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Baseline Values of Trunk Endurance and Hip Strength in Collegiate Athletes

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Context: Injuries involving the lumbar spine and lower extremities in athletes are among the most disabling. Lack of trunk and hip strength may predispose athletes to such injuries.

Objective: To measure trunk endurance and hip strength in a population of National Collegiate Athletic Association Division III athletes.

Design: Cross-sectional design of 5 collegiate athletic teams.

Setting: An athletic training facility during preparticipation physical examinations.

Patients or Other Participants: 105 Division III athletes.

Main Outcome Measure(s): The series of tests included the 60-second back-extension endurance and 60-second tall-kneeling tests. The scores of these tests were reported in repetitions. A handheld dynamometer was used to measure maximal hip external rotation strength bilaterally. The double-leg lowering test was measured in degrees, and the Star Excursion Balance Test was measured in 4 directions as a percentage of the subject's leg length. Descriptive statistics were calculated for each exercise and each team.

Results: The average score for the 60-second back-extension endurance test was 53 ± 13 repetitions. The 60-second tall-kneeling test had an average score of 30 ± 8 repetitions. For the 2 hip external-rotation strength tests, the average score was 7 ± 4 kg (12% ± 6% of body weight). Average scores were 50° ± 10° for the double-leg lowering test and 94 ± 9 cm (105% ± 9 % of leg length) for the Star Excursion Balance Test.

Conclusions: The descriptive data from these trunk and hip tests allow for the development of baseline values for each test. By investigating these measures in an athletic population, we hope to provide health care professionals with further insights about the trunk and hip muscle performance in athletes to prevent and rehabilitate athletic injuries.

Key Words: descriptive analysis, assessment, musculoskeletal system, athletic injury

Athletes suffer most commonly from musculoskeletal injuries.[1] Among the most disabling injuries in an athletic population are those involving the lumbar spine and lower extremities.[2,3] Many of these injuries are attributed to muscular deficiencies such as weakness[2,4] and poor endurance.[2,5] Accordingly, it has been suggested that lack of trunk and hip strength may predispose athletes to low back and lower extremity injury.[4]

One of the primary functions of a health care professional is to aid in the prevention of injuries. A major component of injury prevention is the identification of potential risk factors. In order to detect these risk factors for injury, a preparticipation physical examination is often performed.[6] Although no standard procedure to quantify trunk endurance and hip strength currently exists, several activities have been identified as potential screening tools.[7–10] Among these tests are the 60-second back-extension endurance test, the 60-second tall-kneeling test, the hip external-rotation strength test, the double-leg lowering (DLL) test, and the Star Excursion Balance Test (SEBT).

Through a screening protocol for trunk endurance and hip strength, health care professionals may be able to better identify those athletes at risk for future injury.[11] Unfortunately, limited information is available in the literature for this specific athletic population. Therefore, our objective was to measure the performance of trunk endurance and hip strength clinical tests in a population of National Collegiate Athletic Association Division III athletes.

METHODS

Subjects

A total of 105 Division III athletes (47 males, 58 females; age = 19.22 ± 1.20 years; height = 173.83 ± 13.42 cm; mass = 69.31 ± 11.41 kg) volunteered for participation in this study during their preseason screening examination by the athletic training staff. Each participant was given a verbal explanation of the study and was required to sign both an approved informed consent and a protected health information disclosure form approved by the institutional review board

