Relationship between agility T-*test* and physical fitness measures as indicators of performance in elite adolescent handball players

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Annotation.

The purpose of this research was to determine the relationships between performance of agility T-*test* and selected physical fitness measures as indicators of performance in elite adolescent handball players. These measures included, explosive power of the lower limbs (PP_{LL}) force-velocity test, jumping, sprinting abilities (velocities of the first step VS and the first 5 m V5). Performance of agility T-*test* was closely related to with the force-velocity test to PP_{LL}. Significant relationships were observed between total time of agility T-*test* and (SJ) and (CMJ). Agility T-*test* is also positively related to (VS) and (V5). In conclusion, the agility T-*test* is much correlated with the majority of specific qualities determining the activity of handball, and could be used to evaluate the familiar potential athletic performances in adolescent handball players.

Хермаси Сухаил, Фатхлун Мурад, Щелли Мохамед Сухаил, Бен Себаа Абделкрим. Взаимосвязь между ловкостью двигательных действии (Т-*test*) и некоторыми показателями физической подготовленности у юных гандболистов. Целью этого исследования было определить отношения между оценкой ловкости двигательных действии (опрелена Т-*test*) и некоторыми показателями физической подготовленности у юных гандболистов. Эти показатели включают в себя, взрывная сила нижней конечности (PP_{LL}) определенна оценкой скоростной силы, прыжками вверх (плиометрические SJ и CMJ), спринтерскими способностями (скорости бега на первом шаге VS и на 5-ом шаге V5). Показатели ловкости (Т-*test*) тесно связаны со скоростно-силовыми результатами на (PP_{LL}). Были замечены существенные взаимоотношения между общим временим (Т-*test*) с результатами (SJ) и (CMJ). Оценка ловкости (Т-*test*) также положительно относится к (VS) и (V5). В заключении, ловкость двигательных действий (Т-*test*) значительно коррелируется с большинством особых качеств, определяющие игровую деятельность гандбола, и может использоваться как оценка специфического потенциала физических возможностей у юных гандболистов.

Хермасі Сухан, Фатхлун Мурад, Щеллі Мохамед Сухан, Бен Себа Абделкрім. Взаємозв'язок між спритністю рухових дій (Т-test) і деякими показниками фізичної підготовленості у юних гандболістів. Метою цього дослідження було визначити відносини між оцінкою спритності рухових дії (попрілості t-test) і деякими показниками фізичної підготовленості у юних гандболістів. Ці показники включають у себе, вибухову силу нижньої кінцівки (ppll) визначену оцінкою швидкісної сили, стрибками вгору (плиометрическом sj і cmj), спринтерськими здібностями (швидкості бігу на першому кроці vs і на 5-му кроці v5). Показники спритності (t-test) тісно пов'язані зі швидкісно-силовими результатами на (ppll). Були помічені істотні взаємовідносини між загальним часом (t-test) з результатами (sj) і (cmj). Оцінка спритності (t-test) також позитивно відноситься до (vs) і (v5). У висновку, спритність рухових дій (t-test) значно корелюється з більшістю особливих якостей, що визначають ігрову діяльність гандболу, і можуть використовуватися як оцінка специфічного потенціалу фізичних можливостей у юних гандболістів.

Keywords:

handball, agility, power, jumping, acceleration.

гандбол, ловкость двигательных действия, сила, прыжки, ускорение.

гандбол, спритність рухових дій, сила, стрибки, прискорення.

Introduction.

The basic movement pattern of handball requires the player to perform many diverse activities such as jogging, sprinting, and jumping. In this type of sport, players are required to accelerate, decelerate, and change direction throughout the game in response to a stimulus, such as an opposing player's movements or the movement of the ball (15, 2, 9). Agility has traditionally been thought of as simply the ability to change direction quickly. Similarly, tests of agility have been shown to distinguish between playing standards in Australian rules football (9) and netball, (17) as well as between different age groups and standards of play in rugby league (21, 5). An understanding of the various definitions of agility is important when considering the merits of different protocols.

