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Assessing the reliability and validity of agility testing in team sports: A systematic review.

Running title: **Agility testing in team sports: A systematic review.**

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ABSTRACT

The aims of this systematic review were to: 1) examine the reliability of the reactive agility tests and, 2) analyse the discriminatory validity of the agility tests. A literature search was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We explored PubMed, SPORTDiscus and Cochrane Plus databases looking for articles about agility in team sports. After filtering for article relevance, only 42 studies met the inclusion criteria; 37 of which assessed the reliability of agility tests and 22 assessing their validity. Reliability showed a high ICC in almost all studies (range 0.79-0.99) with the exception of two studies. In addition, other studies also assessed the reliability of decision time (ICC=0.95), movement time (ICC=0.92) and decision accuracy (ICC=0.74-0.93), all of which exhibited acceptable reliability. Furthermore, these data show high discriminatory validity, with higher performance players being faster than lower performance level players (mean = 6.4%, range = 2.1-25.3%), with a faster decision time (mean = 23.2%, range = 10.2-48.0%) with the exception of one study, and better decision accuracy (mean = 9.3%, range = 2.5-21.0%). Thus, it can be concluded that reactive agility tests show good reliability and discriminatory validity. However, most agility tests occur in simple contexts whereby only two possible responses are possible. Therefore, future research should consider creating more specific and complex environments which challenge the cognitive process of high-level athletes.

KEYWORDS

“reactive agility”, “performance”, “decision-making”, “speed”, “change of direction”.

INTRODUCTION

Team sports performance depends on both physical and cognitive factors. Players in team sports must constantly adapt their movements and actions to different game situations [1, 5, 8, 48, 52, 53, 58], highlighting the importance of agility, a concept which has evolved over time. Traditionally, agility has been defined as the ability to change direction quickly without taking into account the response to an external stimulus [2,15,35,39] and its importance in team sports performance, where changes in movement patterns are constant [5,69], has been proven in many studies [25,37,45,53,75]. However, Sheppard and Young [64] proposed a change in the paradigm arguing that changing direction always occur as a consequence to a specific sporting stimulus. Thus, the definition of agility was expanded taking into account both motor and cognitive factors, defining it as “a rapid whole-body movement with change of velocity or direction in response to a stimulus” [64]. This definition recognizes that both physical qualities and decision-making processes encompass the definition of true agility. Furthermore, it seems logical to think that the inclusion of cognitive factors should also be a determining factor in agility performance for team sports athletes. In recent years, there have been an increase in the number of studies researching reactive agility (RA) [3,4,9,14,16,19,26,29,30,47,60,65,67]. These studies have aimed to determine the discriminatory validity of the tests at different performance levels [16,21,23,30,31,38,44,45,49,52,58,71,73,74], determining the factors which may affect RA ability [17,24,55,56,68,69,75] and its trainability [6,10,18,26,33,46,72]. Furthermore, many of these studies have identified agility as being a different athletic quality to change of direction speed [12,20,40,44,51,57,66].

To understand the influence of both physical and cognitive factors, some studies [22,25,26,58] evaluated not only the time to complete the test, but also the decision time referred to as the time difference between the appearance of the elicited stimulus to the first response of the athlete, and decision accuracy defined as whether a player chose the correct timing gate, in response to a given stimulus [22].

In 2015, Paul et al. [48] published a review about testing, training and factors impacting agility performance. However, since 2015, a substantial amount of new research has been published, with new methods of evaluating and training agility, such as the SpeedCourt© and the "Stop'n'Go" agility tests. Therefore, a more up-to-date review encompassing new investigations relating to agility is warranted.

Therefore, the aims of this systematic review are to: 1) examine the reliability of the reactive agility tests used so far and, 2) analyse the discriminatory validity of the agility tests in relation to their ability to discriminate between different population groups (basically between different performance levels, age groups or type of sports) in team-sports players.

