MODULE 2: Speed and Agility Assessments

UNIT 2.1 Generalities about the Evaluation of Change of Direction Speed and Agility

2.1.1 Introduction to Speed and Agility Assessments

The complexity of agility in athletes' distinct motor skills means the process of assessing agility is also complex. Therefore, taking into account everything presented in the previous courses, it is necessary to distinguish between agility testing and change of direction speed testing.

> The initial definitions of *agility* considered it to be the ability to change direction quickly (Bloomfield et al, 1994, Clarke, 1959, Mathews, 1973) but also as the ability to change direction quickly and appropriately (Barrow et al, 1971, Johnson et al, 1969). When it comes to defining agility, other authors have included the whole body in the change of direction, including the upper limbs (Baechle, 1994, Draper and Lancaster, 1985). (González De Los Reyes, 2012).

Using the term *quickness* which was defined as the multiplanar or multidirectional ability that combines acceleration, explosiveness and reactivity (Baker, 1999, Moreno, 1995) as a synonym for agility did not provide clarity on the topic. It must be noted that this concept does not involve the ability to decelerate or change direction at speed. Nonetheless, in literature it has been used synonymously with agility and exercises and tests have emerged from this (Baker, 1999, Moreno, 1995).

In addition to the above, the term *cutting* has been used as a reference to the change of direction during a movement of acceleration (Bernier, 2003, Besier et al, 2001, Colby, 2000) This term only takes into consideration the moment of change of direction in which the athlete's foot makes contact with the ground, applies force and generates the change of direction. Consequently, this term is included as part of the general concept of agility.

Young, James and Montgomery (2002) proposed a concept of agility that included perceptual and decision-making factors and, on the other hand, change of direction speed (which takes into account movement technique, linear acceleration speed and muscular qualities).

The above concept allowed Young et al. (2002) to distinguish between the term change of direction speed (COD), wherein no reaction to a stimulus is required, and agility, as a quick movement in reaction to a stimulus.

Keeping the previous statement in mind, change of direction speed would only specifically be assessed in the event of implementing a test where everything is known beforehand and which only includes one stimulus that indicates a reaction to it (known) and the subsequent movements' sequence.

A test with a known stimulus and a predetermined motor sequence would obtain data related to the time it took to complete a determined distance (moving speed), variable according to the test, which could include one or more changes of direction. On the other hand, the athlete's movement could also be analyzed. If gross technical errors are detected, corrective exercises could be provided.

Beyond this, we consider it important to present some tests that have been standardized and that make it possible to assess agility (although the correct term would be *change of direction speed*) of the lower limbs, without tactical movements to solve (no decision-making), without movable objects (ball) and without opponents.

This is how constitutive elements of change of direction speed (referred to as agility by its authors) could be analyzed:

- Acceleration ability.
- Deceleration ability.
- Dynamic stability and balance.
- Movement techniques (mainly change of direction).
- Braking, braking action.
- Change of direction speed.

Sheppard and Young (2006) have defined agility as a rapid whole-body movement with change of speed or direction in response to a stimulus. This definition takes into account cognitive components of visual scanning and decision-making, which contribute to an improvement in agility performance in sports (Abernathy et al., 2999, Chelladurai, 1976, Young et al. 2002), as well as physical performance involved in acceleration, deceleration and change of direction when avoiding an opponent, accelerations with change of direction in order to make contact with the ball or another player, or the start of a whole-body movement in response to a stimulus.

For these authors (Sheppard and Young, 2006), to be considered an agility task, the movement will not only involve change in speed or direction, but must also be an open skill, such as a reaction to a stimulus, in which there may be more than one movement.

Agility should be considered as the motor response to a stimulus, therefore tests to evaluate it should include stimulus, and from these, individuals should react and demonstrate their best change of direction speed (COD), as well as acceleration/deceleration included in the test. Thus, an agility test should include:

- Stimulus.
- Situation reading.
- Decision-making
- Specific motor action (related to acceleration, deceleration and change of direction speed).

It must be clear from the start exactly what is being tested and, from this, obtain important information in terms of results.

Nonetheless, in order to measure and evaluate perceptive factors, it may not be necessary to formalize a test, but record training data that allows us to quantify, in a qualitative manner, the player's participation. Even so, performance is collective, and these tests only attempt to obtain individual data, therefore we are still a long way away from being able to record competitive performance data.

2.1.2 Evaluation of Change of Direction Speed

Basic movement patterns for many sports require athletes to make sudden changes in body movement direction while simultaneously and rapidly moving their arms. An athlete's ability to successfully use these maneuvers in sports depends on other factors: visual processing, coordination, reaction time, perception and anticipation. Although all of these factors are reflected within the agility of an athlete, the purpose of agility tests has been, for a long time, to simply measure the ability to quickly change body position and direction in a horizontal plane.

The common theme in agility testing used by the majority of authors working in this area, citing Baker (1999); Draper and Lancaster (1985); Webb and Lander (1983); Young, Hawken and McDonald (1996 and Young et al. (2002), is that there is no stimulus present and none of these tests require a cognitive or reactive component.

Stimuli classification is very important. These can be classified into stimuli that require:

- Simple decision-making: Conditioned stimulus and conditioned response
- Complex decision-making: unconditioned stimulus and unconditioned response

Additionally, a large variability has been registered in the tests used, even though none of these studies were related to tests requiring a reaction to a stimulus (which would pertain to a conditioned stimulus or simple decision-making), with a change of direction or a movement.

In light of the above, it is clear that in most cases, literature has reported tests to assess performance in terms of change of direction speed, but not in terms of agility. This is proven by the fact that none of the tests, which have been commonly used or which are currently used to measure agility, are performed considering perceptive factors and decision-making, understanding agility within situational sport as the ability that includes interpreting and solving situations based on determined stimuli.

This material distinguishes the difference between change of direction speed tests and agility tests as planned and unplanned agility tests, respectively.

2.1.3 Characteristics and Classifications of Different Change of Direction Tests

Several tests have been used to evaluate COD speed performance and many are continuously developed by researchers in order to evaluate the specific demands of the sport in which they are used. As we can see from an important review by Brughelli, Cronin, Levin, and Chaouachi (2008) there is a large variety of tests that have been used to determine the ability to change direction. The author has tried to classify every test within three areas (energy requirement, force application type and number of changes of direction) for a better understanding of the relationships between the tests and interest variables.

The length and intensity of change of direction speed tests (which must adapt to competition needs) will determine the relative contribution of the predominant energy system that supplies adequate fuel for performance. Gastin (2001) explains that the anaerobic energy system depends on phosphocreatine during the first five seconds of exercise. After that, it uses glycolytic energy, followed by energy produced by the aerobic system. Thereby, tests lasting different amounts of time could be subjected to energy influences other than COD ability testing. In addition to energy needs, cognitive and perceptive needs need to be taken into account when a test is chosen or designed.

The complexity of each test can be categorized by the number of COD required or by the type of movements and forces that are mainly used throughout the test.

Some commonly used tests (up and back test or L-test) can have one, two or three CODs while others (Illinois test) can include 12 changes of direction. So each COD requires a braking force, followed by a propulsion force with a turn and, as the number of turns goes up, the need for eccentric-concentric muscular force and resistance increases, as well.

The application of force during the actual COD is much harder to determine because it is closely related to individual technique, since each player has his own mechanisms according to his physiological and mechanical characteristics. Nonetheless, it has been accepted that lateral forces are involved in safe COD movements such as those in the *T-test* when the COD is preceded by pulling movements.

Brughelli, Croning, Levin and Chaouachi (2008), present a classification of tests according to previously developed parameters, such as: test duration, number of direction changes, force application direction at the time of the COD (Table 1).

Table 1: Test Classification Based on Different Parameters: Time to Complete the Test, Number of Direction Changes and Primary Force Applied During the Test (Brughelli, Cronin, Levin and Chaouachi, 2008)

Table III. Characteristics of the different agility tests commonly used

Time to complete test	
0–5 sec	t-test,[11] 10-yd (9-m) shuttle,[17] 20-yd (18-m) shuffle,[24] 5-0-5[31]
5–9 sec	t-test,[13,15,25] 48-ft (14.6-m) sideways shuffle,[32] 4×5.8-m shuttle,[29] L-run,[18,26,19] tennis-specific shuttle,[14] zigzag test;[4] up and back[31]
>10 sec	10×5m shuttle,[27] t-test,[3,10,22,28] 6×5-m shuttle,[20] Illinois,[31,28] Box test,[12] 30 m with 5 CODs,[21] slalom run,[33] hurdle test[33]
No. of CODs	
2–3	48-ft (14.6-m) sideways shuffle,[32] 4×5.8-m shuttle,[29] L-run,[18,26,16] 10-yd (9-m) shuttle,[17] tennis-specific shuttle,[14] 20-yd (18-m) shuffle,[24] zigzag test,[4] 5-0-5,[31] up and back[31]
4–6	t-test,[3,10,11,13,15,22,28,25] 6×5-m shuttle,[20] 30 m with 5 CODs[21]
>7	10×5m shuttle,[27] Illinois,[31,28] box test,[12] slalom run,[33] hurdle test[33]
Primary application of force throughout the entire test	
Horizontal	10×5m shuttle,[27] t-test,[3,25] 4×5.8-m shuttle,[29] L-run,[18,26,16] 10-yd (9-m) shuttle;[17] tennis-specific shuttle;[14] 6×5-m shuttle,[20] 20-yd (18-m) shuffle,[24] Illinois,[31,28] box test,[12] 30-m with 5 CODs,[34] zigzag test,[4] slalom run,[33] hurdle test,[33] 5-0-5,[31] up and back[31]
Lateral	48-ft (14.6-m) sideways shuffle[32]
Both	t-test[10,11,13,15,22,28]

COD = change of direction.

Source: Brughelli, Cronin, Levin and Chaouachi, 2008.