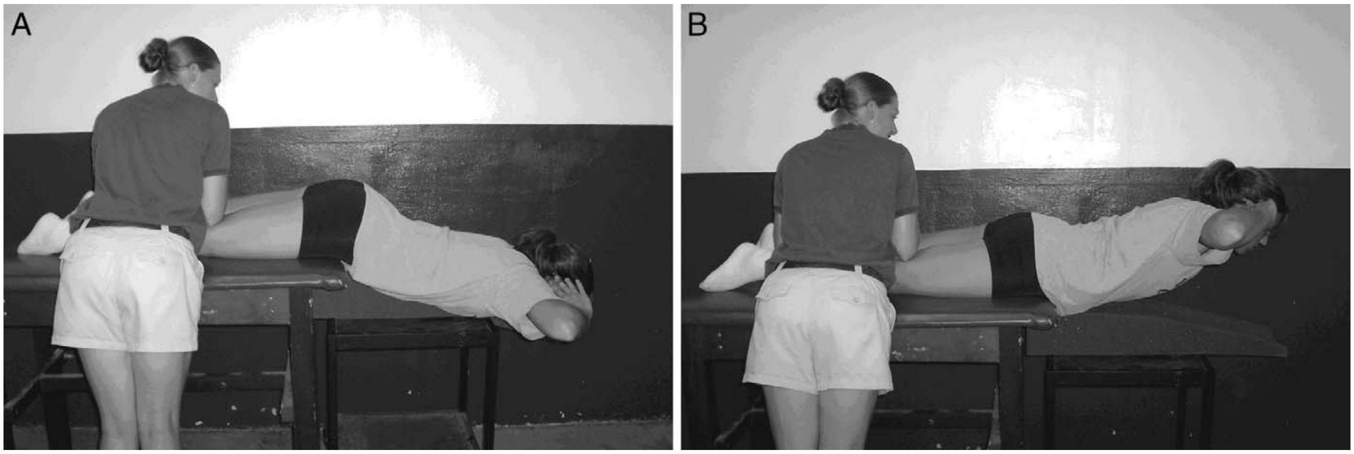

Figure 1. The 60-second back-extension endurance test. A, Starting position with the subject in 45° of trunk flexion. B, Ending position with trunk parallel to the floor.

(which also approved the study) before participating in the study. No exclusion criteria existed. To be included in the study, each individual participating had to be a current member of a collegiate team, regardless of previous injury history.

Procedures

To assess the trunk and hip, each subject underwent a battery of tests. We counterbalanced the order of testing to prevent fatigue bias, using a station format during testing. The average time for an athlete to complete data collection was 30 minutes, with approximately 1 minute's rest between tests. We completed between-day reliability testing on 5 subjects for each of the 5 tests before beginning data collection, and these findings are reported below.

60-Second Back-Extension Endurance Test. The 60-second back-extension endurance test is a dynamic strength assessment of the trunk extensor muscles.[7] To perform the test, the subject was positioned prone on a treatment table with the iliac crests at the edge of the table. An assistant manually secured the lower body to the table at the level of the hips and the midcalf. Before beginning the test, the subject rested the upper body on a stool and placed his or her hands behind the head (Figure 1A). We instructed the subject to lift the upper body off the stool (Figure 1B). With the spine kept straight, the subject extended the trunk to neutral and then lowered the upper body so the trunk was flexed to 45°. The athlete had 60 seconds to perform as many repetitions as possible. We counted the number of successful repetitions out loud, and this number was recorded as the score. An unsuccessful repetition was not counted if the subject's back did not extend fully to the neutral position. Reliability testing from our study revealed high values (intraclass correlation coefficient [ICC] 2,1 = .98, SEM = ±1.0 repetitions).

60-Second Tall-Kneeling Test. The 60-second tall-kneeling test, also a dynamic test, assesses the eccentric strength of the iliopsoas and rectus femoris muscles. To perform the test, subjects were instructed to assume a position of tall kneeling, by kneeling on both knees with the trunk aligned directly over the thighs and the arms folded across the chest (Figure 2A). We had each subject lean posteriorly until the angle between the lower leg and thigh reached 70° as measured with a standard goniometer. The position of the torso was marked with the investigator's hand. To begin the test, we instructed the subject to lean back to the hand marker while maintaining a neutral posture and without bending at the waist (Figure 2B). The athlete had 60 seconds to perform as many repetitions as possible. We counted the number of successful repetitions out loud, and this number was recorded as the score. An unsuccessful repetition was discarded if the subject's torso did not reach the investigator's hand or if the neutral posture of the torso to the thighs was not maintained during the trial. Reliability testing from our study for the tall-kneeling test resulted in moderate values (ICC 2,1 = .70, SEM = ±3 repetitions).

