested later in rehabilitation. Test-retest reliability is between 0.95 and 0.96 (Figure 6).[13,37,43,50,69]

Single-Leg Hop

For the single-leg hop,[17,18,31,53,56,61,63,66,67,71] the score is the distance from the start to the location of the posterior heel of the landing leg (Figure 7).[10] Healthy men (controls) did not differ in distance hopped, compared with the uninvolved limb of anterior cruciate ligament (ACL) patients at 13 and 54 weeks following reconstruction.[56] This may be helpful because the uninvolved leg, regardless of limb dominance, can be utilized as a control when evaluating return to sports following cruciate reconstruction.[56] Others have found significant differences observed between right and left limbs of athletes, suggesting that the uninjured limb cannot be used as a control.[19,34,45,52,57] Regardless, the single-leg hop is simple and can be used in isolation or with a combination of quick field tests to determine knee function.[17,18] Reliability for the single-leg hop test is 0.77 to 0.99.[2-7,13,21,22,29,31,36,38,43,51,61,70]

Many ACL-deficient patients (42%) demonstrate abnormal limb symmetry in the single-leg hop[31] (low sensitivity, 38%[66] and 58%[61]). Recent evidence found that following ACL reconstruction, patients can exhibit impairments in the involved knee despite achieving clinically normal hop ratios. During takeoff, knee motion is 25% decreased, resulting in a 40% reduction in peak knee moment and 38% reduction in peak knee power on the involved side.[54] Furthermore, during landing, knee motion was reduced by 18%, resulting in a reduction of peak power absorption by 43% on the involved side.[54] Multiple factors may influence results. Balance and proprioception play important roles.[63] A cluster of tests may increase test sensitivity (timed hop test).[61] Combining the figure-of-8 hop, the up-down test, and the side-hop test with the single-leg hop will increase sensitivity to 82%.[31] There are fair relationships of the scores of single-leg hop distance to concentric quadriceps peak torque and to scores of single-leg hop to concentric quadriceps work.[14] There are moderate-to-good relationships between the single-leg hop distance and concentric quadriceps peak torque measurements for dominant and nondominant lower extremities.[22,66]

Figure 6. Horizontal jump for distance. Reprinted with permission from Reiman and Manske.[58]

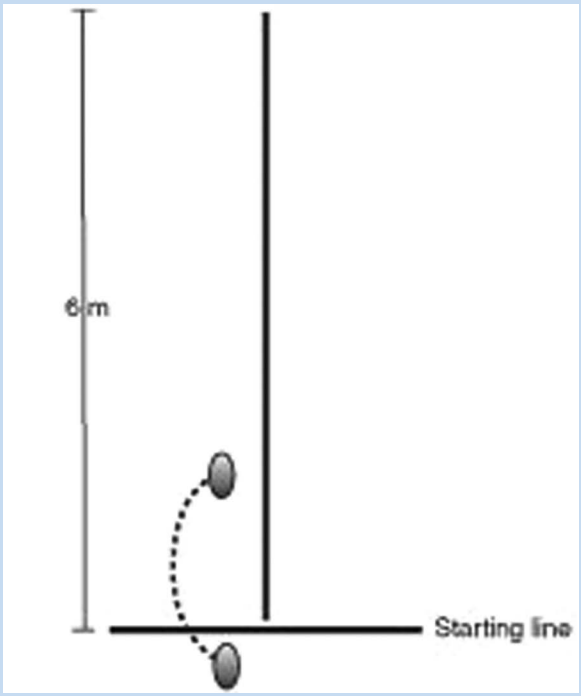

Figure 7. Diagram of the single-leg hop test. Reprinted with permission from Reiman and Manske.[58]

In the lower extremity, it can be clearly seen that each test has limitations. It is possible that a variety of tests may be needed to better determine function than any single test in isolation. Others agree that with a variety of hop tests, different hop qualities can be evaluated and, thereby, the opportunity to detect discrepancies in hop performance increases.[25]

Upper Extremity Power Test: Seated Shot-Put Throw

For the seated shot-put throw,[49-51] to isolate the upper extremities, the athlete sits on the floor with the back against a wall (Figure 8). The score is the distance the shot is thrown. Reliability is 0.84 and 0.95 for the 10-lb shot and 0.98 for the 8-lb shot.[49-51] The seated shot-put test correlates to power based on a percentage of 1-RM bench press. Loads of 30% and 60% were scored by the length of time it took to move the bench press bar through a 0.26-m distance. The test scores related to 30% (r = 0.67) and 60% (r = 0.75) bench press power in healthy college men.[49] The minimal detectible change was 17 in (males) and 18 in (females).[51] A 9% difference is expected between dominant and nondominant extremities in healthy, young, active participants.[51]

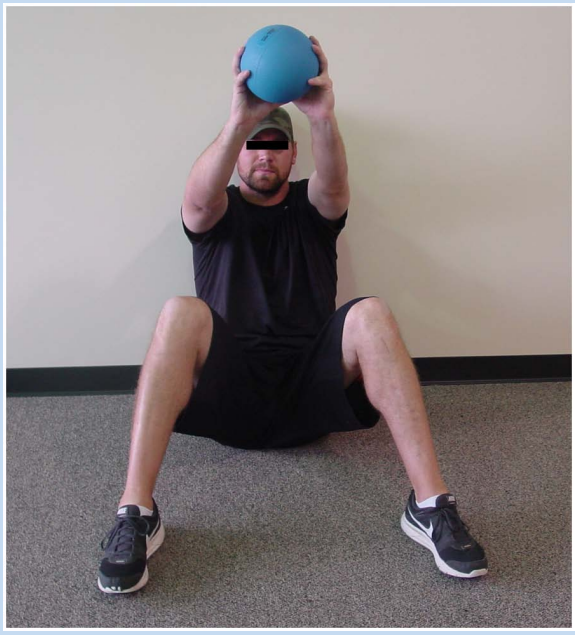

Figure 8. Seated shot-put throw for distance.

CONCLUSION

Functional performance tests can help determine when an athlete can return to unrestricted activity. However, further research is desperately needed in this area to determine how adaptations during functional tests can be measured and quantified. Additionally, a lack of standardization exists, as little information is known about how various tests relate to one another and which tests are best to use in isolation or in combination as a means to assess a broad range of function. It is highly likely that performance-based function testing should utilize a wide range of assessments, including patient self-report questionnaires, assessment of psychological factors (eg, fear), and quality of movement during functional tests during assessment of return to function.

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