Some significant correlations were found among these tests in terms of interrelations. For example, between the *Illinois test* and the *Up and back test* (r=0.63), and between the *Up and back test* and *5-0-5* (0.51); but not between the *Illinois test* and the *5-0-5 test* (0.25). Researchers suggested that results of many COD tests were independent of each other and they understood this was due to the duration and complexity of each test. Brughelli, Cronin, Levin and

Chaouachi (2008) also believed that in some cases, this independence was due to differences in direction and application of force and/or energy requirements.

Reliability of the Different Tests

Not many authors have clearly reported reliability coefficients of the COD tests they have used as reliable information. The reliability and variation of results are especially important for studies on training when it is essential to know if exercises performed cause or yield changes in the measured variable.

In the review done by Brughelli, Cronin, Levin and Chaouchi (2008) only nine studies reported the reliability of their measurements. This shows one of the limitations to research within this area, as indicated in the methodological ratings.

However, despite the length of the test, the number of CODs or the direction in which many of the forces were applied, all of the tests used to measure COD ability showed similar reliability (0.8-0.96 intraclass correlation, 1-5% variation coefficient)

As shown in Table 2, a large variety of COD tests were used in the research report. These tests needed different energy requirements (approximately between 1.65-135 seconds), COD (2-10) and primary force production as previously described. According to this variation, it would be difficult to arrive at a consensus such as correlation or performance prediction in COD.

In order to describe the magnitude of the correlations, Brughelli, Cronin, Levin and Chaouachi (2008) use Cohen's work, who has worked extensively in this area and has described the correlation magnitude as: >0.5 being large, 0.5 to 0.3 being moderate, 0.3 to 0.1 being small and less than 0.1 being insubstantial or trivial.

Table 2: Reliability of the Different Tests (Brughelli, Cronin, Levin and Chaouachi, 2008)

Table IV. Measurements of reliability for specific change of direction (COD) tests

Study	COD test	Reliability	Time to complete (sec)	Application of force throughout the entire test	No. of CODs
Christou et al.[27]	10 × 5 m shuttle	ICC = 0.94 CV = 1.01%	20	Horizontal	9
Cronin et al.[11]	Modified t-test	ICC = 0.88 CV = 2.1%	4	Horizontal and lateral	4
Gabbett et al.[18]	L-run	ICC = 0.90 TEM = 2.8%	6	Horizontal	3
Gabbett[3]	t-test	ICC = 0.85 CV = 2.9%	11	Horizontal	4
Gabbett[19]	L-run	ICC = 0.90 TEM = 2.8%	6	Horizontal	3
Markovic et al.[24]	20-yd (18-m) shuffle	ICC > 0.9 CV < 4.1%	5	Horizontal	2
McBride et al.[22]	t-test	ICC = 0.94% TEM = 2.09	11	Horizontal and lateral	4
Tricoli et al.[12]	Box test	ICC = 0.80	16	Horizontal	11
Alricsson et al.[33]	Slalom run	ICC = 0.96 CV = 2.3%	>10	Horizontal	10
	Hurdle test	ICC = 0.90 CV = 4.9%	>10	Horizontal	7

CV = coefficient of variation; **ICC** = intra-class correlation; **TEM** = typical error of measurement.

Source: Brughelli, Cronin, Levin and Chaouachi, 2008.

2.1.4 Cognitive Considerations for the Assessment of Agility

Some authors (Chelladurai, Yuhaz and Sipura, 1977) examined subject's reactions using light stimuli. This was the first experience done on fast movement reactions to an external stimuli that approaches the current concept we have of this ability.

This attempt, similar to others (whole-body response with a change of velocity or direction to different light signals), while respecting the concept of variable external stimulus response, it does not respond to stimulus specificity with regards to sports. That is to say, it should consider elements that are characteristically and specifically related to sports, such as: situational reading, presence of opponents, using or not using an object (element or ball), implementation on the sport-specific field of play, sport-specific tactical action.

Maybe we should ask ourselves if using preferential simulated situations we are able to asses, in a qualitative way, exercise quality (performed by athletes). So this type of test (like the one developed by Chelladurai et al., 1977) would only be valid to distinguish between elite and non-elite athletes.

Other researchers (Hertel, Denegar, Johnson, Hale, and Buckely, 1999) evaluated the reliability of a device designed to measure universal agility performance (Cybex Reactor). The device consists of 14 target sensors on the floor to facilitate training. These sensors were interfaced with a video monitor and computer. It contained large number of scenarios which required athletes to react to visual stimuli by moving their feet on the floor sensors. Like any other electronic stimuli developed, the athlete was exposed to general and two dimensional stimuli. The required movement patterns were not specific to any sport and the images presented did not correspond to any particular sport situation. For all of that, this type of equipment to assess agility, although it includes visual scanning and decision-making, is not completely effective because it is not sport-specific.

That is why the elements specific to athletes and sports should be respected when assessing agility. This is referring to the movement patterns being tested, the perception of specific stimuli and decisions related to the sports dynamics. One aspect that distinguishes high performance athletes is directly related to their ability to anticipate their opponents' movements. In fact, significant differences between high performance athletes and non-elite athletes have been noticed (Abernethy and Russel, 1987).

Therefore, it is important to know the demands specific to different sports in order to design and apply valid, reliable and reproducible agility tests. In some cases, tests have been developed where the athletes watched films on sport situations and needed to quickly solve them using change of direction speed (Farrow, Young, & Bruce, 2005; Sheppard and Young 2006). Other tests had athletes react to an opponent's defensive movement, this way making it more sport-specific (Wheeler and Sayers, 2010). Thus, it would be necessary to create a specific test for every sport model. In this sense, it may be more efficient to create different preferential simulated situations (tasks), where this type of parameter can be controlled.

In summary, the trend in the application of agility tests is for them to provide the greatest specificity in:

- Replication of sport situations (offense and defense).
- Perception of specific situations.
- Decision-making
- Anticipation.
- Sport-specific motor skills (with or without elements, adapted to positions and/or functions, with or without tactical actions.).

UNIT 2.2 Evaluation of Change of Direction Speed (Closed Agility) and Agility (Open Agility)

2.2.1 Programmed or Closed Agility Assessment

T-Test (Semenick, 1990)

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: low number of COD (4).
- COD complexity: high (COD of 90° and 180°).
- Force application: Predominantly horizontal
- Test duration: between 8.5 to 12 seconds (predominance of glycolytic anaerobic system).

Equipment

- Cones (4) from 80 cm (31.3 inches) to 100 cm (39.4 inches) tall.
- Photocells (2). Alternatively, chronometer.
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

The total course distance is 40 meters (43.7 yards). Cone A (start and finish of the test) is located 9 meters (9.8 yards) from cone B. Perpendicular to cone B, cones C and D are placed 4.5 meters (4.9 yards) to the right and 4.5 meters (4.9 yards) to the left (Figure 1).

Execution

This test was designed by Semenick (1990) and adapted by Harman, Garhammer and Pandor (2000, cited in Baechle and Earle, 2007).

The test process consists of running 9.14 m (10 yards) in a straight line from cone A to cone B. When the athlete gets to cone B, he must touch the base of the cone with his right hand. Then, the subject turns left, running laterally 4.5 meters (4.9 yards) and touches the base of cone C with his left hand. The subject immediately turns right, running laterally 9.14 meters (10 yards) to cone D and touches the base with his right hand. Next, the athlete turns left and runs laterally to touch the base of cone B with his left hand. Lastly, the athlete runs backwards towards cone A. When he reaches it, the chronometer is stopped (Figure 1).

The author suggests having an assistant and a mat placed a few meters behind cone A for safety reasons, in case the subject falls while running backwards.

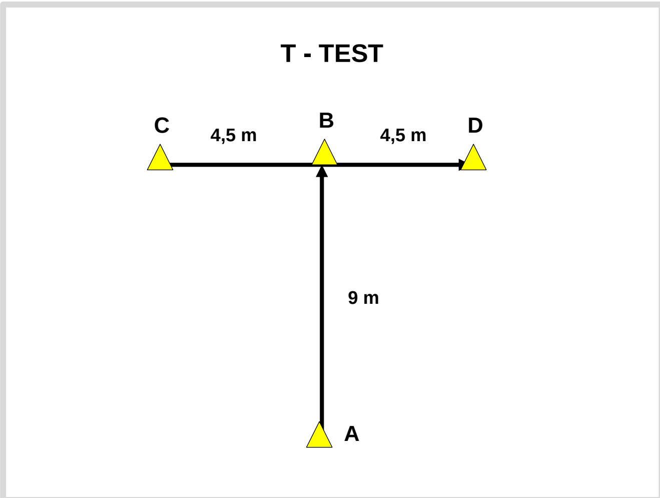
Semenick suggests taking the best time out of two attempts. If time is recorded with a manual chronometer, then a tenth of a second error should be taken into account for the final result.

There are several reasons to invalidate the test:

- Not touching the base of the cones.
- Crossing one foot over the other when turning.
- Not running facing forward throughout the course (except for the last section from cone B to cone A, where movement is backwards).

It is suggested to use an athlete's data from his first test as reference to compare subsequent measurements. The time is registered in seconds and hundredths of a second.

Figure 1: T-Test by Semenick (1990), Adapted by Harman, Garhammer and Pandorf 2000, in Baechle and Earle, 2007.



Source: Baechle and Earle, 2007.

T Test (Pauole, Madole, Garhammer, Lacourse and Rozenek, 2000)

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: low number of COD (4).

- COD complexity: high (COD of 90° and 180°).
- Force application: predominantly horizontal
- Test duration: between 7 to 9 seconds.

Equipment

- Cones (4).
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

The total course distance is 30 meters (32.8 yards). Cone A (start and finish of the test) is located 5 meters (5.4 yards) from cone B. Perpendicular to cone B, cones C and D are placed 5 meters (5.4 yards) to the right and 5 meters (5.4 yards) to the left (Figure 2).