Hip External-Rotation Strength Test. The hip external-rotation test is an isometric strength evaluation of the hip external rotator muscle group. To perform the test, subjects assumed a seated position on a flat table with the knees and hips in 90° of flexion. We positioned each subject in 15° of external rotation and asked him or her to push as hard as possible against our stationary hand (Figure 3).[12] Subjects repeated the movement 3 times bilaterally, and the amount of force generated by the subjects during each trial was measured with a handheld dynamometer (J-Tech Inc, Salt Lake City, UT) held just superior to the medial malleolus. We recorded the maximal isometric value of the 3 trials for each leg as the subject's score.

In order for the subject's scores to be reported for our study, the coefficient of variation for the 3 efforts had to be less than 15%. In our study, reliability for this procedure was found to be moderate for both the right (ICC 2,1 = .62, SEM = ±13N) and left (ICC 2,1 = .75, SEM = ±8.9N) legs.

Double-Leg Lowering Test. The DLL test evaluates the strength of the rectus abdominus and oblique muscles.[8] To test lower abdominal strength, the subject was positioned supine on a treatment table, with the hip joint aligned with a goniometric grid positioned on a wall adjacent to the table. Before beginning the test, we administered several practice trials to acquaint the subject with the posterior pelvic tilt position. During the first trials, the subject practiced the posterior pelvic tilt in a position with both knees bent and feet flat on the table. When comfortable with the initial position, the subject then attempted to maintain a posterior pelvic tilt with 1 leg supported on the table and 1 leg unsupported. The subject practiced these maneuvers until comfortable with the pelvis stabilized in the same manner as would be required during testing. We placed a standard sphygmomanometer, inflated to

Figure 2. The 60-second tall-kneeling test. A, Starting position with the subject in a vertical position. B, Ending position, identified by the tester's hand posterior to the subject. This position is determined with a goniometer placed at the knee joint (not pictured).

40 mm Hg, under the subject's lumbar spine and used this to monitor the maintenance of posterior pelvic tilt.[13] The subject received visual feedback by watching the pressure change on the sphygmomanometer dial.

To begin the test trial, we passively assisted the subject's legs into a position of 90° of hip flexion while the knees were actively fixed in full extension and the pelvis in a posterior tilt (Figure 4A). We then instructed the subject to maintain knee extension and posterior pelvic tilt while lowering both legs simultaneously to the table (Figure 4B). We visually determined the angle of the legs from horizontal and recorded the value when subjects lost control of the posterior pelvic tilt. Objectively, the loss of posterior pelvic tilt was determined by a 10–mm Hg decrease in pressure on the sphygmomanometer dial.[13] Reliability testing from our study for the DLL test resulted in average scores (ICC 2,1 = .63, SEM = ±6.0°).

Star Excursion Balance Test. The SEBT is a dynamic assessment of postural control.[10] The test layout of the SEBT consists of 4 lines applied to the floor with athletic tape. The 2 anterior lines are oriented 45° from directly anterior, and the 2 posterior lines are oriented 45° from directly posterior. The lines are positioned perpendicularly to each other to form 4 diagonal positions: right-anterior, left-anterior, right-posterior, and left-posterior (Figure 5). A square marked at the center point of the 4 lines represents the starting position of the feet. The square is large enough to fit the subject's feet while he or she straddles the vertical line. We used a standard tape measure, secured to each of the 4 lines, for measurement readings to the nearest centimeter.

To begin the test, the subject was instructed to stand with both feet inside the starting box. To initiate the trial, the subject reached in 1 of the 4 diagonal directions. The right foot was used to reach along the lines to the subject's right, while the left leg remained in a single-leg stance. Similarly, when reaching along lines to the left, the subject used the left foot to reach and the right leg to balance. The subject was allowed to move in any way possible to achieve a maximal reach distance without moving the support foot and without touching the ground with the reaching foot. We measured the maximal reaching distance achieved with the subject's foot along the secured tape measure with the shoe on. The trial was completed as the subject returned in a controlled manner to the starting position. After completion of each trial, the subject was given time to regain resting balance before initiating the next trial. Six practice trials in each direction were allotted to allow for familiarity of the test.[9] Three consecutive trials were then completed in 1 direction, followed by completion in each of the 3 remaining directions. We recorded the greatest reach distance achieved out of the 3 trials in an individual direction as the maximal reach in that direction. From our study, reli-

