Journal of Strength and Conditioning Research, 2000, 14(4), 443–450

Reliability and Validity of the T-Test as a Measure of Agility, Leg Power, and Leg Speed in College-Aged Men and Women

KAINOA PAUOLE, KENT MADOLE, JOHN GARHAMMER, MICHAEL LACOURSE, AND RALPH ROZENEK

Department of Kinesiology and Physical Education, California State University Long Beach, Long Beach, California 90840.

ABSTRACT

The reliability and validity of the T-test as a measure of leg power, leg speed, and agility were examined. A total of 304 college-aged men ($n = 152$) and women ($n = 152$), selected from varying levels of sport participation, performed 4 tests of sport skill ability: (a) 40-yd dash (leg speed), (b) countermovement vertical jump (leg power), (c) hexagon test (agility), and (d) T-test. For both men and women, significant differences ($p < 0.05$) in mean scores were found among groups for the T-test. The intraclass reliability of the T-test was 0.98 across 3 trials. For men, the Pearson product moment correlations between the T-test and the 40-yd dash, vertical jump, and hexagon test were $r = 0.53$, $r = -0.49$, and $r = 0.42$, respectively ($p < 0.05$). For women, the corresponding correlations were $r = 0.73$, $r = -0.55$, and $r = 0.48$ ($p < 0.05$). Regression analyses showed that for men 48% of the variability and for women 62% of the variability of the T-test scores can be predicted from measures of leg power, leg speed, and agility ($p < 0.05$). Computing partial correlations assessed the criterion validity of the T-test as a measure of agility, leg power, and leg speed. The T-test appears to be highly reliable and measures a combination of components, including leg speed, leg power, and agility, and may be used to differentiate between those of low and high levels of sports participation.

Key Words: physical ability, movement skill tests, sport participation, fitness testing

Reference Data: Pauole, K., K. Madole, J. Garhammer, M. Lacourse, and R. Rozenek. Reliability and validity of the T-test as a measure of agility, leg power, and leg speed in college-aged men and women. *J. Strength Cond. Res. 14(4):443–450. 2000.*

Introduction

Coaches, trainers, and athletes continually search for effective methods to identify and develop physical characteristics that may contribute to sport performance. A common method of assessing athletic talent is through physical ability testing (2). A variety of tests are available to measure athletic abilities, such as anaerobic power, speed, and agility. Such tests help coaches, physical educators, and conditioning specialists assess athletic ability, diagnose specific weaknesses, screen for possible health risks due to strenuous exercise, provide data for outlining individualized exercise prescriptions, and assess change in physical characteristics during specific cycles of a training period (1). In general, assessment allows for the development of confidence in the planning and administration of training programs (2).

Agility, leg power, and leg speed are believed to be important physical components necessary for successful performance in many sports and recreational activities (3, 4, 6, 10). It is not surprising then that a strong interest exists for developing field tests that can effectively measure these components. One test of physical ability that has become popular is the T-test (11). The T-test is described as a measure of 4-directional agility and body control that evaluates the ability to change directions rapidly while maintaining balance without loss of speed (11). The test is relatively simple to administer, because it requires minimal equipment and preparation. The description of the test suggests that agility and some combination of leg power and leg speed are required for successful test performance. A single test that simultaneously measures leg speed, leg power, and agility would be useful to the sport and fitness communities for testing and evaluation purposes. Although the T-test is believed to primarily measure agility, there is no published literature indicating whether the T-test is a reliable and valid measure of agility or what the contributions of leg power and leg speed are to test performance.

The purposes of this investigation were to evaluate the reliability and validity of the T-test as a measure of leg speed, leg power, and agility and to establish normative values of the T-test for college-aged men and women of varying levels of sport participation.

Methods

Subjects

A total of 304 college-aged men (n = 152) and women (n = 152) participated in the study. To ensure sample heterogeneity and improve statistical estimation, subjects were selected from various levels of sport participation. All subjects completed informed consent forms before participation in the study. The mean (±*SD*) age and body mass of the men were 22.3 (±4.0) years and 77.1 (±13.3) kg. For women, the mean (±*SD*) age and body mass were 22.4 (±3.9) years and 61.3 (±11.4) kg. A university institutional review board for the protection of human subjects approved testing procedures. Subjects were required to complete an information questionnaire before testing that included questions regarding their level of sport participation. To qualify for participation in the study, subjects had to be at least minimally active (defined as exercising at least 1 but not more than 2 days per week). Subjects were then classified into 1 of the following 3 groups based on level of sport participation: (a) low sport participation (G1)—defined as exercising less than 3 days per week, less than 30 minutes per day, and not competing in any organized sport activities; (b) recreational sport participation (G2)—defined as exercising at least 3 days per week for 30 minutes or more; and (c) intercollegiate sport participation (G3)—defined as training at least 5 days per week for 1 hour or more and competing in athletic events. Based on the results of this questionnaire, sample sizes for each sex group by level of sport participation were as follows: male–low participation (n = 47), male-recreational (n = 58), male-competitive (n = 47), female–low participation (n = 44), female-recreational (n = 52), and female-competitive (n = 56).