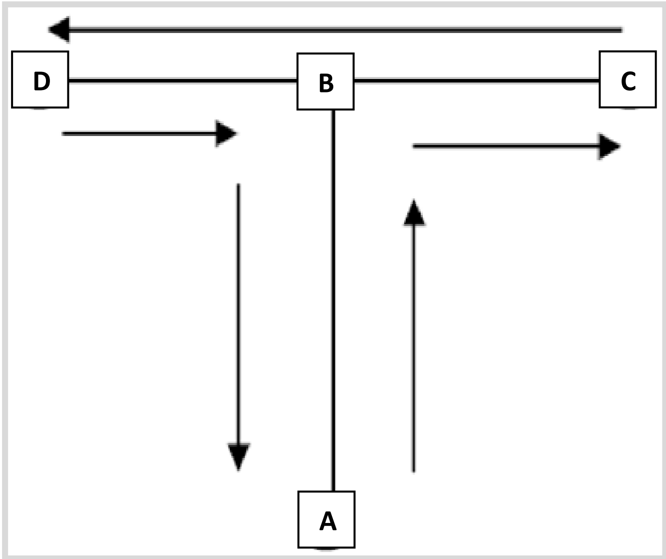
Execution

The cones are placed into a T shape, each 5 meters (5.4 yards) apart. (Figure 2). The start is the cone at the base of the T.

> When the subject breaks the photocell beam, he begins running forward to touch the cone placed 5 meters (5.4 yards) directly in front of the starting cone. Then, he runs 5 meters (5.4 yards) laterally to touch the cone on the left. Next, he runs 10 meters (10.9 yards) laterally to touch the cone on the right side of the T, to return running 5 meters (5.4 yards) laterally to the cone placed at the top of the T. Lastly, the subject runs 5 meters (5.4 yards) backwards until he has run passed the cone at the base of the T and cut the beam of the second photocell. (Sainz de Baranda Andújar and Ayala, 2009).

Two attempts are made with a rest period of approximately 2 minutes in-between. The better of the two results is chosen to analyze the results.

Figure 2: T test, a 30 meters (32.8 yards) Course in the Shape of a T (Pauole et al., 2000)



Source: Pauole, Madole, Garhammer, Lacourse and Rozenek, 2000.

Illinois Agility Test

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: high number of COD (12).
- COD complexity: high (COD of 45° and 180°).
- Force application: Predominantly horizontal
- Test duration: between 15 and 20 seconds for men and 17 to 22 seconds for women.

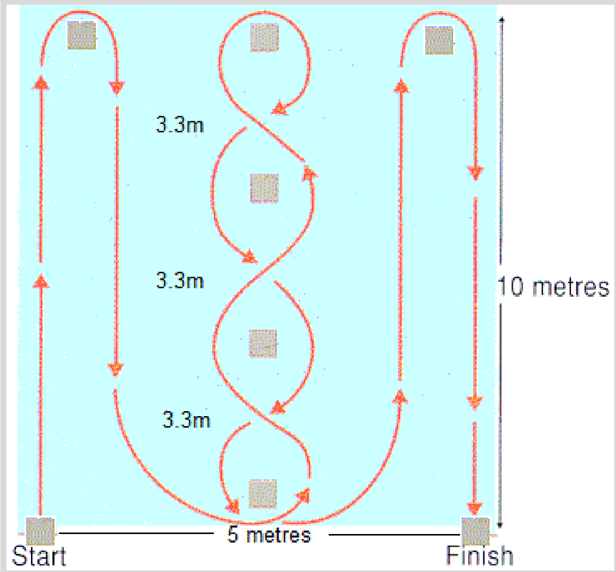
Equipment

- Cones (8).
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes. Preferably, it should not be slippery.

Organization

Total course distance is approximately 65 meters (71 yards). The cones are arranged as shown in Figure 3.

Figure 3: Organization of the Illinois Agility Test

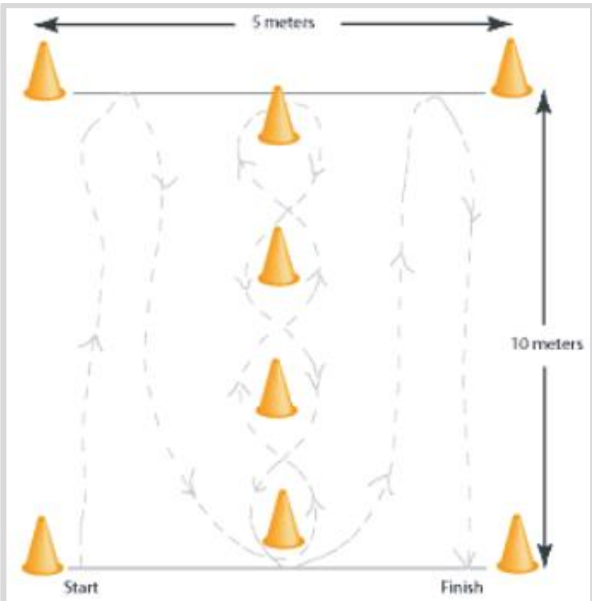


Source: [Image titled above *test Illinois agility*]. (s. f.). Source http://goo.gl/GPBsQj

Execution

The starting position is laying prone on the ground with the subjects' heads on the starting line and hands at shoulder height. On the start signal, the subjects must press up from the ground and sprint full-speed following the circuit shown in Figure 4. It must be done without knocking the cones over and the time it takes to finish the whole course is recorded. The time is registered in seconds and hundredths of seconds.

Figure 4: Representation of the Illinois Agility Test Circuit



Source: [Image titled about Illinois Agility Test, 2]. (s. f.). Source http://goo.gl/xDbku

The central cones must be 3.3 meters (3.6 yards) apart and should be placed in the center (2.5 meters (2.7 yards) from the lateral cones).

Reported Data

In this test, Reilly, Williams and Nevill (2000) reported an average time of 14.60 seconds for professional soccer players from the English Premier League.

Filming the test is suggested in order to be able to qualitatively assess each agility component evaluated. This refers to the possibility of analyzing each change of direction, accelerations, decelerations, etc. Other measurements can be assessed within these different elements, in general lines: feet placement, body posture, step length while accelerating and decelerating, among others. Figures 5, 6 and 7 show a sequence of photos taken of an Illinois test done by a soccer player. The time is registered in seconds and hundredths of seconds. A table is also presented in which the athlete's qualification can be assessed according to his timing on the Illinois Test (Table 3).

Figure 5: 180° Change of Direction in the Illinois Test

Source: Prepared by the authors

Figure 6: Acceleration in Illinois Test

Source: Prepared by the authors

Figure 7: Diagonal Change of Direction in the Illinois Test

Source: Prepared by the authors

Table 3: Athlete Qualification According to Time Ranges in Illinois test (Separated into Male and Female)

Gender	Excellent	Above average	Average	Below average	Poor
Male	<15.2 seconds	15.2 to 16.1 seconds	16.2 to 18.1 seconds	18.2 to 19.3 seconds	>19.3 seconds
Female	<17.0 seconds	17.0 to 17.9 seconds	18.0 to 21.7 seconds	21.8 to 23.0 seconds	>23.0 seconds

Source: Prepared by the authors

5-0-5 Agility test (5-0-5 test)

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: low number of COD (1).
- COD complexity: high (180° COD).
- Force application: Predominantly horizontal
- Test duration: less than 10 seconds

Equipment

- Cones (4) from 80 cm (31.3 inches) to 100 cm (39.4 inches) tall.
- Photocell (1).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

The test consists of a 20 meters (21.8 yards) course, of which only the final 10 meters (10.9 yards) that include one 180° COD are timed.

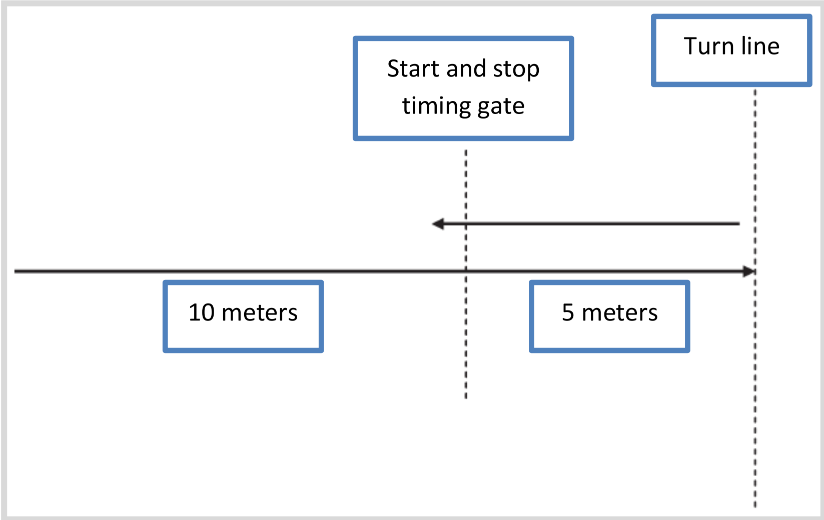
A mark is placed at the start line. A photocell is placed at 10 meters (10.9 yards) which will record the start and end of the test. 5 meters (5.4 yards) after the photocell, another line will be placed that marks the turning point or COD (Figure 8).

Execution

The test only consists of frontal movements. The subject begins the test with a 10 meters (10.9 yards) run, accelerating to his top speed. When he reaches the 10 meters (10.9 yards) mark the photocell will start the time measurement. The athlete runs 5 meters (5.4 yards), changes direction 180°, re-accelerates and runs the same 5 meters (5.4 yards) in the opposite direction. When the athlete cuts the photocell's beam for the second time he has reached the end of the test and the time is recorded.

Thus, the test consists of a total of 20 meters (21.8 yards), of which only the final 10 meters (10.9 yards) are timed (Figure 8). The time is registered in seconds and hundredths of seconds.

Figure 8: Execution of 5-0-5 test



Source: Buttifant, Graham & Cross, 1999.

Up and Back Test (4 x 9 M Shuttle run test)

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: low number of COD (4).
- COD complexity: high (180° COD).
- Force application: Predominantly horizontal
- Test duration: about 10 seconds

Equipment

- Cones (4).
- Photocell (1).
- Sponges or 10 x 5 x 5 cm (3.9 x 1.9 x 1.9 inches) wood blocks (2)
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

The total course distance is 36 meters (39.3 yards), running 9 meters (9.8 yards) four times, back and forth. The photocell is located at the start and finish line.