The traditional definition of the ability to rapidly change direction has been redefined as change of direction speed (19, 5, 6) or planned agility (4) More recently it has been suggested that agility contains both a change of direction movement and a perceptual and decision making component, since changes of direction and speed are often performed in response to an opponent's actions (4). Highly skilled players produced significantly faster movement times and decision times than less skilled players, the latter defined as the time between the instant of ball release from the video display to the instant of foot plant to change direction. Other authors have incorporated sport-specific stimuli into reactive agility protocols (21, 6, 4, 7). Construct validity has been supported by the ability of these reactive agility tests to distinguish between team players of differing standards (21, 6, 4, 7). Currently, the association between different physical components of agility is not well described. The aim of the current study was to assess the association of a new agility test that used commercially available timing gates to measure straight acceleration as well as reactive agility while running forward, the most used test to assess agility was the T-test (8, 12, 13). It is well accepted as a standard test of agility, it is simple to administer and requires minimal equipment and preparation. The T-test involves speed with four directional changes. To address the need for a more specific agility test with change of direction speed, we propose a modified version of the agility T-test. In this new version, we maintained the same nature of displacement but we reduced the total distance covered (20 m).

The purpose of this study was therefore evaluated and to examine its relationship with leg power of lower limb, vertical jumping ability and sprint performance. We hypothesised, like the T-test it would have a stronger relationship with explosive power and jumping and speed performance.

The aim and methodology of the research.

This study was designed to first examine the possible association between the agility T-*test* and abilities elicited when performing as explosive power of lower limbs running velocity of first step, 5-m sprint, squat and counter movement jump tests. All participants completed two familiarization trials in the two weeks prior to definitive testing. On each occasion, the protocol included a force-velocity test to evaluate the muscle power of lower limb. The countermovement jumps (CMJ) and squat jump (SJ) were determined to assess leg power. Testing sessions were carried out at the same time of the day, and under the same experimental conditions, at least 3 days after the most recent competition. Players maintained their normal intake of food and fluids during the trial. However, they abstained from physical exercise for one day before testing, drank no caffeine-containing beverages in the four hours preceding testing, and ate no food for two hours before testing. Verbal encouragement ensured maximal effort throughout the tests of muscle performance.

Subjects:

Subjects were told that they were free to withdraw from the trial without penalty at any time. Our investigation was focused on twenty adolescent male handball players (age: 17.1 ± 0.8 years, body mass: 89.72 ± 7.13 kg, height: 1.89 ± 6.3 m, percentage body fat: 13.1 ± 1.1 %), all drawn from a single team, their mean handball experience was 7.2 ± 0.3 years. All subjects were examined by the team physician prior to the study, with a particular focus on orthopedic and other conditions that might preclude resistance training, and all were found to be in good health. All procedures were approved by the Institutional Review Committee for the ethical use of human subjects, according to current national laws and regulations. Participants gave written informed consent after receiving both a verbal and a written explanation of the experimental design and its potential risks.

Testing procedures.

Agility T-test

The Agility T-*test* (Figure 1) was performed using the same directives protocol of the T-*test*, except that the total distance covered and measures of intercone distance were modified. The number of directional changes were maintained the same. Subjects covered a total distance of 20 m on the modified T-test instead of 36.56 m on the T-test. Criteria for accepted test trials were the same of those used on the T-test. The recorded score for this test was the better of two last trials (test–retest session) (18).