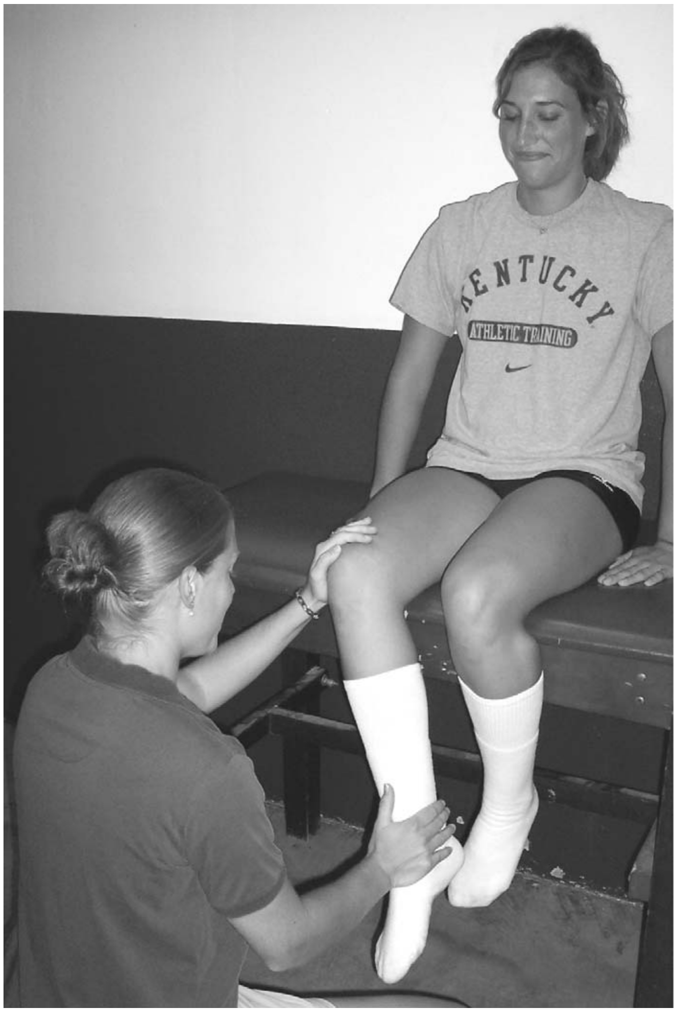

Figure 3. The hip external rotation test position. The athlete was allowed to stabilize the trunk by placing his or her hands on the surface of the plinth.

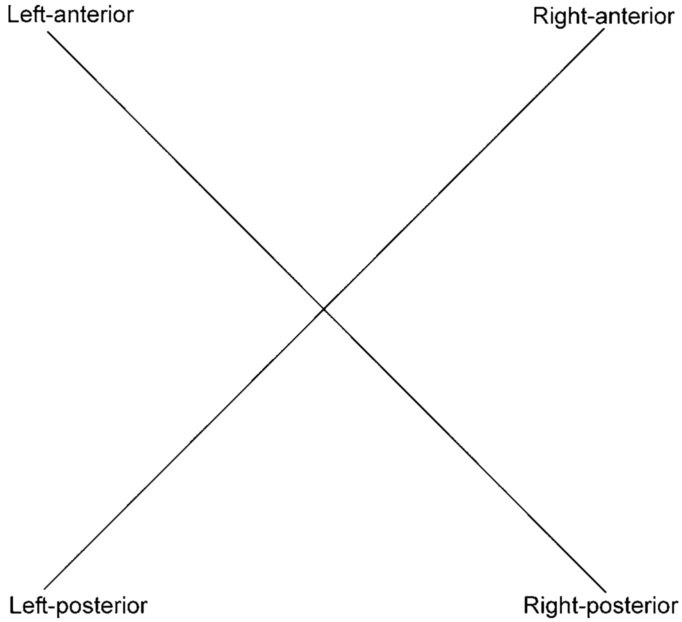

Figure 5. Schematic drawing of the Star Excursion Balance Test.

ability for the SEBT was determined to be high for all reach directions (ICC 2,1 = .84 to .97, SEM = 1.64 to 3.7 cm).