Testing Procedures

All testing was conducted indoors at various college gymnasiums on hardwood floors to maintain a consistent surface and to eliminate the extraneous variables normally encountered outdoors. Before testing, subjects were allowed 10–15 minutes to perform individual warm-up, including 3–5 minutes of light jogging and stretching exercises. Subjects were allowed practice trials on all tests before the actual test trials. During the test session, each subject first performed the T-test, followed by the hexagon test, countermovement maximal vertical jump test, and 40-yd dash. The order of testing was consistent for all subjects. Tests that required high skill movements (T-test and hexagon test) were administered before tests that produced fatigue (40-yd dash) to avoid confounding subsequent tests. Each subject was allowed a minimum of 3 minutes between tests to ensure adequate recovery. All procedures for each test were administered by the same individual.

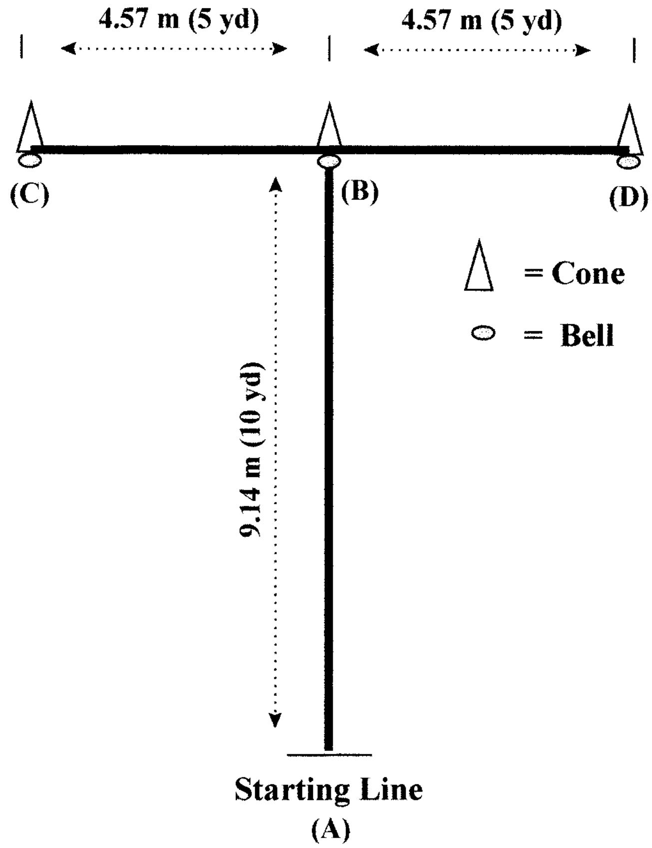

Figure 1. Layout of the T-test. Modified from Semenick (11).

T-Test

The T-test was administered using the protocol outlined by Semenick (11) with minor modifications (Figure 1). Specifically, bells were placed at the base of 3 cones (B, C, and D) in an attempt to monitor consistency and accuracy of test execution. Subjects began with both feet behind the starting point A. At their own discretion, each subject sprinted forward 9.14 m (10 yd) to point B and rang a bell at the base of a cone with the right hand. They then shuffled to the left 4.57 m (5 yd) and touched a bell at the base of a cone (C) with the left hand. Subjects then shuffled to the right 9.14 m and touched a bell at the base of a cone (D) with the right hand. They then shuffled to the left 4.57 m back to point B and touched a bell with the left hand. Subjects then ran backward, passing the finishing line at point A. Three test trials were performed, and times were recorded to the nearest one-hundredth of a second using an electronic timing system (Brower Timing System, Salt Lake City, UT). Two electronic timing sensors mounted on tripods were set approximately 0.75 m above the floor and were positioned 3 m apart facing each other on either side of the starting line. The clock started when subjects passed the electronic sensors, and the clock stopped the instant the subjects again crossed the sensor plane. The test was repeated if a subject failed to ring the bell at the base of each cone, crossed his or her feet when shuffling, and/or did not face forward at all times. The fastest trial was used for statistical analyses.