The force–velocity test:

Force-velocity measurements on the legs were performed on a standard Monark cycle ergometer (model 894 E, Monark Exercise AB, Vansbro, Sweden). The instantaneous peak velocity was used to calculate the maximal anaerobic power (MAP) for each braking force. The maximal velocity (Vmax) was defined as the greatest velocity attained without external loading. The peak power (PP) was defined as the greatest power output calculated for the different braking forces. The subject was judged to have attained the braking force corresponding to his maximal anaerobic power if an additional load induced a decrease in power output. Parabolic relationships were obtained only if it was observed that a decline of PP over two successive braking forces was evident. The parameters measured with the force velocity test were: PP expressed in Watts (W) and W/kg of total body mass, maximal force (Fmax) and maximal velocity (Vmax). The relationship between braking force (F) and velocity (V) can be expressed by the following equation:

$$V = b - a \times F$$

$$V = V_0 - V_0 \frac{F}{F_0} = V_0 \left(1 - \frac{F}{F_0}\right)$$

Where V_0 is the intercept with the velocity axis (i.e., the theoretical maximal velocity for a braking force of zero and F_0 is the intercept with the force axis i.e., the theoretical maximal braking force corresponding to a velocity of zero) (23). A valid force-velocity test requires short all-out sprints of approximately 7 s duration, using a suitable sequence of ergometer braking forces (1). Subjects were verbally encouraged to reach their maximal pedalling rate as quickly as possible. The peak velocity was recorded, and was used to calculate the force-velocity relationships.

Squat Jump (SJ) and Countermovement Jump (CMJ)

Characteristics of the SJ and the CMJ were determined by a force platform (Quattro Jump, version 1.04; Kistler Instrumente AG, Winterthur, Switzerland) and jump height was determined as the center of mass displacement, calculated from the recorded force and body mass. The subjects were instructured to keep their legs absolutely straight throughout the flight phase. The subjects began the SJ at a 90° knee angle and performed a vertical jump by pushing upward on their legs, avoiding any downward movement. For the CMJ, subjects began from an upright position, making a downward movement to a 90° knee angle and simultaneously beginning the push-off phase. The best of 3 jumps was recorded for each test.

Sprint Running Performance.

After familiarization, subjects performed a maximal 5-m sprint on an outdoor tartan surface. Body displacement was filmed by cameras (Sony Handycam, DCR-PC105E; 25 frames per second) placed at the 5-m mark, perpendicularly to the running lane. Participants performed 2 trials, separated by an interval of at least 5 min, with the fastest trial being recorded. The software (Regavi &Regressi; Micrelec, Coulommiers, France) converted measurements of hip displacement to the corresponding velocities of the first step (VS) and the first 5 m (V5). The reliability of the camera and the data processing software has been previously described (3). In actual play, a sprint usually commences with a standing or jogging start. Preliminary trials have compared 3 types of sprints (standing, jogging and crouching) in 12 players, according to a random block design. We adopted a crouching start with starting blocks for our definitive tests because of its greater reliability (Interclass Correlation Coefficient [ICC] of 0.86, in contrast to the jogging and standing starts where ICC are 0.81 and 0.71, respectively).

Statistical Analysis.

Data are reported as mean ± standard deviation (SD).

Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk W test. Pearson's product moment correlations and linear regression analysis were used to examine the relationships between the total time of agility T-*test* was and the various physical tests related to handball. A comparison between variable means was performed using paired t-tests. Significance was assumed at 5% ($p \leq 0.05$). The reliability of track running velocity and jumping ability were assessed using intraclass correlation coefficients (Table 1). Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) (version 16.0 software for windows).

Analysis and discussion of research results.

The total time of agility T-*test* was 6, 10 ± 0, 35 second (mean ± SD). Absolute values for the (PP_{LL}) force-velocity test, first step (VS) and the first 5 m (V5) were 634.37 ± 112.35 watt; 3.73 ± 0.38 $m \cdot s^{-1}$ and 7. 23 ± 0.82 $m \cdot s^{-1}$, respectively (Table 2). The ICC for first step (VS) and the first 5 m (V5) ranged from 0. 92 to 0.97. Whereas, the ICC for CMJ height was from 0.96 to 0.99 and the ICC for SJ was similar (ICC = 0.98)

The total time for of agility T-*test* is related to the absolute peak power of the lower limbs, calculated from the force-velocity test ($p < 0.001$; Table 3, Figure 2). Moreover, performance of agility T-*test* is closely related to the SJ and CMJ ($p < 0.01$; Table 3 Figure 3). Our results also showed that running accelerations of (VS) and the first 5 m (V5) are related to the total time for of agility T-*test* ($p < 0.01$; Table 3 and Figure 4).