METHODS

Literature search

This systematic review was performed following the systematic review methodology proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [43], as presented in Figure 1. Studies were identified by searching within the electronic databases of PubMed, Cochrane Plus and SportDiscus (SportDiscus + MEDLINE). The search was conducted up to and including 7 January, 2019. The key words used in the search were "reactive agility", "agility", "team sports" and "test". The specific search strategy for PubMed was: (agility AND "team sports" with the additional filter of "Humans"). The specific search strategy for SportDiscus was: (agility AND "team sports"). The specific search strategy for Cochrane Plus was: (agility AND "team sports") in title, abstract or key words. Also, reference lists of retrieved full-text articles and recent reviews were examined to identify additional articles not found by the initial search.

A review was done on the selection of the studies in two consecutive screening phases. The first phase consisted of screening for (1) duplicates, (2) title, and (3) abstract. The second phase involved screening the full paper using the aforementioned inclusion criteria.

Inclusion and exclusion criteria

Eligibility criteria for inclusion in final analysis required one or both of the following: 1) a minimum of one test comparing results on two separate occasions under similar conditions (enabling reliability to be determined) or, 2) a comparison between different levels or playing ability (enabling validity to be determined). Moreover, studies were included if they: 1) were written in English or Spanish, 2) were published in peer-reviewed journals, 3) used an agility test whereby participants performed a change of direction or velocity in response to a cognitive stimulus or, 4) used subjects that were actively involved in team sports. Studies published in other languages, used unpublished data, reported results in animals, used subjects not involved in team sports, or used agility tests which didn't determine the reaction time or reliability/validity in response to a cognitive stimulus, were excluded.

No exclusions were made based on study design. Therefore, experimental and cross-sectional studies assessing reliability which compared the results of a test in two separate sessions or the validity of a given test comparing results between different groups, were included in this review.

Quality assessment

The methodological quality of studies was assessed using two different tools. For quality assessment of cross-sectional studies, we used the "quality assessment tool for observational cohort and cross-sectional studies" proposed by the National Heart, Lung and Blood Institute [63] (NIH National Heart, Lung and Blood Institute, website), grading articles on a scale of 14 points. The scale used to assess training interventions was adopted from a modified quality-assessment screening scoring system proposed by Brughelli et al. [8]. This is a 10-item scale (with a scoring range of 0-20) designed for rating the methodological quality of training intervention studies.

RESULTS

Included studies

The initial search from the different databases procured 322 articles and 2 more articles were identified through additional sources, giving a total of 324 records. After removing duplicates, 261 publications were kept for the article selection process. These 261 articles were screened for title and abstract relevance, which resulted in the exclusion of 181 articles. Subsequently, 80 full-text articles remained and were screened for eligibility using the inclusion and exclusion criteria, resulting in a further 38 articles being excluded. Twenty-eight were removed because they did not report any reliability or validity data, eight were removed because the selected test did not use a cognitive stimulus, and two were removed because subjects were not team sports athletes. This left 7 experimental studies and 35 cross-sectional studies which were included in this systematic review after applying the appropriate quality scoring assessment.

[Figure 1 near here]

Quality assessment results

Thirty-five studies were assessed using the "quality assessment tool for observational cohort and cross-sectional studies" proposed by the National Heart, Lung and Blood Institute (NIH National Heart, Lung and Blood Institute, website). From a maximum of 14 points, scores ranged from 3 to 6, with the exception of two studies: one that scored two points (Henry et al. [31]) and one that scored a single point (Gabbett & Benton [22]). Because this tool is not intended for sports sciences, the results obtained in the quality scoring assessment appear low; however, as the analyzed studies are descriptive in nature, some of the criteria were not applicable due to the type of variables measured (e.g., exposures measured only once over time or drop-outs after baseline). Thus, the questions related to these variables were deleted from the scale (questions 6, 7, 8, 10, 13) and the highest attainable score was 9. Furthermore, additional information such as the eligibility of subjects or blinding assessors, was not always reported.

Seven studies were assessed using the scale used to assess training interventions proposed by Brughelli et al. [8]. Quality scores ranged from 13-17, with the exception of one study that scored eight points (Bullock et al. [9]). Most studies provided a detailed description of their methods and interventions, and also used appropriate statistical analyses. However, some studies did not include inclusion and exclusion criteria [6,9,37,72], a control group [9], or test groups for similarity during baseline protocols [9-11,33,37,72].