RESULTS

The average score for the 60-second back-extension endurance test was 53 ± 13 repetitions, whereas the 60-second tall-kneeling test had an average score of 30 ± 8 repetitions (Table 1). An average score of 7 ± 4 kg (Table 1) and a weighted average score of 12% ± 6% body weight (Table 2) were obtained for the 2 hip external-rotation strength tests. The average score for the DLL was 50 ± 10° (Table 1). An average score of 94 ± 9 cm (Table 1) and a weighted average score of 105 ± 9% of leg length (Table 2) were obtained for the 4 SEBT positions.

DISCUSSION

One major component of injury prevention is the identification of potential risk factors. Risk factors for low back and

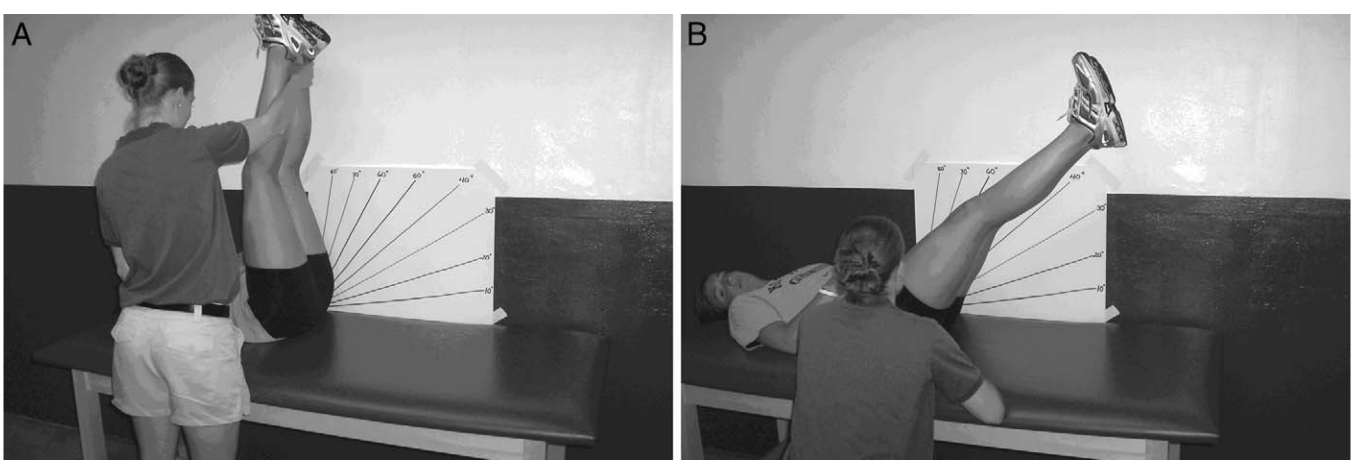

Figure 4. The double-leg lowering test. A, Starting position, with the subject instructed to maintain a neutral pelvis while lowering the legs independently. B, Ending position as determined by the investigator's inspection of the loss of pelvic neutral position. The angle of the thighs is recorded for data collection.

Table 1. Average Raw Trunk Endurance and Hip Strength Test Scores in Collegiate Athletes

Test	Men's Soccer (n = 35)	Women's Soccer (n = 19)	Men's Cross-Country (n = 12)	Women's Cross-Country (n = 14)	Field Hockey (n = 15)	Volleyball (n = 10)	Men's Average (n = 47)	Women's Average (n = 58)	Total Average (n = 105)
60-s back-extension endurance (repetitions/min)	58 ± 18	45 ± 10	57 ± 7	59 ± 9	49 ± 5	45 ± 11	57 ± 1	49 ± 6	53 ± 13
60-s tall kneeling (repetitions/min)	32 ± 5	24 ± 6	25 ± 6	23 ± 6	37 ± 3	33 ± 4	28 ± 6	29 ± 7	30 ± 8
Right hip external rotation (kg)	6 ± 2	11 ± 2	11 ± 5	10 ± 2	3 ± 1	4 ± 1	9 ± 4	7 ± 4	7 ± 4
Left hip external rotation (kg)	6 ± 2	10 ± 2	11 ± 4	10 ± 1	3 ± 1	5 ± 1	9 ± 3	7 ± 4	7 ± 3
Double-leg lowering (°)	48 ± 11	50 ± 11	44 ± 9	48 ± 10	50 ± 10	59 ± 7	46 ± 3	52 ± 5	50 ± 10
Star Excursion Balance Test (cm)									
Right-anterior	92 ± 7	84 ± 6	94 ± 7	84 ± 9	84 ± 5	98 ± 8	93 ± 1	87 ± 7	90 ± 9
Left-anterior	92 ± 9	83 ± 7	95 ± 6	85 ± 8	84 ± 5	98 ± 7	93 ± 2	87 ± 7	90 ± 9
Right-posterior	100 ± 8	92 ± 6	103 ± 6	93 ± 7	94 ± 8	104 ± 6	101 ± 2	96 ± 6	98 ± 9
Left-posterior	99 ± 10	91 ± 8	100 ± 7	92 ± 5	91 ± 9	101 ± 5	99 ± 1	94 ± 5	97 ± 9