Analysis and discussion of research results.

The present study shows the total time for of agility T-*test* test is significantly associated with the majority of athletic qualities related to handball, such as the explosive muscular power of lower limbs, vertical jump performance, and acceleration. The main finding of the present study was that the performance of agility T-*test* and leg power were closely related. Furthermore, total time for of agility T-*test* had a moderately strong relationship to the first step (VS) and the first 5 m (V5).

The present study reported a very large correlation between lower body anaerobic power, as measured by the force-velocity test, and performance in agility T-*test* ($r = – 0.80$; $n = 20$). To our knowledge, this is the first

Table 1

Intraclass correlation coefficients showing the reliability of various measures of jump tests, track running velocities (20).

	ICC	90% CI
Jump tests		
Squat Jump	0.96	0.91 to 0.98
Counter Movement Jump	0.97	0.93 to 0.98
Track running velocity		
Velocity for first step after start	0.91	0.93 to 0.98
Velocity over first 5 m	0.92	0.91 to 0.97

Table 2

Results of all parameters measurements, values are given as mean ± SD, (n = 22).

	Mean	± SD
Total times agility T-*test* (s)	6.10	0.35
Power (w)	634.37	112,35
SJ (cm)	41.35	5.15
CMJ (cm)	46.42	7.38
VS ($m \cdot s^{-1}$)	3.73	0.65
V5 ($m \cdot s^{-1}$)	7.23	1.40

Table 3

Coefficients of correlation between total time of agility T-test and measures of all parameters (n = 20 for all relationships).

	Total times agility T-*test* (s)
Power (w)	-0.80 (0.73-0.84, ± 2.1) ***
SJ (cm)	- 0.75 (0.70-0.78, ± 2.2) ***
CMJ (cm)	- 0.66 (0.54-0.69, ± 3,1) **
VS ($m \cdot s^{-1}$)	0.76 (0.69-0.80, ± 2.4) **
V5 ($m \cdot s^{-1}$)	0.63 (0.51-0.69, ± 2.1) **

Correlation coefficients, with the 90% confidence limits and the estimated error of the estimate (expressed as a percentage of the predicted variable) in parentheses.

*p< 0.05; **p <0.01; ***p <0.001

investigation to demonstrate the substantial relationship of lower limb force-velocity to the agility Test, in addition to various physical qualities of performance related to handball. In agreement with our hypothesis, the total time agility Test was found to be significantly associated with all athletic qualities measured that relate to performance in handball. This study is also likely to be the first investigation to demonstrate a substantial relationship between agility T-*test* and physical qualities related of handball players.

Performance of force/velocity test of lower Limb:

Cycle ergometer force-velocity tests are a little demanding for field-testing, and for handball players, are a less familiar exercise than jumping. Muscle coordination can influence maximal power output and thus underestimation of performance. Nevertheless, force-velocity tests are helpful in confirming the above reasoning. The power calculated from such exercise reflects largely concentric muscle contraction and is thus analogous to the SJ, despite activation of different muscle groups. The cycle ergometer assessment of absolute leg power is an effective predictor of both velocities and accelerations over a short distance and time. Our findings thus support the grading of short-distance displacement as agility test performance, by the force-velocity test in laboratory and field situations, respectively.