Hexagon Test

The hexagon test is a measure of agility that involves balance and coordination while moving the feet quickly around a hexagon from the center to each of the 6 sides (8). The test purportedly measures foot quickness as performers face in one direction and execute 2-legged hops backward, forward, and sideways. A 120° hexagon template was constructed with each side, measuring 0.61 m. The template was used for each test session to outline a consistent hexagon with tape on the hardwood floor. Subjects began the test by standing on a touch-sensitive timing pad that was taped to the floor in the center of the hexagon. At their own discretion, each subject began the test by double-leg hopping from the center position over one side of the hexagon and immediately hopping back to the center position. This pattern was continued in a clockwise direction. The test was concluded after the subjects completed 3 revolutions of the hexagon and their feet were back in the middle of the hexagon. The clock started with the release of pressure on the timing pad initiated by the subject, and it stopped the instant the subject's feet landed back in the center of the hexagon after the final double-leg hop. Subjects were required to face the same direction throughout the test, and the feet could not touch the taped edges of the hexagon or the trial was stopped and repeated. Each subject performed 3 test trials. The duration of each trial was recorded to the nearest one-hundredth of a second using an electronic timer. The fastest trial was used for statistical analyses.

Countermovement Maximal Vertical Jump Test

The countermovement vertical jump test involves jumping to a peak height and requires explosive leg power (5). Subjects were initially weighed using a calibrated medical scale. Scale calibration was checked before each testing session. The standing vertical reach was determined with the dominant arm. Countermovement vertical jumps were measured using a Vertec height measurement device. Subjects were allowed to swing their arms freely but were not allowed any preparatory step before jumping. The subjects performed 3 test trials that were measured to the nearest 1.3 cm (0.5 in.). Trials with noticeable faults were repeated. The maximum vertical jump was calculated from the difference between the standing reach and peak jump height and was used for statistical analyses.

40-yd Dash

The 40-yd dash is a commonly used measure of leg speed. At the subjects' discretion, one foot was placed on a touch-sensitive timing pad, while the subjects kept their weight forward. The timer was set to start the moment the subjects released their weight from the pad. The subjects then sprinted the 40-yd distance. The clock stopped when the subjects ran through 2 timing sensors that were positioned on either side of the finish line and mounted on tripods that faced each other approximately 2 m apart. Subjects performed 3 test trials that were recorded to the nearest one-hundredth of a second using an electronic timer. The fastest trial for each subject was used for statistical analyses.

Statistical Analyses

Data analyses were performed using the Statistical Package for Social Sciences (SPSS version 6.0 for Windows). Comparison of mean scores for all tests was made using a 1-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) follow-up test. Intraclass reliability coefficients were computed for each test using ANOVA. Descriptive statistics were computed for each test and normative scores for each of the deciles and quartiles were determined. A Pearson product moment correlation was computed between the T-test and the each of the other tests, followed by the computation of partial correlations to obtain estimates of criterion validity. Regression analysis was conducted to determine which tests were the best predictors of the T-test performance. Discriminant analysis was performed to determine whether the T-test could be used to differentiate between individuals of low and high levels of sport participation. The α level for all statistical tests was established at $p \leq 0.05$.

Results

Mean scores of all tests for female and male subjects are presented in Table 1a,b. For all tests, men scored significantly better than women ($p < 0.05$). Differences were also tested between the levels of sport participation groups. For the women and men who performed the T-test, groups G1, G2, and G3 were significantly different ($p < 0.05$) from one another, with G3 having the best scores.

The intraclass reliabilities for 1-, 2-, and 3-trial measurement protocols were computed (Table 2). The reliability coefficient (R) for the T-test was found to be 0.98 across 3 trials. The reliability changed very little when administering 1, 2, or 3 trials. This indicates that administering 1 trial of the T-test is reliable.

Pearson product moment correlations were computed independently between all tests for both women (Table 3a) and men (Table 3b). The T-test was significantly correlated to all other tests for both women and men ($p < 0.05$). The largest zero-order correlation was

Table 1. Mean scores (± *SD*) for the T-test, hexagon test, 40-yd dash, and vertical jump in female and male subjects.