Study characteristics

Reliability

A total of 37 studies assess the reliability of agility tests (Table 1). In total, 1724 participants (median = 36, maximum = 500, minimum = 8) were studied. Of these, the majority of the subjects were male (1541) with only 183 participants being female. In addition, studies determined test reliability using a wide range of sporting populations. Specifically, twelve studies used rugby or Australian football players, nine studies used soccer athletes and eight studies used basketball athletes. Furthermore, two studies used handball and netball players, respectively two with one study using softball players. Participant ages ranged from 10 to 28 years (mean = 18). The level of competition of subjects ranged from amateur to professional players, with most studies using high performance level players (e.g., professional or national level).

[Table 1 near here]

Validity

A total of 22 studies assessed the validity of agility tests (Table 2) by determining differences in performance levels on any given test. In total, 1554 participants (mean = 40, maximum = 500, minimum = 12) were studied. Of these, the majority of the subjects were male (1450) with only 104 participants being female. In addition, most studies determined test validity using rugby or Australian football players (9 studies), followed by soccer (5 studies) and basketball players (3 studies). Furthermore, one study was conducted using handball players, one with netball players, one with softball players and one with hockey players. Subject ages ranged from 10 to 27 years (mean = 17), with the level of competition ranging from amateur to professional. Most studies compared between performance levels, with the exception of three studies that compared between different age groups and one that compared between agility saturated sports (referring to a sport where athletes have to constantly change of direction in response to a specific sporting situation such as team, combat or racket sports) and non-agility saturated sports (such as track sports, swimming and gymnastics).

[Table 2 near here]

Study findings

Seventy-five per cent of the studies included tests where Y-shaped or T-shaped tasks were used, where athletes had to respond to a light (16 studies), human (16 studies) or video (7 studies) stimulus. In thirty-two of the tests, [10-12,19,24,25,27-29,31,38,41,47,49,55-62,65,67,69,71-74] each athlete had to perform either a single 45 or 90º change of direction. However, in more recent literature, most studies included more than a single change of direction and/or more than one reaction to a given stimulus. The distance of the tests ranged between 5 and 159 m, but most had a distance that ranged between 7 and 12 m. When reporting test reliability, the intraclass correlation coefficient (ICC) was reported, considering a value of 0.75 or above as an indicator of a good reliability [50]. For RA tests using a light stimulus, ICC ranged between 0.79 and 0.91, for tests using a human stimulus, ICC ranged between 0.79 and 0.99, with the exception of Holding et al. [33] that used a real situation simulating a 1 vs. 1, reporting an ICC of 0.64. When considering video stimulus, ICC ranged between 0.81 and 0.83, except Young et al. [74] who compared between a video in response to a human movement or the direction of an arrow, and reported an ICC of 0.33 and 0.11 for human and arrow stimulus, respectively. ICC for the decision time showed a value of 0.95, while the decision accuracy ranged between 0.74 and 0.93, and the movement time reported an ICC value of 0.92.

Agility tests used in the included studies seem to have a high level of discriminatory validity. All studies found the highest level of test performance in players competing at the highest competition level. Highest performing players were 6.4% faster than their lower performing counterparts, ranging from 2.1 to 25.3%. Furthermore, higher performing players showed faster decision time (mean = 23.2%, range = 10.2-48.0%), with the exception of Gabbett et al. [23] who found a slower decision time on players of lower performance, perhaps because of the slightest difference in performance level between groups, confirmed by starters and non-starters. Players with higher performing levels also had a better score on decision accuracy across the different tests using different stimulus (mean = 9.3%, range = 2.5-21.0%) than lower performing players. Effect size (ES) data was calculated in all studies to determine the magnitude of difference between groups and classified as trivial (<0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0), and very large (2.0-4.0) [34] finding in most cases moderate, large and very large ES (Table 2).