There are limited published data investigating the relationship of agility T-*test* and muscle power. Nevertheless, force-velocity tests are helpful in confirming the above reasoning. Our results agree with these findings, showing strong correlations between total time and agility T-test and peak power of lower limb, offering at least an equally reliable estimate of short-distance sprinting ability in handball players. The power calculated from such exercise reflects largely concentric muscle contraction and it is thus similar to the explosive action, despite activation of different muscle groups (14). The agility test focuses both on the capacity to carry out intermittent exercise leading to a maximal / or near maximal activation of the anaerobic system, and the capacity of an individual's ability to recover from repeated exercise with a high contribution from the anaerobic system. (2) Our results indicate that the critical ability of handball players to change direction quickly and sustain a high velocity over a distance of 5m or less can be predicted in the laboratory by the power output achieved in a cycle ergometer force-velocity test.

Relationship between total time agility T-test, first step (VS) and the first 5 m (V5):

Acceleration and rapid changes in direction are inherent to both practice and competition in handball. Initial velocity and acceleration are important information for coaches, but the regular filming of players is hardly practical. The velocity over the first step (VS) showed a strong relationship to the total time of agility T-*test*. Empirical evidence demonstrates that this produces a biomechanical position where foot contact is far ahead of the hips (15). This creates a significant variation from the "pushing" position one strives for during an acceleration movement (10, 16). An athlete who would place his foot in this position while trying to accelerate on the ground would prematurely stand upright and take himself out of the optimal accelerating position.

Protocol design is likely to influence the level of association between different linear and agile movements, particularly whether straight sprints measure speed or acceleration and the complexity and demands of an agility

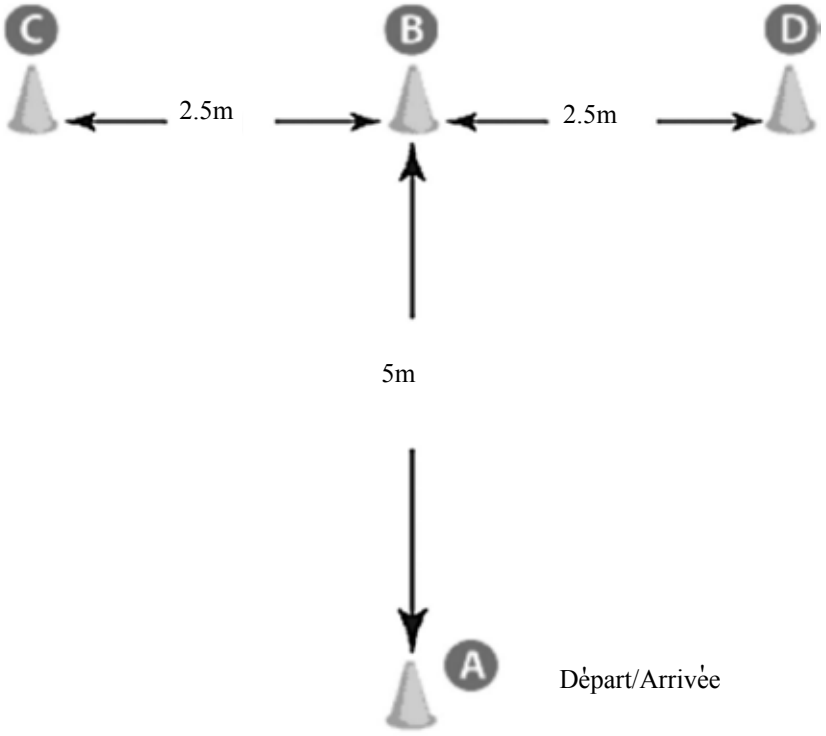

Figure 1 Modified agility T-test. Reprinted, bay permission of Sassi RH, Dardouri W, Yahmed MH, Gmada N, Mahfoudhi ME, Gharbi Z. Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. J Strength Cond Res. 2009 Sep; 23(6):1644-51.