Group	*n*	T-test (s)	Hexagon test (s)	40-yd dash (s)	Vertical jump (cm)
Female subjects					
Low sport (G1)	44	13.55 ± 1.33	14.31 ± 1.92	6.34 ± 0.48	35.90 ± 9.24
Recreational sport (G2)	52	12.52 ± 0.90*	13.21 ± 1.68	5.81 ± 0.43*	39.00 ± 7.83
College athletes (G3)	56	10.94 ± 0.60*†	12.87 ± 1.48*†	5.54 ± 0.37*†	46.30 ± 8.74*†
Male subjects					
Low sport (G1)	47	11.20 ± 0.80	14.20 ± 1.93	5.12 ± 0.29	52.74 ± 12.75
Recreational sport (G2)	58	10.49 ± 0.89*	12.33 ± 1.47	4.99 ± 0.29	62.07 ± 11.82
College athletes (G3)	47	9.94 ± 0.50*†	12.29 ± 1.39*†	4.98 ± 0.32*	63.34 ± 11.17*†

* G2 or G3 is significantly different ($p < 0.05$) from G1.
† G2 and G3 are significantly different ($p < 0.05$) from each other.

Table 2. Intraclass reliability for the T-test, hexagon test, 40-yd dash, and vertical jump.

Test	*R* (1-trial)	*R* (2-trial)	*R* (3-trial)
T-test	0.94	0.97	0.98
Hexagon test	0.86	0.94	0.95
40-yd dash	0.89	0.95	0.96
Vertical jump	0.99	0.99	1.00

Table 3. Intercorrelation coefficients (*r*) between tests for female and male subjects.

Variable	Vertical jump	40-yd dash	Hexagon test
Female subjects			
Vertical jump	—	—	—
40-yd dash	−0.55*	—	—
Hexagon test	−0.22*	0.40*	—
T-test	−0.55*	0.73*	0.48*
Male subjects			
Vertical jump	—	—	—
40-yd dash	−0.29	—	—
Hexagon test	−0.27	0.24	—
T-test	−0.49*	0.55*	0.42*

* $p < 0.05$, 2-tailed.

between the T-test and the 40-yd dash for both women and men. Correlations coefficients between the T-test and the 40-yd dash were 0.73 and 0.55 for the women and men, respectively ($p < 0.05$) (Figure 2a,b). The correlation coefficients for the T-test and vertical jump for women and men were $r = 0.55$ and $r = 0.49$ ($p < 0.05$) (Figure 3a,b). Correlation coefficients for the T-test and hexagon test for women and men were $r = 0.48$ and $r = 0.42$ ($p < 0.05$) (Figure 4a,b).

Stepwise multiple regression was performed to determine the relative strength of each test as a predictor of T-test performance. The multiple correlation for women was 0.79 ($r^2 = 0.62$), which indicates that 62% of the variability of the T-test can be predicted from scores obtained from the other 3 tests. The 40-yd dash ($\beta = 0.58$) was also the strongest predictor of T-test scores for women, followed by the vertical jump test ($\beta = -0.23$) and hexagon test ($\beta = 0.21$). The multiple correlation for men was 0.69 ($r^2 = 0.48$), which indicates that 48% of the variability of the T-test can be predicted from scores obtained on the remaining 3 tests. The strongest predictor was the 40-yd dash ($\beta = 0.40$), followed by the vertical jump test ($\beta = -0.30$) and hexagon test ($\beta = 0.25$).

The computed partial correlations indicate the common variability between the T-test and each of the other tests independently while holding all other test scores constant. This statistic may be used to indicate the degree of criterion-related validity of the T-test as a measure of agility, leg power, and leg speed. The partial correlations for women and men are presented in Table 4. The highest partial correlation was observed between the T-test and the 40-yd dash for both women ($r_{[T,40.VJ,Hex]} = 0.57$) and men ($r_{[T,40.VJ,Hex]} = 0.46$). These values indicate that for women 32% and for men 21% of the variability of a T-test score is related to leg speed when controlling for agility and leg power. The partial correlations of the vertical jump (VJ) and hexagon (Hex) tests with the T-test for women were $r_{(T,VJ.40,Hex)} = -0.11$ and $r_{(T,Hex.VJ,40)} = 0.31$, respectively. The partial correlations of the vertical jump and hexagon tests with the T-test for men were $r_{(T,VJ.40,HEX)} = -0.36$ and $r_{(T,HEX.VJ,40)} = 0.31$, respectively.

Normative tables displaying decile and quartile scores for women and men for all tests are presented in Table 5a,b. These values were computed from data collapsed across the 3 levels of sport participation groups. This procedure was necessary because of insufficient sample sizes in each level of sport participation by sex cohort.