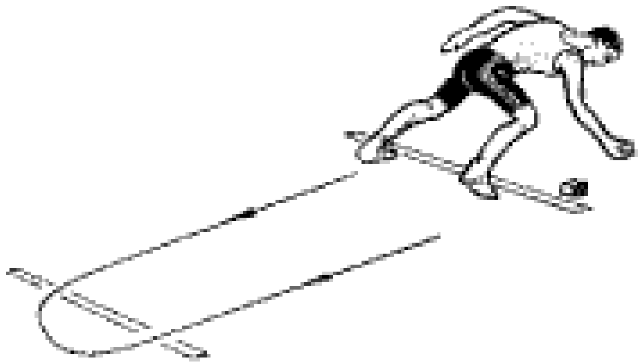
The test is organized by placing 2 cones as reference on the starting line and on another parallel line, 9 meters (9.8 yards) from it 2 more cones are placed. Approximately 10 cm (3.9 inches) behind this line, 2 sponges are placed (Figure 9).

Execution

The aim of this test is to measure a subject's moving speed and agility.

On the court or field, 2 parallel lines are drawn 9 meters (9.8 yards) from each other. The subject stands behind the first line in a standing ready position facing the second line, where two pieces of wood are placed on the ground (Figure 9).

Figure 9: Up and back test, or the 4x9 Shuttle run



Source: [Image titled above *test up and back*]. (s. f.). Source http://goo.gl/nKeuAv

On the signal from the tester, the subject sprints at full speed towards the second line, where he will pick up one piece of wood and sprint back towards the first line where he will place the piece of wood on the ground. The sequence is then repeated with the second block.

The time needed to complete the test, from the "go" signal, the 2 up and backs until the second block of wood is placed on the starting line is recorded (in seconds and hundredths of seconds).

The better of two attempts will be recorded. (Martínez López, 2003).

It is suggested to use an athlete's data from his first test as reference to compare subsequent measurements.

L-Test

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: average number of COD (5).
- COD complexity: high (COD of 90° and 180°).
- Force application: predominantly horizontal.
- Test duration: about 10 seconds

Equipment

- Cones (3).
- Photocell (1).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

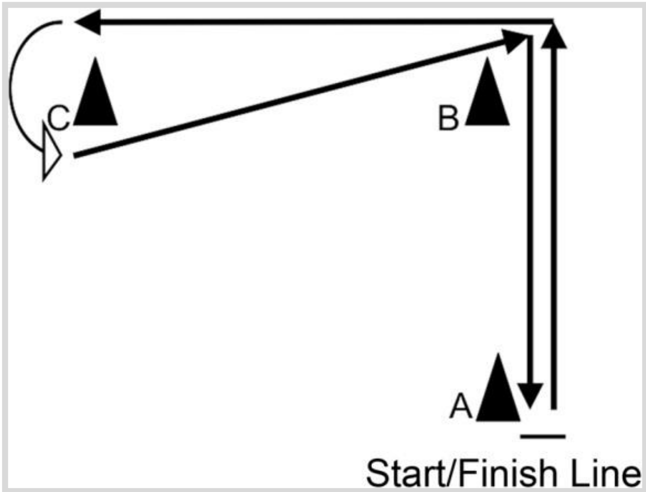
The L-Test requires three cones to be placed in a 90° angle, which forms an L shape, 5 yards (4.5 meters) from each other. The test consists of a total of 30 yards (27.4 meters), 10 yards (9.1 meters) up and back and then 20 yards (18.2 meters) in an L shape (Figure 10).

Execution

The aim of this test is to measure a subject's change of direction speed.

The athlete must run up and back 10 yards (9.1 meters) and then run 20 yards (18.2 meters) in the shape of an L, as shown in Figure 11. The time is registered in seconds and hundredths of seconds.

Figure 10: Execution of the L-Test



Source: [Image title above execution of the L-*Test*]. (s. f.). Source http://goo.gl/J2Atdl

Zig-Zag Test

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: average number of COD (5).
- COD complexity: high (45° COD).
- Force application: predominantly horizontal.

Equipment

- Cones (5).
- Photocell (1).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

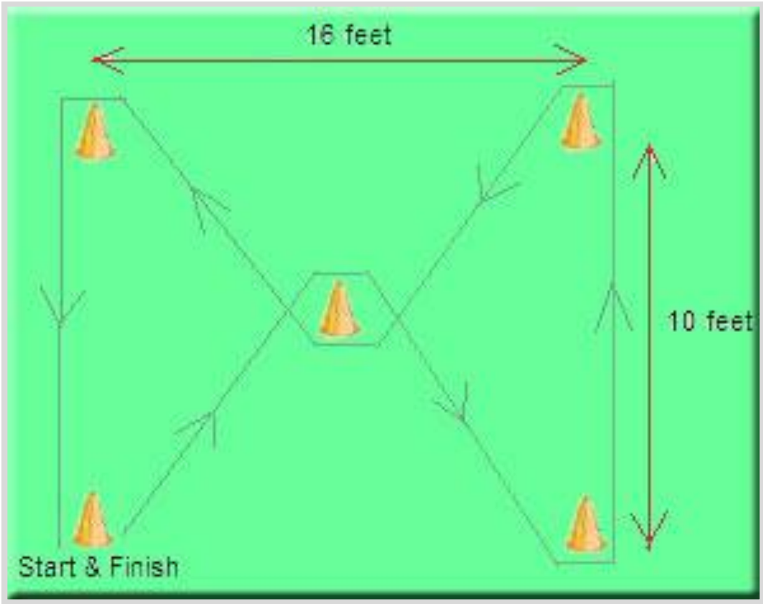
The zig-zag test requires four cones each placed at a 90° angle from each other, forming a rectangle which is 16 feet (4.8 meters) long and 10 feet (3 meters) wide. Another cone will be placed in the center of the rectangle. The test consists of a total of 50 feet (15.2 meters) (Figure 11).

Execution

The objective of this test is to measure subject's the change of direction speed in a zigzag course making approximately 45° changes of direction.

The athlete must run around 50 feet (15.2 meters) as fast as possible, as indicated in Figure 11. The time is registered in seconds and hundredths of seconds.

Figure 11: Zig-Zag Test Execution



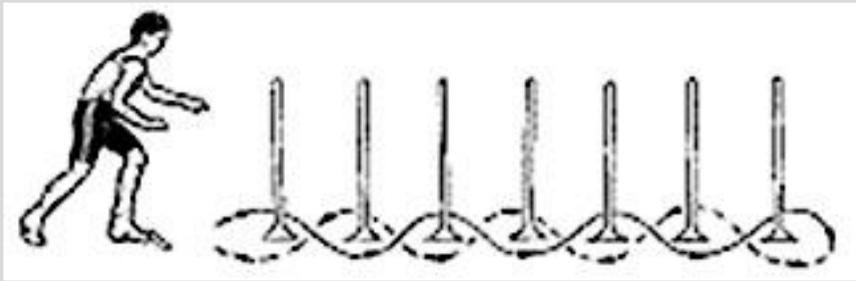
Source: [Image title above execution of the zig-zag *Test*]. (s. f.). Source http://goo.gl/qTWGrB

Slalom-run

This test measures the running agility and movement of the subject.

To begin the test the subject will be placed behind the start line in a standing position. The subject will run 2 meters (6.5 feet) and then around seven posts placed vertically and aligned with 1 meter (3.2 feet) of separation in-between (Figure 12). (Martínez López, 2003)

Figure 12: Slalom Test



Source: [Image titled above *slalom test*]. (s. f.). Source http://goo.gl/9gQFhZ

> On a signal from the tester, the subject must run as fast as possible through the constructed slalom, running in a zig-zag around the outside of the seven posts.
>
> The time it takes for the subject to run up and back to the start line is the time recorded. A subject is disqualified if he knocks over any of the seven posts.
>
> The better of two attempts is recorded.
>
> According to Albl, Baldauf et al., this test has, in 18-year-old male subjects, a reliability coefficient of 0.92 (Fetz and Kornexl, 1976).
>
> The material necessary for this test is a smooth, flat, non-slip field, 7 posts and a chronometer. (Martínez López, 2003)

It is suggested to use an athlete's data from his first test as reference to compare subsequent measurements.

Slalom Test

This test measures an athlete's change of direction speed in a slalom style course.

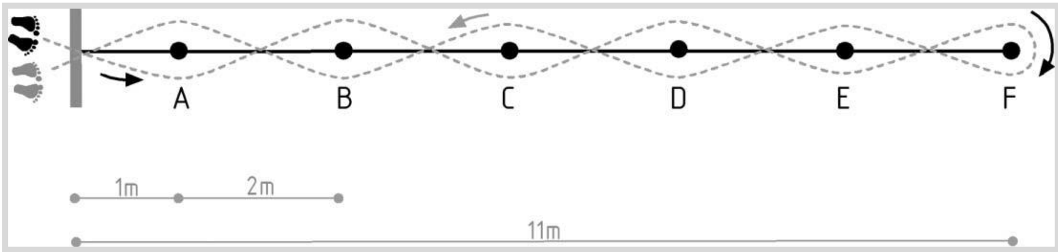
To begin the test, the subject must stand behind the start line in a standing, ready position. The subject will run 1 meter (3.2 feet) and then, he will run around 6 cones placed in a line, 2 meters (6.5 feet) apart from each other (Figure 13).

On the signal from the tester, the subject must run as fast as possible through the slalom course, up and back, running in a zig-zag around the six cones.

The best of three attempts, recorded by a photocell, will be assessed (knocking over cones is not allowed).

The material necessary for this test consists of a smooth, flat, non-slip field, 6 cones and a photocell.

Figure 13: Slalom Test



Source: Sporis, Jukic, Milanovic and Vucetic, 2010.