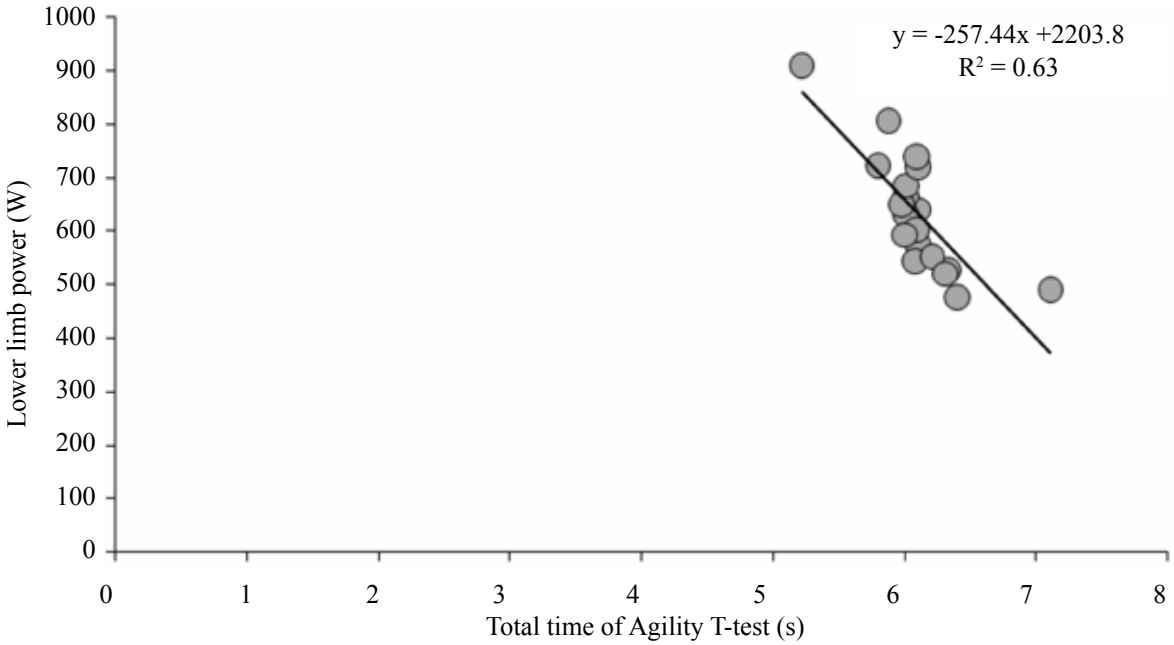

Figure 2: Relationships between total time of Agility Test-test and absolute lower limb peak power