Discriminant analysis was conducted to determine

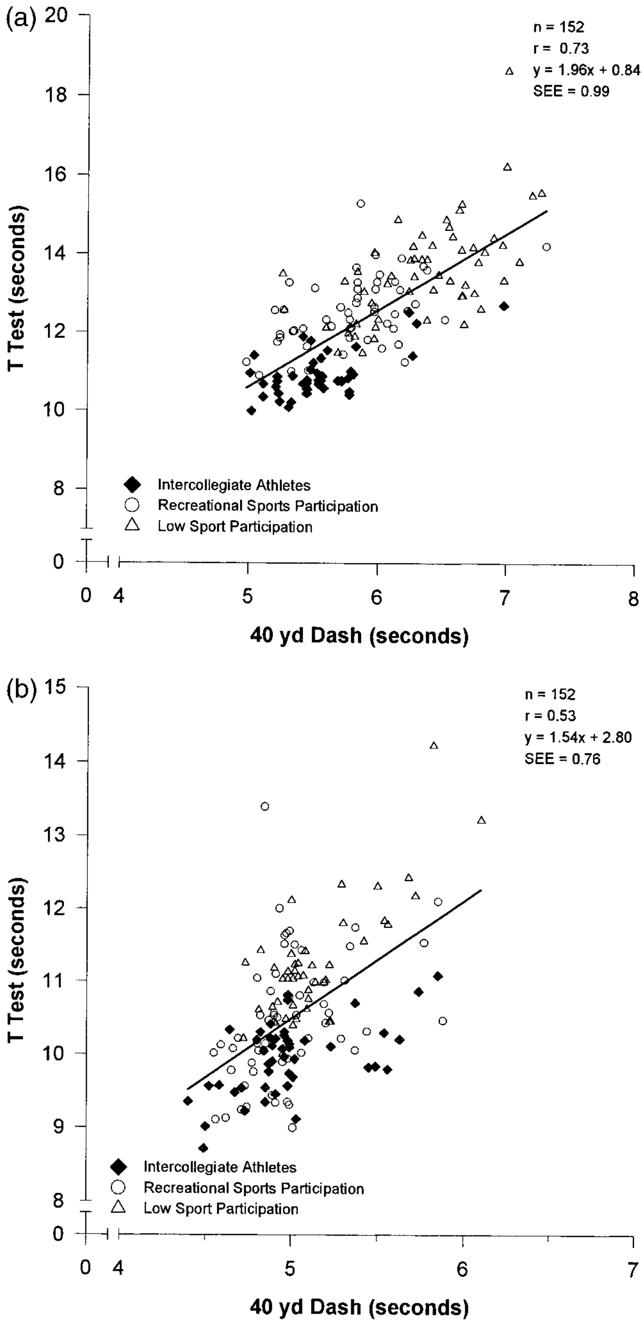

Figure 2. (A) Relationship between 40-yd dash times and the T-test times for women. (B) Relationship between the 40-yd dash times and the T-test times for men.

whether scores from the T-test could successfully predict level of sport participation group membership. For women, the correlation between the T-test and level of sport participation classification was 0.72 ($r^2 = 0.52$). This indicates that 52% of the variability in level of sport participation classification can be predicted by an individual's score on the T-test. For men, the correlation between T-test scores and level of sport participation group membership was 0.55 ($r^2 = 0.30$). This value indicates that 30% of the variability in level of sport participation classification can be predicted from an individual's score on the T-test. Level of sport participation groups were found to be significantly different from each other for both women ($F[2,149] = 80.91$; $p < 0.05$) and men ($F[2,149] = 32.16$; $p < 0.05$). Tukey HSD tests were performed on differences between means of each level of sport participation group for both women and men. All groups were found to be significantly different from each other for both women and men ($p < 0.05$).

Discussion

A primary purpose of this study was to evaluate the reliability and validity of the T-test as a measure of leg speed, leg power, and agility. The reliability of the T-test measurement protocol as described by Semenick (11) was found to be high across 3 measurement trials. Moreover, estimates of reliability for 1- and 2-trial protocols indicate that these measurement protocols are also reliable, suggesting that only a single test trial is required to obtain a true score on the T-test. Although estimating the reliabilities of the hexagon, vertical jump, and 40-yd dash tests was not a primary goal of this study, it appears from the data that only a single measurement trial is required of each of these tests to achieve satisfactory reliability as well.

The validity of the T-test as an independent measure of agility, leg speed, and leg power was examined by computing partial correlations. Of these 3 physical characteristics, leg speed had the highest partial correlation with the T-test and, therefore, the highest validity. Although the T-test is defined as primarily a measure of agility, it is not surprising that leg speed contributes substantially to the variability in T-test scores. It seems reasonable to assume that how fast an individual can sprint, shuffle, or back pedal would be determined primarily by leg speed.