lower extremity injury include muscular imbalances and dysfunction.[2,4–6,14–17] To detect these factors, preparticipation physical examinations are often used. To date, no prospective research has been conducted to assess trunk endurance and hip strength as predictors of low back and lower extremity injury. As such, no standard procedure to quantify trunk endurance and hip strength currently exists.

It has been suggested that athletes with poor trunk muscle endurance may easily injure passive, pain-sensitive structures of the lumbar spine.[18] Similarly, reduced back extensor muscle endurance may be a risk factor for nonspecific low back pain.[2,5] To assess back extensor muscle endurance, a dynamic version of the Biering-Sorensen test has been previously described as a reliable measure of back extensor muscle function.[5,7] Although the original Biering-Sorensen test assessed trunk extensor strength isometrically, the repeated version of this test, described by Moreland et al,[7] evaluated more dynamic and functional movements of the back extensor muscles. Results from their investigation of healthy, active adults revealed high interrater reliability (ICC = .78) for this dynamic extensor endurance exercise. To further assess the reliability and variability of a dynamic lumbar extension protocol, Udermann et al[5] evaluated a dynamic-repetition back-extension endurance test in a healthy, athletic population, demonstrating a high reliability (r = .96) and low variability (total error = 1.6 repetitions). As we reported, the reliability values from our current study agree with these previous findings of high reliability for the dynamic back-extensor endurance assessment, allowing us to conclude that lumbar muscle endurance can be reliably assessed by dynamic tests.

Diminished eccentric hip strength has been linked to low back pain[19] as well as to lower extremity muscle strains and soreness.[20] In running activities, the rectus femoris functions eccentrically to control knee flexion during the early and middle swing phases and with increases in pace as the muscles are required to withstand rapid and severe lengthening.[20] Lengthening changes within muscles have been implicated in the development of muscle injury; therefore, it has been suggested that strength training for runners should include eccentric strengthening of the hip and knee flexors and extensors.[20] Although it has been proposed that runners should incorporate eccentric hip-strengthening exercises into their strength training protocols, minimal research has been conducted to evaluate eccentric hip-strengthening exercises. In our investigation, we used the 60-second tall-kneeling test as a measure of eccentric hip flexor endurance. Because this test incorporates a dynamic component of repeated eccentric hip flexor contractions, it may be appropriate for use among running athletes, who are required to repeatedly contract their hip flexors eccentrically during the running cycle. One limitation noted during the execution of the tall-kneeling test was the use of the investigator's hand as the marker of the lean distance. As it is likely that the tester's hand moved over the course of the minute-long trial, we suggest that future authors use a more rigid marking mechanism.