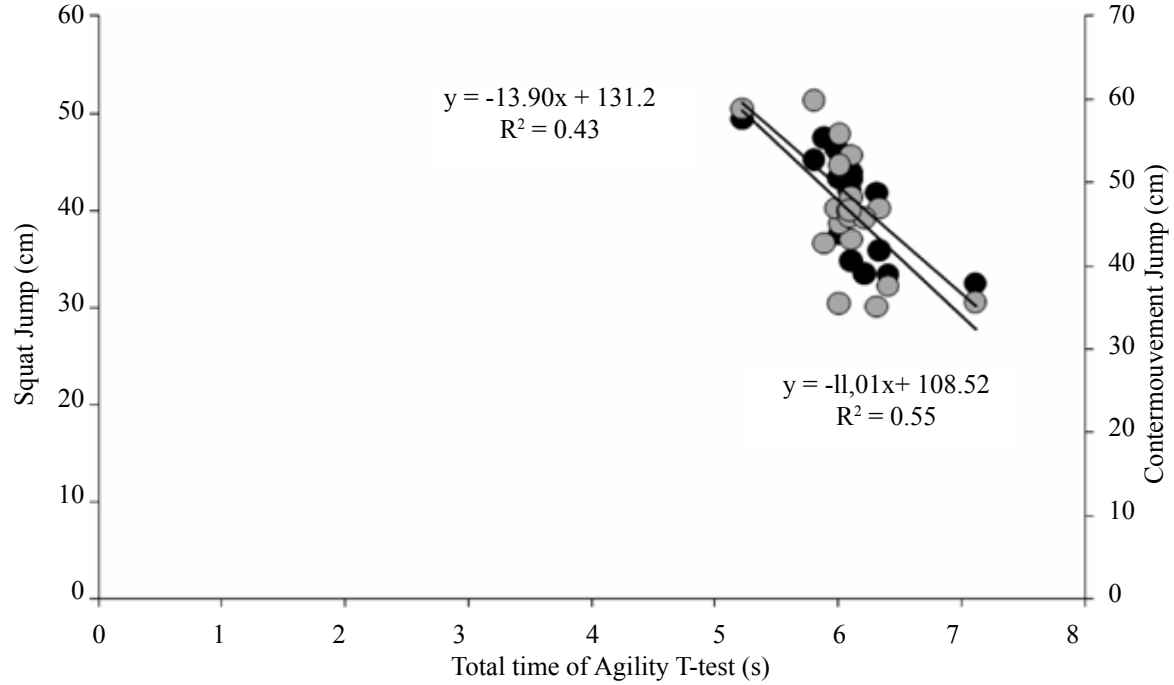

Figure 3: Relationship between the total time of Agility Test-test, Squat Jump (SJ) and counter movement jump (CMJ)

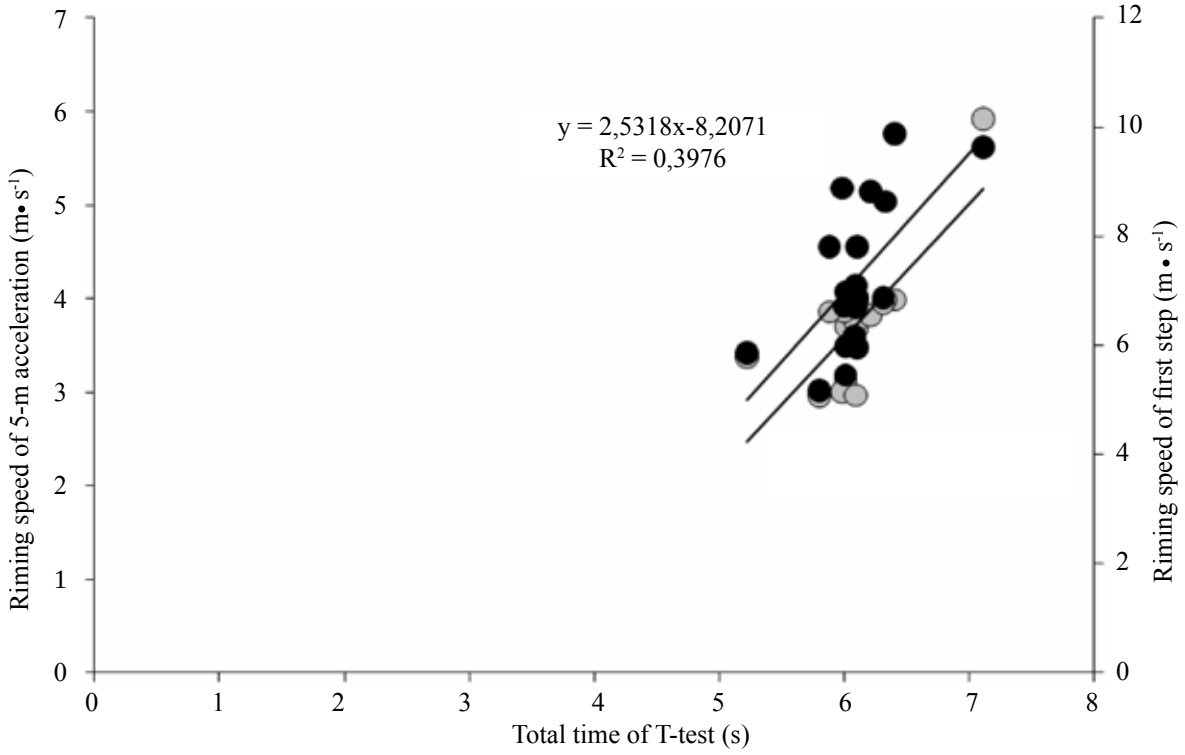

Figure 4: Relationship between the total time of Agility Test-test, running speed of first step and running speed of 5-m acceleration

test. Previous research has shown that the strength of the relationship between linear sprint speed and planned agility is reduced with greater changes in direction. In the current study, participants were required to perform a single agile movement with a moderate cutting angle while running forward, which can be considered a relatively simple agility task.