Although there is no consensus "gold standard" measure of agility, the hexagon test was selected as the criterion measure, because it purportedly measures quickness when changing direction over a relatively short distance (9). The United States Tennis Association, for example, has used the hexagon test for assessing the agility of their athletes. They have found it to be a valid predictor of tennis performance, despite the fact that tennis players are required to move across areas that are much larger than the hexagon test area (9).

Although in this investigation the hexagon test was found to be significantly correlated to the T-test, the partial correlation (when controlling for leg speed and power) was relatively low, indicating insufficient validity to classify the T-test as a measure of agility. Therefore, the belief that the T-test is a measure of agility was not supported. One caveat to this conclusion is that perhaps the hexagon test is not the most valid criterion measure of agility. An alternative test that has

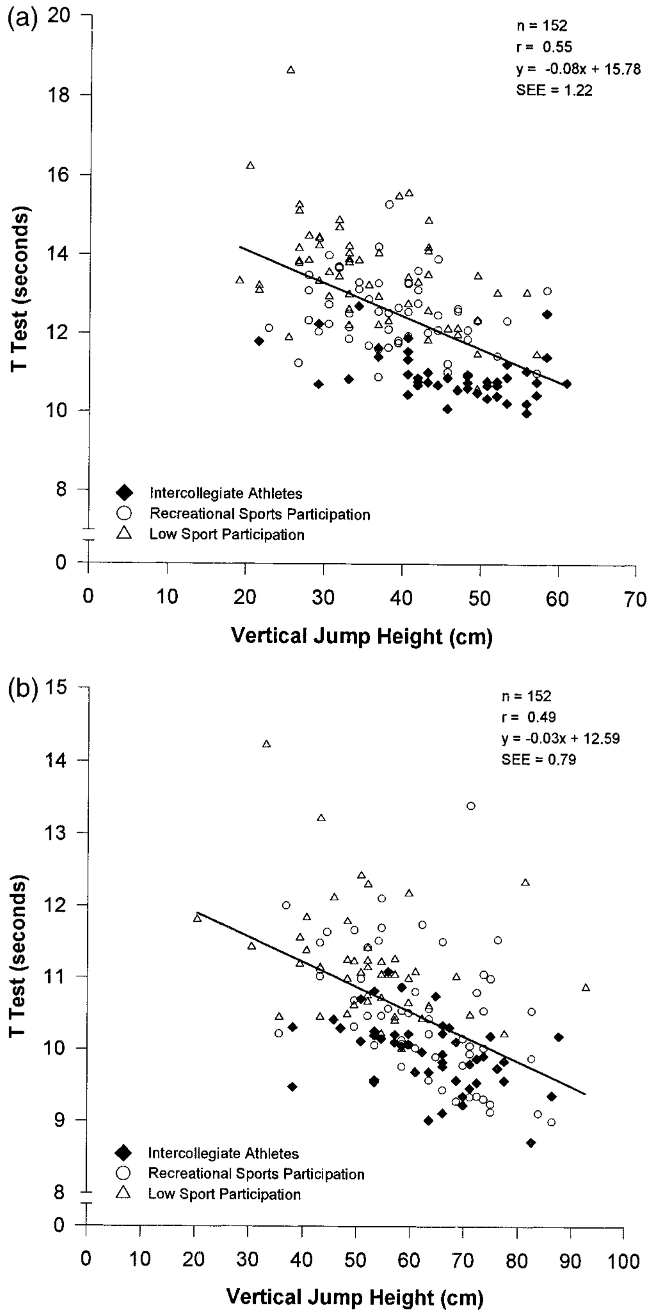

Figure 3. (A) Relationship between vertical jump heights and the T-test times for women. (B) Relationship between vertical jump heights and the T-test times for men.