Wildcat Agility Test

Test Characteristics

- Type: planned or pre-planned.
- Number of COD: low number of COD (3).
- COD complexity: high (180° COD).
- Force application: predominantly horizontal

Equipment

- Cones (2).
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

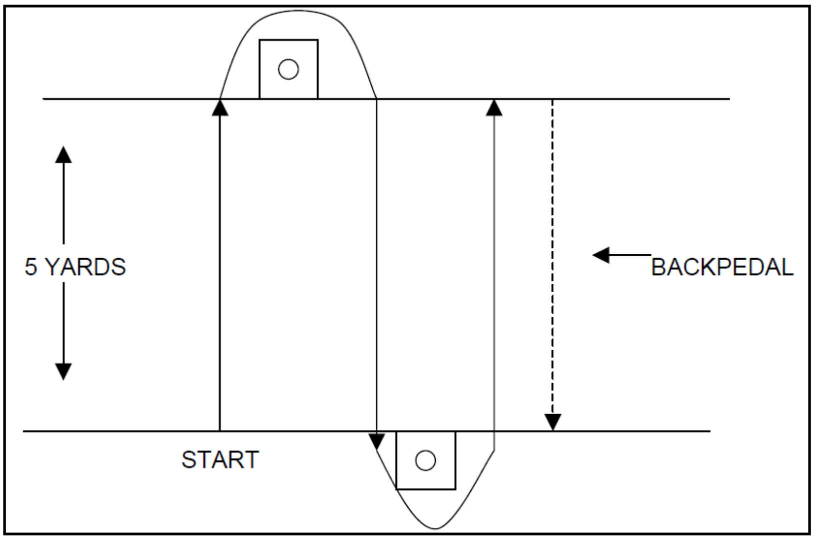
Organization

This test requires two parallel lines, 5 yards (4.5 meters) apart. One cone is placed on each line. One photocell is placed at the beginning of the test (start line) and another at the end of the test (finish line) (Figure 14).

Execution

This test assesses an athlete's change of direction speed ability, as well as their foot speed. In this test the subject starts when the tester gives the signal, running forward to the cone located 5 yards (4.5 meters) in front of the start line. The subject goes behind the cone and, running forward, returns to the start line. He then must go behind the cone on the start line and run towards the other cone again. When he arrives to this cone for a second time, he must stop and run backwards towards the start/finish line, where the test is concluded (Figure 14). The time is recorded in seconds and hundredths of seconds.

Figure 14: Wildcat test execution



Source: Sporis, Jukic, Milanovic and Vucetic, 2010.

4 x 5 meter (4.3 x 5.4 yards) Sprint Test

Test Characteristics

- Type: unplanned or non-pre-planned.
- Number of COD: low number of COD (3).
- COD complexity: high (COD of approximately 180° and 90°).
- Force application: predominantly horizontal and lateral

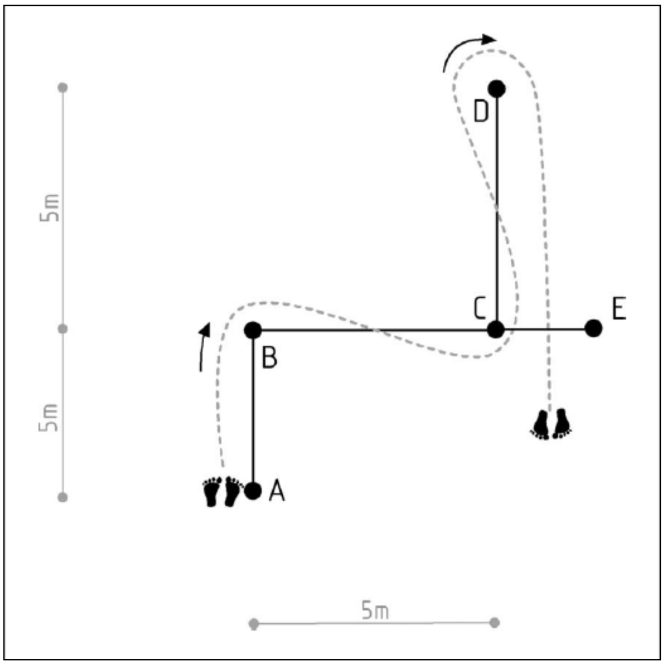
Equipment

- Cones (4). The cones are placed 5 meters (5.4 yards) apart, as shown in Figure 15.
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Execution

The participant starts with both feet behind the start line (Point A). On the signal from the tester, the subject accelerates to point B, completing a COD of 90° going behind the cone and moving laterally (without crossing his feet) to point C. From there, he runs forward passing behind point D and running forward to arrive at the finish line (point E) (Figure 15).

Figure 15: 4 x 5 Meter (4.3 x 5.4 Yards) Sprint Test



Source: Sporis, Jukic, Milanovic and Vucetic, 2010.

90° Turn and Sprint Test (S90)

Test Characteristics

- Type: unplanned or non-pre-planned.
- Number of COD: intermediate number of COD (6).
- COD complexity: high (90° COD).
- Force application: predominantly horizontal and lateral

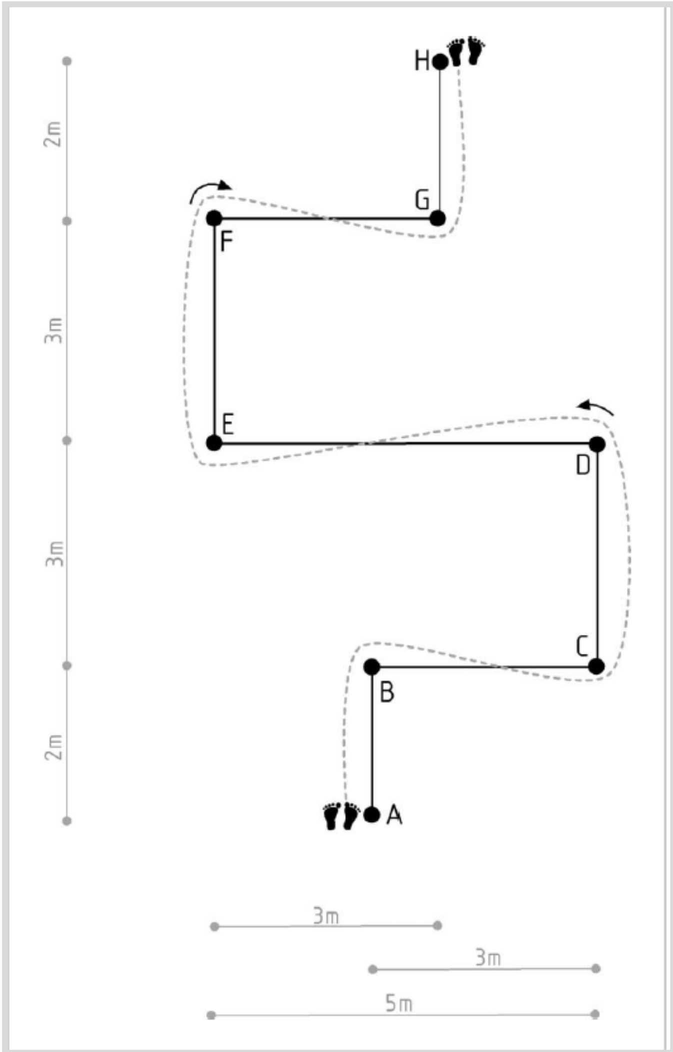
Equipment

- Cones (8). The cones are placed as shown in Figure 16.
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Execution

The participant starts with both feet behind the starting line (Point A). On the signal from the tester, the subject accelerates to point B, completes a 90° COD going behind the cone and running forward to point C. There, he must complete another 90° COD and sprint to cone D, where he must go behind it and go to point E. He completes another 90° COD to point F, where he changes direction and runs to point G, completing a 90° COD for the last time, and running one last sprint to point H where the test is concluded. (Figure 16).

Figure 16: 90° Turn and Sprint Test (S90)



Source: Sporis, Jukic, Milanovic and Vucetic, 2010.

In the case of FC Barcelona, it is necessary to study which test will be done and why. It can include simple or complex decision-making but this could result in multiple variations becoming a task that is too open.

FC Barcelona uses the T-test to measure aspects of conditioning and to have player evolution data. They do not, at the moment, give tests that include decision-making.

2.2.2 Non-Programmed or Open Agility Assessment

The Reactive Agility Test for Netball

At the Australian Institute of Sport in Canberra, Australia, Young and Farrow (2006) developed the reactive agility test that makes players complete sport specific movement patterns. This protocol used prerecorded videos of various netball movements as stimuli for the subjects.

Test Characteristics

- Type: unplanned or non-pre-planned.
- Number of COD: low number of COD (3).
- COD complexity: high (COD of approximately 180°, 90° and 45°).
- Force application: predominantly horizontal and lateral

Equipment

- Cones (2).
- Photocells (4).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Execution

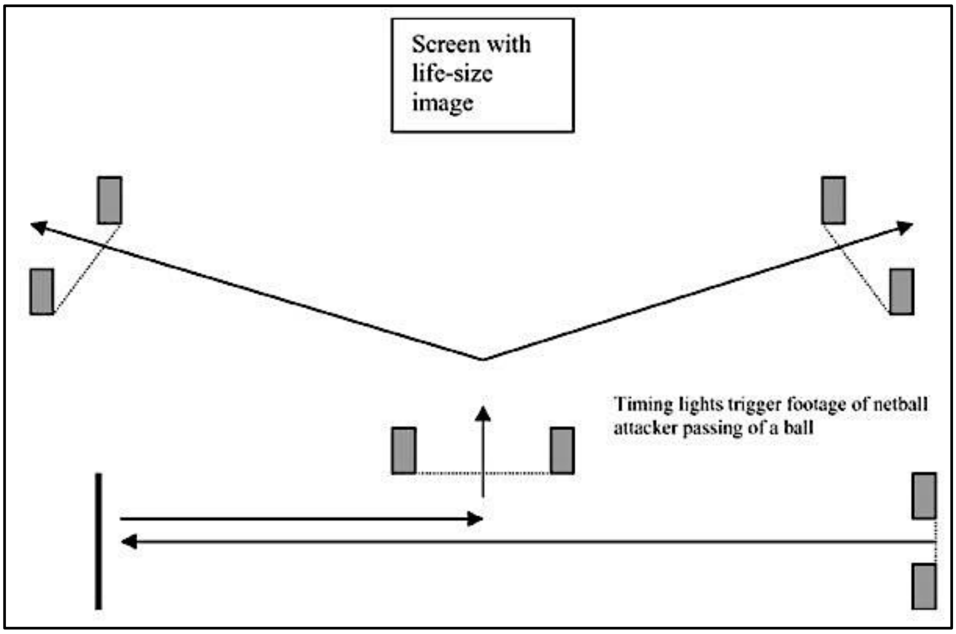
The test begins when the subject, reacting to a visual stimulus, breaks the photocell beam that is located at the start of the test. From there, he must run in a straight line, complete a COD of 180°, and return in the opposite direction. Then, as he approaches the second photocell, he must watch the on-screen video and react, either to the left or right, depending on the video prompt.