Peterson et al. (15) reported a significant correlation between T-test and acceleration (20-yard as split time of 40- yard) and sprint velocity (40-yard) Pauole et al. (16) reported low to moderate significant correlations ($p < 0.05$) between T-test for change of direction speed and a 40-yard sprint ($r = 0.73$ for women and $r = 0.55$ for men). Likewise, Little and Williams (11) reported a low significant correlation between agility (zigzag test, 20 m) and acceleration (10 m) and maximum speed (20 m). Nevertheless, Thomas and Nelson (22) indicate that T-test for change of direction they are specific or somewhat independent in nature with acceleration. Based on these results, it seems that change of direction speed and straight sprint were two specific determinant qualities on performance.

The reported relationships between agility test and both linear acceleration and planned agility are considerably stronger than has previously been reported for protocols utilizing a sport-specific stimulus. (21,4,7) Gabbett et al (8) found significant relationships between reactive agility and a number of planned agility tasks as well as linear sprinting; however, common variance was ≤34%, suggesting little generality in the different measures. Differences in the findings of the current study when compared with previous research might be the result of the protocol design (discussed above) or the stimulus used. Participants were required to react to a flashing light in the current study, a method that is being routinely used in an applied setting using commercially available timing gates.

Jumping performance:

The few studies that have used more sensitive measures, such as height and power developed during the jump task, have all reported stronger correlations with T test agility (18, 11, 24). Peterson et al. (15) reported a significant correlation between T-test and vertical jump (CMJ) in women but not in men. Similarly, Pauole et al. (16) reported low to moderate significant correlations ($p < 0.05$) between T-test for change of direction speed and a vertical jump ($r = 20.55$ for women and $r = 20.49$ for men). Young et al. (25) found low and non significant correlation between CMJ Similarly, Webb and Lander (24) reported a low and non significant correlation between the ‘‘L’’ run test for change of direction speed and vertical jump. In the women’s group, the common variances found between both MAT and FCMJ, and MAT and 10mSS, were 25% and 14%, respectively. Agility is a very complex concept that requires interactions of physiological and biomechanical components. In fact, the complex control motor and coordination of several muscle groups could contribute considerably to the change of direction speed performance (25).

Identifying the predictive ability of more sensitive kinetic jump measures with agility test performance requires further research. The various jumps are performed with rapid stretching and height velocity contarctions of the muscles in the lower extremities. This is similar to sprinting except that there is an increase in the vertical motion. The elastic properties of the muscles, with their stored energy, are necessary for maximal sprint performance (25). Furthermore, the elastic properties of the knee flexors and hip extensors to propel the body forward, and the capacity of these muscles to rapidly contract and produce the force needed to create velocity correlate well with 15 m sprint performance (22).These results of our study provide further evidence suggesting that the relative explosive leg power in either the CMJ or SJ is an important aspect of total time of agility T-*test*.

Summary and conclusions.

It is concluded that total time of agility T-*test* is significantly associated with the selected of athletic qualities related to handball, i.e., explosive muscular power of lower limbs, vertical jump performance and acceleration ability

Therefore, these results for top level handball players suggest that agility T-*test* is a unique fitness quality that is associated to several important physiological variables simultaneously. This finding is of great practical interest for coaches and fitness trainers and suggests that the agility T-*test* total time test may be considered a field test that is relevant to handball players and consequently maybe used in training prescription and talent identification. However, coaches and trainers were challenged to select the most appropriate

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