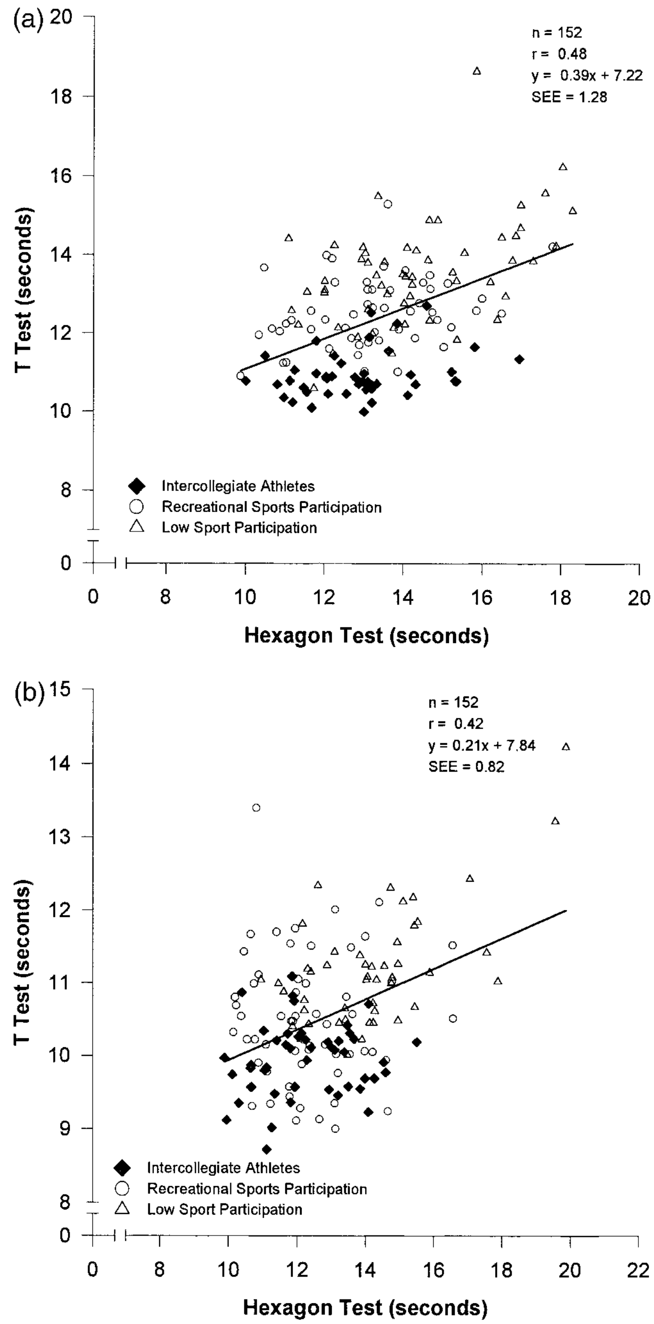

Figure 4. (A) Relationship between hexagon test times and T-test times in women. (B) Relationship between hexagon test times and T-test times in men.

been used to measure agility is the Edgren Side Step Test (12). This agility test requires the performer to shuffle laterally between designated lines as quickly as possible for 10 seconds (12). However, little is known regarding the reliability and validity of this test.

The vertical jump test was also found to have low validity as a predictor of performance on the T-test. There are at least 2 possible interpretations of this finding. First, it is possible that leg power is indeed less important than leg speed for T-test performance and that leg power does not contribute substantially to T-

Table 4. Partial correlations between T-test and hexagon test, 40-yd dash, and vertical jump.

Test	Partial *r*	
	Female subjects	Male subjects
40-yd dash	0.57*	0.46*
Hexagon test	0.31*	0.31*
Vertical jump	0.11	0.36*

* $p < 0.05$, 2-tailed.

Table 5. Deciles and quartiles for female and male subjects.

Measure	T-test (s)	Hexagon (s)	40-yd dash (s)	Vertical jump (cm)
Female subjects				
Deciles				
90	10.69	11.17	5.24	53.34
80	10.92	12.01	5.44	48.76
70	11.48	12.53	5.56	45.72
60	11.99	13.02	5.77	41.91
50	12.34	13.22	5.84	40.64
40	12.73	13.71	5.99	36.83
30	13.24	14.23	6.23	33.02
20	13.69	14.94	6.40	30.48
10	14.23	16.34	6.72	27.94
Quartiles				
75	11.23	12.20	5.48	46.99
50	12.34	13.22	5.84	40.64
25	13.41	14.62	6.29	33.02
Male subjects				
Deciles				
90	9.45	10.68	4.71	74.93
80	9.82	11.32	4.82	71.12
70	10.06	11.87	4.89	66.04
60	10.22	12.14	4.95	62.23
50	10.44	12.58	4.98	58.42
40	10.64	13.20	5.01	54.86
30	10.99	13.84	5.08	53.34
20	11.22	14.25	5.22	49.53
10	11.69	14.96	5.50	43.18
Quartiles				
75	9.95	11.74	4.86	69.52
50	10.44	12.58	4.98	58.42
25	11.07	14.05	5.14	52.07

test performance. Second, it is possible, as with the hexagon test, that the vertical jump test is not the best criterion measure of leg power. Perhaps another test would be a more valid indicator of leg power. The Margaria-Kalamen stair test, for example, is a measure of leg power that requires sprinting up stairs (7). The primary difference between the Margaria-Kalamen stair test and the vertical jump test is that the former requires static leg power, whereas the latter requires dynamic leg power. Future research could examine the validity of the T-test as a predictor of dynamic leg power as measured by the Margaria-Kalamen stair test.