The hip musculature plays an important role in transferring forces from the lower extremity toward the spine during upright activities. As the link theory of injury explains, injury migrates from distal to proximal structures.[4] Conversely, however, it has also been suggested that low back pain or hip strength deficits (or both) may increase the likelihood of distal injury,[4] such as patellofemoral pain syndrome (PFPS).[21] Especially prone to PFPS are female runners who have demonstrated significant knee valgus and hip internal rotation movements during running.[21] Although the ability of females to control these motions depends on the strength of the proximal muscle groups, such as the hip external rotators, apparent weakness of these muscles may cause excessive femoral adduction or internal rotation.[21] Because these altered femoral movements may lead to disruptions throughout the kinetic chain, the measurement of hip muscular function is indicated.[4]

The assessment of muscle strength is often quantified with use of a handheld dynamometer. Muscle testing with a handheld dynamometer provides a more objective measurement of muscle strength than manual muscle testing by computing a continuous range of torque values[22] and has been found reliable among several age populations, as well as in the assessment of both upper and lower extremity strength.[23] A previous author,[24] using handheld dynamometry, identified body weight as a predictor of force production during muscle testing. In order to account for this relationship, force values may be normalized for weight. Ireland et al[21] recorded isometric hip

Table 2. Average Weighted Trunk Endurance and Hip Strength Test Scores in Collegiate Athletes*

Test	Men's Soccer (n = 35)	Women's Soccer (n = 19)	Men's Cross-Country (n = 12)	Women's Cross-Country (n = 14)	Field Hockey (n = 15)	Volleyball (n = 10)	Men's Average (n = 47)	Women's Average (n = 58)	Total Average (n = 105)
Right hip external rotation (% body weight)	8 ± 3	17 ± 4	17 ± 7	18 ± 3	5 ± 1	6 ± 2	13 ± 6	12 ± 7	12 ± 6
Left hip external rotation (% body weight)	9 ± 3	16 ± 3	16 ± 7	17 ± 2	5 ± 1	7 ± 2	12 ± 5	11 ± 6	11 ± 6
Star Excursion Balance Test (% leg length)									
Right-anterior	101 ± 7	96 ± 6	105 ± 7	102 ± 9	99 ± 5	110 ± 8	103 ± 3	102 ± 6	101 ± 9
Left-anterior	99 ± 9	95 ± 7	105 ± 6	104 ± 8	99 ± 5	109 ± 7	102 ± 4	102 ± 6	101 ± 9
Right-posterior	109 ± 8	105 ± 6	115 ± 6	113 ± 7	111 ± 8	116 ± 6	112 ± 4	111 ± 5	111 ± 9
Left-posterior	107 ± 10	104 ± 8	111 ± 7	112 ± 5	107 ± 9	113 ± 5	109 ± 3	109 ± 4	108 ± 9

*No weighted scores were calculated for the 60-s back-extension endurance, 60-s tall kneeling, or double-leg lowering tests.

external rotation strength measurements with a handheld dynamometer for 30 active female subjects, 15 subjects with PFPS and 15 control subjects. Subjects with PFPS were 36% weaker in hip external rotation than the control subjects. Thus, females with PFPS may have insufficient strength to protect the knee from excessive internal rotation moments and may be predisposed to the further development of PFPS. One limitation noted with the handheld dynamometer in our investigation was that the device was manually secured. Because the strength of the tester may vary through the course of testing, the results of the test may have been affected. We suggest that future researchers use a nonelastic strap in order to improve the reliability of the testing procedure and reduce the variability from the examiner.

The abdominal muscles function to resist the pull of the hip flexor muscles in order to maintain proper alignment of both the pelvis and the spine.[25] Therefore, abdominal strengthening exercises are often recommended in the prevention of low back injury.[8] Unfortunately, standard exercises for abdominal strengthening, namely the sit-up, often involve more activity of the hip flexor muscles than of the abdominal muscles.[12,25] When using the sit-up to assess abdominal strength, marked weakness of this muscle group is often masked by compensatory actions of the hip flexors and low back.[12] The DLL test, however, has been accepted as an advanced test of abdominal strength because it requires coactivation of all the abdominal muscles to stabilize the pelvis and low back,[8] rather than relying on subsequent recruitment of the hip flexor muscles to maintain core stability. Exercises that promote coactivation and strengthening of the oblique abdominal muscles may increase both trunk stiffness and intra-abdominal pressure, thus providing greater protection of the spine during functional tasks.[8] One limitation noted with the DLL test is the positioning of the subject's knees in full extension. Hamstring tightness may affect the positioning of the pelvis, and the activity of the abdominals in controlling the pelvic tilt may have been masked. We suggest that future authors allow slight knee flexion during testing to minimize hamstring flexibility bias.