Initially, this test was done as a planned version and subsequently, it was done as unplanned. The first consisted of the total time of the test. The second, as stated above, included the ability to analyze a visual stimulus and to react rapidly and effectively to it.

The results showed there was a difference between athletes that are able to read stimulus better compared to those who have not yet developed this skill. Significant differences were seen between those subjects who possess better reaction skills to stimulus than those who do not, while there was no significant difference between them in the first attempt (planned situation).

While these differences prove insightful with respect to the effectiveness of agility assessment, this test does have some drawbacks, such as: filming the sport specific situations, equipment costs (photocells, video screen, projector, etc.), and time to learn the test.

Figure 17: Execution of the Reactive Agility Test (Young and Farrow, 2006)



Source: Young and Farrow, 2006

Planned or Reactive Agility Test with Light Stimulus (Oliver & Mayers, 2009)

Test Characteristics

- Type: planned, unplanned and non-pre-planned variations.
- Number of COD: Low number of COD (1), or none, in the case of only running linearly.
- COD complexity: medium (COD of approximately 45°).
- Force application: predominantly horizontal and lateral

Equipment

- Cones (6).
- Photocells (5).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

Organization

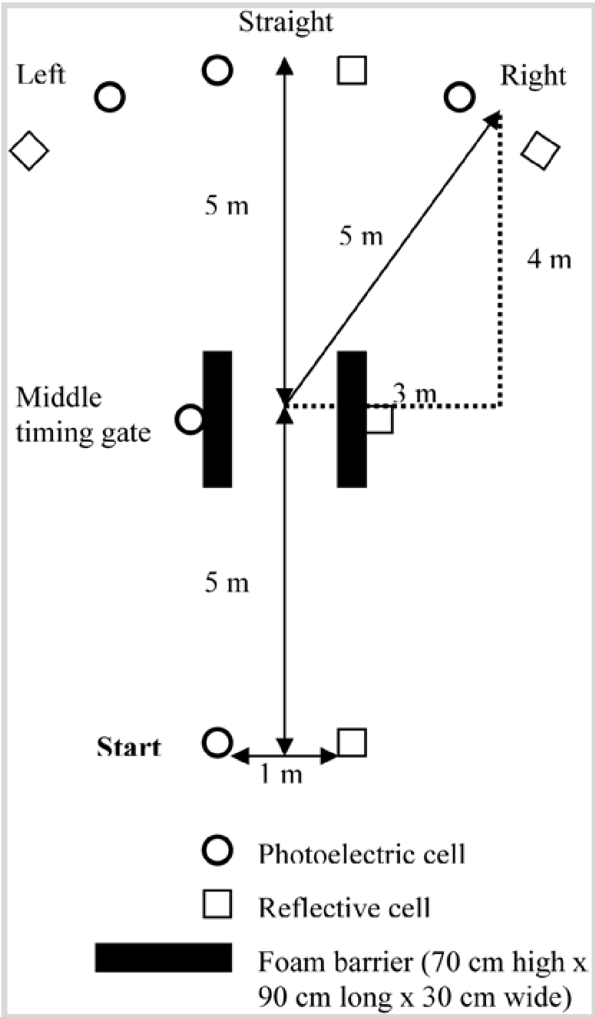
The test requires a marked starting line, cones and photocells, as indicated in Figure 18.

Execution

As stated above, this test can be either planned or unplanned. In the case of a planned test, the subject must perform lineal accelerations or accelerations with change of direction while running, which must be previously determined before the test begins. In the case of an unplanned test, the test requires the athlete to accelerate in a straight 5-meter (5.4 yards) line and to be ready for a light signal to indicate in which direction he must perform the change of direction (to the right or the left), or to continue linearly (Figure 18).

Ten attempts are done. All of the attempts are recorded and then an average is found for each subject.

Figure 18: Planned or Reactive Agility Test with Light Stimulus (Oliver & Mayers, 2009)



Source: Oliver & Mayers, 2009.

The Reactive Agility Test for Rugby (Wheeler & Sayers, 2010)

Test Characteristics

- Type: unplanned or non-pre-planned.
- Number of COD: low number of COD (2).
- COD complexity: high (COD of approximately 45° and 90°).
- Force application: predominantly horizontal and lateral

Equipment

- Cones (6).
- Photocells (2).
- Suitable field. It is suggested to use the type of surface on which the subject trains and competes.

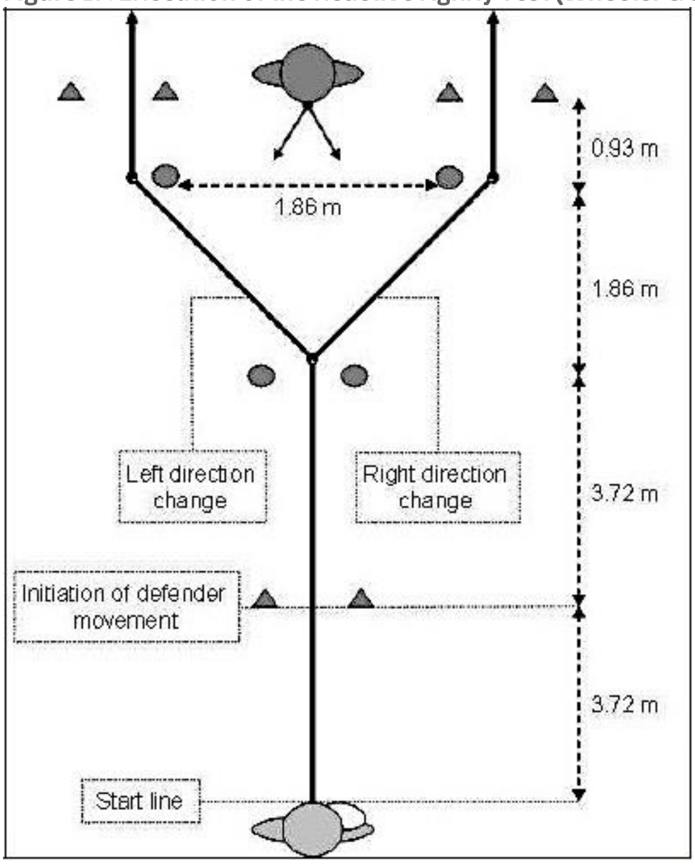
Organization

The test requires a marked start line, cones and photocells.

Execution

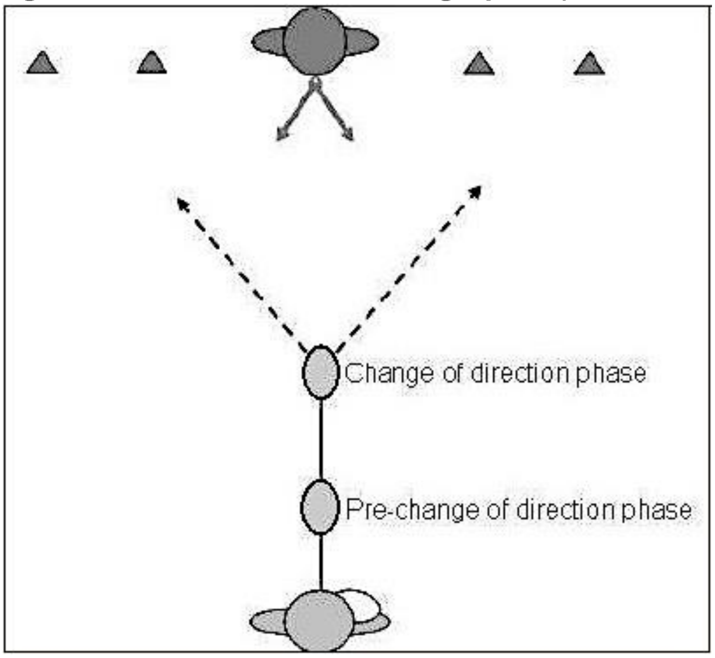
The athlete begins the test from the start line while carrying a movable element (ball). Upon passing the first point, marked by cones (3.72 meters (4 yards) from the start) the pre-change of direction phase begins and the defender begins to move forward. Upon passing the second mark (3.72 meters (4 yards) from the first), the change of direction phase begins, where, depending on the location of the defender, the attacker must pass by him with a change of direction. The defender must try to touch the attacker before he reaches a determined finish line or goal marked by cones. Six attempts are allowed and the time of each attempt is recorded. The average of the six attempts is then found for each subject.