Although the T-test is apparently a more valid measure of leg speed than either leg power or agility, correlation and regression analyses indicate that for both men and women the T-test involves a combination of leg speed, leg power, and agility for performance. Surprisingly, however, these 3 physical characteristics predict less than 50% of variability in T-test performance for men and only 62% of the variability in women. The remaining variability in T-test scores is unaccounted for by these variables. It is possible that the T-test measures either other known physical characteristics, such as dynamic balance, or physical characteristics that have yet to be defined.

Because of the apparent contribution of many physical characteristics to T-test performance, the test cannot be considered an indicator of any one characteristic alone. Instead, test performance should be interpreted as an indicator of a unique set of physical characteristics that may represent general athletic ability. This finding may be important for coaches, since many types of sporting activities require a combination of several physical performance components. Future research should examine the relationship of T-test scores to various sport-specific performance measures.

The T-test was found to be a valid predictor of level of sport participation in this investigation, because it discriminates among intercollegiate athletes, recreational athletes, and nonathletes. From this study, it is not known whether the T-test can differentiate among athletes in the same sport or different sports. All subjects were classified into 1 of 3 groups based on the type and frequency of sport participation. Discriminant analysis was then used to determine whether the T-test was correlated with level of sport participation. For men, 30% of the variability in group membership can be predicted using the T-test score alone, whereas 52% of the variability can be predicted for women. Although these values are moderate, it is likely that a measure of sport performance that is more sensitive to level of ability within a given sport would yield higher correlations. This research should be undertaken to further explore the potential of the T-test for identifying talented athletes.

A secondary purpose of this study was to generate standardized normative values for the T-test. Decile and quartile scores were established for all classifications of groups. The availability of such tables can be used as a basis to compare and evaluate times on a T-test. This is a valuable tool, because meaningful interpretation can then be brought to a T-test score.

Practical Applications

The T-test appears to be a reliable and valid measure of leg speed and secondarily of leg power and agility. However, the relationship to leg power and agility is moderate to low. Based on the results of this study, the test can discriminate between low and high levels of sport participation. Coaches involved with ground-based sports, such as football, basketball, soccer, and volleyball, may benefit from incorporating the T-test as a field test to assess lower extremity movement skills and potential for participation in these activities. The test may also be of value to conditioning specialists who wish to assess improvement in sport-specific fitness as a result of participating in a training program. Selection of an appropriate field test for a sport or other physical activity should center on the specificity principle and demands of the sport or activity to be evaluated.

References

1. ALTUG, Z., T. ALTUG, AND A. ALTUG. A test selection guide for assessing and evaluating. *NSCA J.* 9(3):62–66. 1987.
2. CHU, D., AND A. VERMEIL. The rationale for field testing. *NSCA J.* 5(2):35–36. 1983.
3. FOX, E.L., AND D.K. MATHEWS. *Interval Training: Conditioning for Sports and General Fitness.* Philadelphia: W. B. Saunders, 1974.
4. HARMAN, E., M. ROSENSTEIN, P. FRYKMAN, AND R. ROSENSTEIN. The effects of arms and counter-movement on vertical jumping. *Med. Sci. Sport Exerc.* 22:825–833. 1990.
5. HENDRICK, A., AND J.C. ANDERSON. The vertical jump: A review of the literature and a team case study. *Strength Cond.* 18: 7–12. 1996.
6. HOOLAHAN, P. Agility. *NSCA J.* 12(3):22–24. 1990.
7. MARGARIA, R., I. AGHEMO, AND E. ROVELLI. Measurement of muscular power (anaerobic) in man. *J. Appl. Physiol.* 21:1662–1664. 1966.
8. ROETERT, E.P., G.E. GARRETT, S.W. BRAN, AND D.N. CAMAIONE. Performance profiles of nationally ranked junior tennis players. *J. Appl. Sport Sci. Res.* 6:225–230. 1992.
9. ROETERT, E.P., P.A. PIORKOWSKI, R.B. WOODS, AND S.W. BROWN. Establishing percentiles for junior tennis players based on physical fitness testing results. *Clin. Sports Med.* 14:1–5. 1995.
10. SEMENICK, D. Anaerobic testing: practical applications. *NSCA J.* 6(5):44–73. 1984.
11. SEMENICK, D. The T-test. *NSCA J.* 12(1):36–37. 1990.
12. SEMENICK, D. Testing protocols and procedures. In: *Essentials of Strength Training and Conditioning*. Champaign, IL: Human Kinetics, 1994. pp. 258–273.