Shields and Heiss[8] studied the muscle activity of the rectus abdominis and the external and internal obliques during the isometric bent-knee curl and the DLL tests. During both exercises, the subjects were instructed to maintain a posterior pelvic position. This pelvic positioning allows examiners to assess abdominal strength as the subject attempts to prevent the naturally occurring anterior pelvic tilt as the legs move into an extended position. The DLL test required higher muscle activation levels than the curl exercise when muscle length and contraction type were controlled. When compared with the curl exercise, the DLL test also demonstrated a narrower base of support of the trunk and upper body segments and a longer lever arm of the leg segments; hence, a greater need for intrinsic trunk stabilization resulted. This finding was the basis for the inclusion of the DLL test in our testing protocol. The emphasis on core stabilization during lower extremity movements is essential for athletes, as most functional athletic tasks incorporate synchronized contractions of the abdominal and lower extremity musculature.

When injury occurs in the lower extremity, the mechanical stability of the joint is compromised.[26] This alteration in joint function requires the neuromuscular system to then compensate for the loss of mechanical stability by improving functional stability.[26] Functional, or dynamic, stability activities are

Table 3. Baseline Values of All Participants' Trunk Endurance and Hip Strength Tests Compared With Previously Reported Values

Test	Current Study Findings	95% Confidence Interval	Previous Findings
60-s back-extension endurance (repetitions/min)	53 ± 13	(28, 78)	46 ± 18[7]
60-s tall kneeling (repetitions/min)	30 ± 8	(14, 46)	N/A*
Hip external rotation (% body weight)	12 ± 6	(0, 24)	17 ± 6[20]
Double-leg lowering (°)	50 ± 10	(30, 70)	86 ± 4[28]
Star Excursion Balance Test (% leg length)	105 ± 9	(87, 123)	88[10]

* N/A indicates not available.

those that cause the center of gravity to move in response to muscular activity.[27] The assessment of dynamic postural control is advantageous in that the demands of proprioception, range of motion, and strength can be evaluated along with those of balance.[10] One such activity used by clinicians to assess dynamic balance is the SEBT.

Hertel et al[9] assessed both intratester and intertester reliability of the SEBT. Both intratester reliability (ICC = .78 to .96) and intertester reliability (ICC = .81 to .93) of the SEBT were relatively high. The findings from our study agree with these reports of moderate to high reliability for the SEBT. The results also suggest that significant learning effects are present with repetitive trials of the excursion directions. The longest excursions occurred during trials 7 through 9 for all directions, thus indicating that at least 6 practice trials in each direction should be performed before recording data. Further investigation of the SEBT suggests that because the subjects are assessed on their ability to achieve a maximal reaching distance, those with longer legs may have an advantage in reaching further than subjects with shorter legs.[10] Therefore, because leg length demonstrated the strongest correlation with excursion distances and leg length and height were highly correlated with each other, Gribble and Hertel[10] recommended that leg length should be considered in normalizing reaching distances for the SEBT. This consideration of leg length was used as the weighting procedure for this test. One notable difference between our study and previous reports is the testing population. Whereas we assessed collegiate athletes, previous authors have tested recreationally active subjects. This population difference is evident when comparing excursion distances from our investigation with those previously reported (Table 3). As would be expected because of our population, excursion values are higher than those of previous investigations. We have included the 95% confidence levels for the test conditions in order to give clinicians a reference for future comparisons.

Conclusions

The descriptive data of the trunk endurance and hip strength tests allow for the development of baseline values for each test. Although scores for several of the tests have been previously reported, none of these reports have included a population of healthy, college-aged athletes; therefore, the previous results may not be applicable to athletes. The population of our study included 105 Division III athletes, all tested as part of a preparticipation physical examination. We set out to describe test procedures and report descriptive data of trunk endurance and hip strength for a variety of athletes. These measures may be used by health care professionals to assist in the screening for participation and, we hope, will be used to further refine the relationship between trunk endurance and hip strength with athletic activity. Certainly several other available tests need to be examined. We have identified the limitations we found in using these clinical tests and offered suggestions for improved utilization of each exercise. Overall, we feel that each test may be of value to health care professionals, depending on the particular needs of the athlete.

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