Figure 19: Execution of the Reactive Agility Test (Wheeler & Sayers, 2010)



Source: Wheeler and Sayers, 2010

Figure 20: Execution of the Reactive Agility Test (Wheeler & Sayers, 2010)



Source: Wheeler and Sayers, 2010

2.2.3 Repeated Sprint Acceleration Tests (RSA)

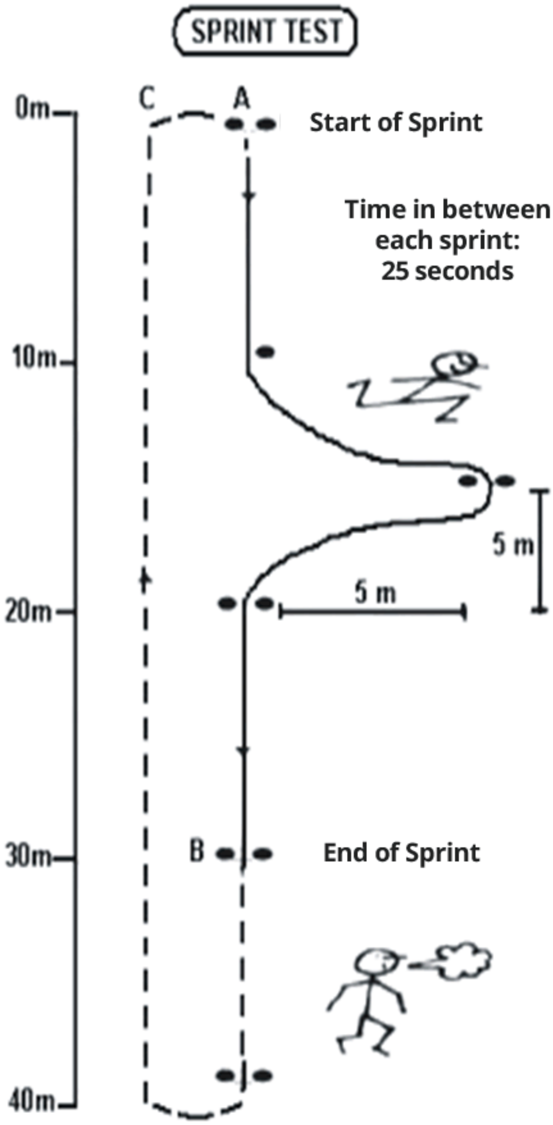
Evaluation of Repeated Sprint Ability

In team sports, athletes must be able to recover very quickly from short, high intensity exercise. Players do not have sufficient time to completely recover between repeated series of sprints (meaning for complete resynthesis of phosphocreatine). That is why it is necessary to measure a player's ability to recover from repeated series of sprints or accelerations (Vargas, 2008).

Bangsbo Sprint Test

The test consists of a series of 7 (seven) repeated accelerations at maximum intensity, with recovery times of 25 seconds between repetitions, running a distance of 30 meters (32.8 yards). The test begins with an initial acceleration of 10 meters (10.9 yards), from the start line, followed by three COD (zigzag pattern) and a final acceleration of 10 meters (10.9 yards). Then, the subject returns to the starting position by jogging at a very low intensity. The time of each attempt must be recorded by a photocell or, alternatively, a chronometer.

Figure 21: Graphic Representation of the Sprint Test Proposed by Jens Bangsbo



Source: Bangsbo, 2005.

Variables Obtained from the Sprint Test

- Best time in seconds: shows peak performance during the test
- Average time (seconds): shows the subject's ability to recover intra and post-exertion.
- Fatigue index: percentage difference between the slowest and fastest times. This indicates how alactic and lactic anaerobic performance are affected.
- Final lactate mmol/Lt: indicates the metabolic cost produced during the test. Generally, values between 9-14mmol/Lt are obtained.

Comments

The Bangsbo Sprint Test combines acceleration speed with changes of direction followed by incomplete (intermittent) recovery time. It provides a very informative assessment due to its close relationship to many determined actions in team sports such as soccer, rugby and hockey. On the other hand, the energy pathways used during this test are the same ones required during critical moments in team sports.

Intermittent Anaerobic Running Test

This test consists of 10 sprints of 20 meters (21.8 yards) each with a recovery time of 20 seconds between sprints. The running direction of each sprint must change, meaning that at the end position of each sprint must become the starting position of the next. Rudolf et. al. (2006), analyzed the reliability and validity of this test in a study of 29 young soccer players from the elite level of Czech club, who completed the test twice, under the same conditions, within the same week. For both tests, blood was drawn at 2, 4, and 6 minutes after the test was completed to assess lactate concentration. They reported through the variance analysis of two pathways, that average times of the 10 sprints was not significantly different between the two evaluations.

References

Abernethy, B., & Russell, D. G. (1987). *Expert novice difference in an applied selective attention task. Journal of Sport Psychology*, 9, 326 345

Abernethy, B., Wood, M. J., & Parks, S. (1999). *Can the anticipatory skills of experts be learned by novices? Research Quarterly for Exercise and Sport*, 70, 313 318.

Alricsson, M., Harms-Ringdahl, K., & Werner, S. (2001). *Reliability of sports related functional tests with emphasis on speed and agility in young athletes*. Scandinavian Journal of Medicine & Science in Sports, 11(4), 229-232.

Baker, D., & Nance, S. (1999). *The relation between running speed and measures of strength and power in professional rugby league players.* Journal of Strength and Conditioning Research, 13, 230-235.

Beachle, T., and Earle, R. (2007). *Principios del entrenamiento de la fuerza y del acondicionamiento físico*. *[Principles of Force Training and Physical Conditioning]* Madrid: Panamericana.

Bernier, M. (2003). *Perturbation and agility training in the rehabilitation of soccer athletes*. Athletic Therapy Today, 8(3), 20 22.

Besier T., Lloyd D., Ackland D, Cochrane J. (2001). *Anticipatory effects on Knee joint loading during running and cutting maneuvers*. M.S.S.E.

Blazevich, A. J., & Jenkins, D. G. (2002). *Effect of the movement speed of resistance training on sprint and strength performance in concurrently training elite junior sprinters*. Journal of sports sciences, 20(12), 981-990.

Bompa, T. (1993). *Periodización de la fuerza*. *[Periodization of strength]* Rosario: Biosystem.

Bompa, T. (1995). *Teoría y metodología del entrenamiento*. *[Training Theory and Methodology]* Barcelona: Paidotribo.

Buttifant, D., Graham, K., & Cross, K. (2002). *Agility and speed in soccer players are two different performance parameters*. En Spinks, W., Reilly, T., & Murphy A. J. (Ed), Science and Football IV, pp. 329-332. London: Routledge.

Brughelli M, Cronin J, Levin G, Chaouachi A. (2008) *Understanding change of direction ability in sport: a review of resistance training studies.* Sports Med; 38(12):1045-63.

Chelladurai, P. (1976). *Manifestations of agility*. Canadian Association of Health, Physical Education, and Recreation, 42, 36 41.

Chelladurai P., Yuhasz M. and Sipura R. (1977). *The reactive agility test.* Perceptual and motor skills, 44, 1319-1324.

Christou, M., Smilios, I., Sotiropoulos, K., Volkalis, A. K., Pilianidis, T., & Tokmakidis, S. P. (2006). *Effects of resistance training on the physical capacities of adolescent soccer players*. The Journal of Strength and Conditioning Research, 20(4), 783-791.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale (NJ): Lawrence Erlbaum.

Colby, S., Francisco, A., Yu, B., Kirkendall, D., Finch, M., & Garrett, W. (2000). *Electromyographic and kinematic analysis of cutting maneuvers.* American Journal of Sports Medicine, 28, 234 240.

Coutts A. J., Murphy A. J., & Dascombe B. J. (2004). *Effect of direct supervision of a strength coach on measures of muscular strength and power in young rugby league players*. The Journal of Strength and Conditioning Research, 18(2), 316-323.

Cressey, E. M., West, C. A., Tiberio, D. P., Kreamer, W. J., & Maresh, C. M. (2007). *The effects of ten weeks of lower-body unstable surface training on markers of athletic performance*. The Journal of Strength and Conditioning Research, 21(2), 561-567.

Cronin, J., McNair, P. J., & Marshall, R. N. (2003). *The effects of bungy weight training on muscle function and functional performance.* Journal of sports sciences, 21(1), 59-71.

Davis, D. S., Barnette, B. J., Kiger, J. T., Mirassola, J. J., & Young, S. M. (2004). *Physical characteristics that predict functional performance in division I college football players*. The Journal of Strength and Conditioning Research, 18(1), 115-120.

Dean, W., Nishihara, M., Romer, J., Murphy, K. S., & Mannix, E. T. (1998). *Efficacy of 4-week supervised training program in improving components of athletic performance*. The Journal of Strength and Conditioning Research, 12(4), 238-242.

Deane, R. S., Chow, J. W. C., Tillman, M. D., & Fournier, K. A. (2005). *Effects of hip flexor training on sprint, shuttle run, and vertical jump performance*. The Journal of Strength and Conditioning Research, 19(3), 615-621.

Draper, J. A., & Lancaster, M. G. (1985). *The 505 test: a test for agility in the horizontal plane*. Australian Journal of Science and Medicine in Sport, 17(1), 15-18.

Farrow, D., Young, W. & Bruce, L. (2005). *The development of a test of reactive agility for netball: a new methodology*. Journal of Science and Medicine in Sport 8, 52-60.

Fry, A., Kraemer, W. J., Weseman, C., et al. (1991). *The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball*. The Journal of Strength & Conditioning Research, 5(4), 174-181.

Gabbett, T. J. (2006a). *A comparison of physiological and anthropometric* characteristics among playing positions in sub-elite rugby league players. Journal of Sports Sciences, 24(12), 1273-1280.

Gabbett, T. J. (2006b). *Performance changes following a field conditioning program in junior and senior rugby league player*s. The Journal of Strength & Conditioning Research, 20(1), 215-221.

Gabbett, T. J. (2006c). *Skill-based conditioning games as an alternative to traditional conditioning for rugby league players*. The Journal of Strength & Conditioning Research, 20(2), 309-315.

Gabbett, T., Georgieff, B., Anderson, S., et al. (2006). *Changes in skill and physical fitness following training in talent-identified volleyball players*. The Journal of Strength & Conditioning Research, 20(1), 29-35.

García Manso, M. (1999a). *Alto Rendimiento. Adaptación y Excelencia Deportiva. [Sports Adaptation and Excellence]* Spain: Gymnos.

García Manso, M. (1999b). La Fuerza. Spain: Gymnos.

Gastin, P. (2001). *Energy system interaction and relative contribution during maximal exercise*. Sports Medicine, 31(10), 725-741.

Gil, S. M., Gil, J., Ruiz, F., (2007). *Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process*. The Journal of Strength & Conditioning Research, 21(2), 438-445.

Gil, S., Ruiz, F., Irazusta, A., et al (2007). *Selection of young soccer players in terms of anthropometric and physiological factors*. The Journal of Sports Medicine and Physical Fitness, 47(1), 25-32.

Harman, E., Garhammer, J., & Pandorf, C. (2000). *Administration, scoring, and interpretation of selected tests. In T. R. Baechle, & R. W. Earle (Eds.), Essentials of strength training and conditioning (pp. 287-317)*. Champaign: Human Kinetics.

Harris, G., Stone, M., O'bryant, H., et al. (2000). *Short-term performance effects of high power, high force, or combined weight-training methods*. The Journal of Strength & Conditioning Research, 14(1), 14-20.

Hertel, J., Denegar, C. R., Johnson, P.D., Hale, S.A., Buckley, W.E. (1999). *Reliability of the cybex reactor in the assessment of an agility task. Journal of Sport Rehabilitation*, 8: pp.24-31

Hoffman, J. R., Cooper, J., Wendell, M., et al. (2004). *Comparison of Olympic vs. traditional power lifting training programs in football players*. The Journal of Strength & Conditioning Research, 18(1), 129-135.

Hoffman, J. R., Ratamess, N. A., Cooper, J. J., et al. (2005). *Comparison of loaded and unloaded jump squat training on strength/- power performance in college football players.* The Journal of Strength & Conditioning Research, 19(4), 810-815.

Hoffman, J., Ratamess, N., Klatt, M., et al. (2007). *Do bilateral power deficits influence direction-specific movement patterns?* Research in Sports Medicine, 15(2), 125-132.

[Image titled above 5-0-5 Agility test]. (s. f.). Source http://www.efdeportes.com/efd167/los-cambios-de-direccion-en-futbol-evaluacion.htm

[Image title above execution of the L-Test]. (s. f.). Source http://www.brianmac.co.uk/zigzag.htm

[Image titled above slalom test]. (s. f.). Source http://entrenamientopruebasfisicas.blogspot.com.ar/2010/07/agilidad-con-slalom.html

[Image titled above test Illinois agility]. (s. f.). Source http://www.sportsscience.co/sport/plyometric-training-for-agility-and-speed/

[Image titled above Illinois Agility Test, 2]. (s. f.). Source http://www.topendsports.com/testing/tests/illinois.htm

[Image titled above Back and forth test]. (s. f.). Source http://www.efdeportes.com/efd66/agil.htm

Kotzamanidis, C., Chatzopoulos, D., Michailidis, C., et al. (2005). *The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players*. The Journal of Strength & Conditioning Research, 19(2), 369-375.

Kraemer, W., Hakkinen, K., Triplett-Mcbride, N., et al. (2003). *Physiological changes with periodized resistance training in women tennis players*. Medicine & Science in Sports & Exercise, 35(1), 157-168.

Little, T., & Williams, A. G. (2005). *Specificity of acceleration, maximum speed, and agility in professional soccer players*. The Journal of Strength & Conditioning Research, 19(1), 76-78.

Malisoux, L., Francaux, M., Nielens, H., et al. (2006). *Stretch-shortening cycle exercises: an effective training paradigm to enhance power output of human single muscle fibers*. Journal of Applied Physiology, 100(3), 771-779.

Markovic, G. (2007a). Does plyometric training improve vertical jump height? A meta-analytical review. British Journal of Sports Medicine, 41(6), 349-355.

Markovic, G. (2007b). *Poor relationship between strength and power qualities and agility performance*. The Journal of Sports Medicine and Physical Fitness, 47(2146-JSM).

Markovic, G., Jukic, I., Milanovic, D., et al. (2007). *Effects of sprint and plyometric training on muscle function and athletic performance*. The Journal of Strength & Conditioning Research, 21(2), 543-459.

Martínez López, E. J. (2003). *Valoración de la agilidad. [Agility Valuation] Resultados y análisis estadístico en educación secundaria. [Statistical Results and Analysis in High School Education]* Source http://www.efdeportes.com/efd66/agil.htm

Mayhew, J. L, Piper, F. C., Schwegler, T. M., et al. (1989). *Contributions of speed, agility and body composition to anaerobic power measurement in college football players*. The Journal of Applied Sport Science Research, 3(4), 101-106.

McBride, J. M., Triplett-McBride, T., Davie, A., et al. (2002). *The effect of heavy-vs light-load jump squats on the development of strength, power, and speed*. The Journal of Strength & Conditioning Research, 16(1), 75-82.

Mcgee, K., & Burkett, L. (2003). *The National Football League combine: a reliable predictor of draft status?* The Journal of Strength & Conditioning Research, 17(1), 6-11.

Miller, M., Herniman, J., Ricard, M., et al. (2006). *The effects of a 6-week plyometric training program on agility.* Journal of Sports Science and Medicine, 5(3), 459-465.

Moreno, E. (1995). *Developing quickness part 2*. Strength and Conditioning, 17, 38 39.

Murphy, A. J., & Wilson, G. J. (1997). *The ability of tests of muscular function to reflect training-induced changes in performance*. Journal of Sports Sciences, 15(2): 191-200.

Negrete, R., & Brophy, J. (2000). *The relationship between isokinetic open and closed kinetic chain lower extremity strength and functional performance.* Journal of Sports Rehabilitation, 9, 46-61.

Oliver J.L., Meyers R.W. (2009) *Reliability and generality of measures of acceleration, planned agility, and reactive agility*. International Journal of Sports Physiology and Performance 4, 345-354

Pauole, K., Madole, K., Garhammer, J., Lacourse, M., and Rozenek, R. (2000). *Reliability and validity of the t-test as a measure of agility, leg power, and leg speed in college-aged men and women*. The Journal of Strength & Conditioning Research, 14(4), 443-450.

Peterson, M., Alvar, B., Rhea, M., et al. (2006). *The contribution of maximal force production to explosive movement among young collegiate athletes*. The Journal of Strength & Conditioning Research, 20(4), 867-873.

Polman, R., Walsh, D., Bloomfield, J., et al. (2004). *Effective conditioning of female soccer players*. Journal of Sports Sciences, 22(2), 191-203.

Reilly, T., Williams, A. M., Nevill, A., et al. (2000). *A multidisciplinary approach to talent identification in soccer.* Journal of Sports Sciences, 18(9), 695-702.

Rhea, M. R. (2004). *Determining the magnitude of treatment effects in strength training research through the use of the effect size*. The Journal of Strength & Conditioning Research, 18(4), 918-920.

Roetert, E. P., Garrett, G. E., Brown, S. W., et al. (1992). *Performance profiles of nationally ranked junior tennis players.* The Journal of Applied Sport Science Research, 6(4), 225-231.

Rudolf P., Václac B. (2006). Reliability and Validity of the intermittent anaerobic running test (IANRT). In Science and Football V. Edited by Thomas Reilly, Jan Cabri and Duarte Araújo. The proceedings of the Fifth World Congress on Science and Football. Routledge Editorial.

Sainz de Baranda Andujar, P. y Ayala, F. (2009). *Efecto agudo del estiramiento sobre la agilidad y coordinación de movimientos rápidos en jugadores de fútbol de División de Honor. [Acute Effect of Stretching on Agility and Coordination of Fast Movements in Soccer Players from the Honor Division]* Kronos; 17, 21-28.

Sayers, S. P., Harackiewicz, D. V., Harman, E. A., et al. (1999*). Cross validation of three jump power equations.* Medicine & Science in Sports & Exercise, 31(4), 572-577.

Semenick, D. (1990). *The T-test. The National Strength and Conditioning Association Journal*, 12(1), 36-37.

Sheppard, J. M., and Young, W. B. (2006). Agility literature review: classifications, training and testing. Journal of Sports Sciences, 24(9), 919-932.

Simenz, C., Dugan, C., Ebben, W., et al. (2005). Strength and conditioning practices of national basketball association strength and conditioning coaches. The Journal of Strength & Conditioning Research, 19(3), 495-504.

Sporis, G., Jukic, I., Milanovic, L., & Vucetic, V. (2010). *Reliability and factorial validity of agility tests for soccer players*. The Journal of Strength & Conditioning Research, 24(3), 679-686.

Tous Fajardo, J. (1999). *Nuevas tendencias en musculación. [New Musculature Trends]* Place: Editorial.

Tous Fajardo, J. (2003). *Master en entrenamiento en deportes de conjunto. [Master in Training in Team Sports] Entrenamiento de la fuerza en deportes de conjunto*. *[Force Training in Team Sports]* Barcelona: Universidad de Barcelona.

Tricoli, V. A., Lamas, L., Carnevale, R., et al. (2005). *Short-term effects on lower-body functional power development: weightlifting vs vertical jump training programs*. The Journal of Strength & Conditioning Research, 19(2), 433-437.

Verjhoshansky, Y., and Siff, M. (2000). Super entrenamiento. [Super Training] Barcelona: Paidotribo.

Young, W., Hawken, M., McDonald, L, et al. (1996). *Relationship between speed, agility and strength qualities in Australian Rules football*. *Strength Cond Coach*, 4(4), 3-6.

Webb, P., & Lander, J. (1983). *An economical fitness testing battery for high school and college rugby teams*. Sports Coach, 7(3), 44 46.

Wheeler, K.W. and Sayers, M.G. (2010). *Modification of agility running technique in reaction to a defender in rugby union*. Journal of Sports Science and Medicine 9, 445-51.

Young, W. B., Hawken, M., & McDonald, L. (1996). *Relationship between speed, agility, and strength qualities in Australian rules football.* Strength and Conditioning Coach, 4(4), 3 6.

Young, W. B., James, R., Montgomery, I., et al. (2002). *Is muscle power related to running speed with changes of direction?* The Journal of Sports Medicine and Physical Fitness, 42(3), 282-288.

Young, W. B., McDowell, M. H., Scarlett, B. J., et al. (2001). *Specificity of sprint and agility training methods*. The Journal of Strength & Conditioning Research, 15(3), 319.

Young W., Farrow D. (2006) *A review of agility*: practical applications for strength and conditioning. Strength and Conditioning Journal 28, 24-29

Wheeler KW, Sayers MG. (2010) *Modification of agility running technique in reaction to a defender in rugby union*. J Sports Sci Med. Sep 1; 9(3):445-51. eCollection 2010.