DISCUSSION

The aims of this systematic review were to examine the reliability of the RA test used so far and to analyze the discriminatory validity of the agility test in relation to their ability to discriminate between different population groups in team-sports players. Good reliability was found in almost all studies regardless the type of stimulus used (light, human or video). Also, high discriminatory validity was found, being able to differentiate between different performance levels and different age categories.

Reliability of the tests

Light stimulus

A wide variety of studies included in this review evaluated agility through the response to a light as an elicited stimulus [3,4,6,11,12,16,29,31,38,47,49,55,59-61,67]. The main advantage of using this stimulus is that the signal can be programmed to appear at the same moment each time throughout the test, which is likely to result in higher levels of reproducibility [48]. However, one disadvantage is that access to this type of technology is expensive and arguably impractical. Nevertheless, the number of studies which have determined agility in response to a light stimulus has increased due improvements in technology [48]. This is supported in the current review, which reported reliability data for sixteen studies using a light stimulus, in comparison to Paul et al. [48] who reported reliability for seven studies using a light stimulus. In summary, the evolution of technology has allowed us to assess agility with a high test-retest reliability through more advanced technology systems and with greater accessibility.

The number of studies evaluating agility performance in the last three years through a single change of direction in response to a sole cognitive stimulus [11,29,31,38,47,59,61], and using a stop and go test in which the player must react consecutively to the appearance of different stimuli [3,4,6,12,16,49,55,60,67], have also increased. Sekulic et al. [60] were the first who introduced this new test named "Stop'n'Go" with the justification that players in team sports have to repeatedly change direction during the game through “Stop’n’Go” movements, including moments of zero-velocity. A similar novel method has also appeared recently; namely the "SpeedCourt©". This test consists of a square formed of nine plates: eight of them forming a square and one central piece, where the athlete has to rapidly change direction to touch the plate that is lit. Subsequently, when a plate has been touched, another one lights up. Depending on the test, the athlete has to respond to a different number of stimuli that appear consecutively. In their study, Duking et al. [16], assessed the reliability of three different tests in response to eight, 15 or 43 stimuli in team sport athletes, using the SpeedCourt© system (mean duration of the test was 7-45 seconds). Results showed that all three tests were able to assess agility reliably (ICC > 0.79; CV < 5%).

Despite most studies employing a Y-shaped test with angles of 45 [11,29,31,38,47,61] and 90º (or almost 90º) [57,67], other studies have used similar shapes combining both 45 and 90° cutting angles. This results in four possible outcomes; two to the right at 45 and 90º, and two to the left at 45 and 90º [49,54,60]. Further to this, other authors such as Duking et al. [16] and Born et al. [6], have used the SpeedCourt© with different cutting angles and distances. Duking et al. [16] used three tests including different distances and number of stimuli to react to, with a total length of 16.5 m, 33 m and 159 m, with seven, 13 and 41 change of direction movements, respectively and involving turns of 45 to 180°. Born et al. [6] used a test which incorporated nine change of direction movements ranging from 10 to 180°. Benvenuti et al. [4] carried out an agility test in a square shape with the stimuli at the corners of the square (ICC = 0.80); Bekris et al. [3], carried out an agility test while dribbling a ball in a cross shape (ICC = 0.90); and Coh et al. [12] used 4 different shapes (frontal, universal, semi-circular and lateral) also reporting high reliability in all of them (ICC = 0.81-0.85).

Thus, all tests that used a light stimulus found acceptable reliability values (ICC > 0.70) [70]. However, the main disadvantage of this method is the non-specificity of the stimulus and its performance in very confined surroundings with few possibilities of decision making (in most of them, movement to the left or the right).

Human stimulus

Sixteen studies included in the current review assessed agility through the response to the movement from a researcher or another player as an elicited stimulus [10,14,24,25,27,28,33,41,56-59,65,71-73]. The main advantage of using this type of agility test is its accessibility and the greater specificity that the stimulus represents. However, it must be acknowledged that this method likely presents greater variability in the presentation time of the stimulus to the player depending on the human's movement. To test that hypothesis, Sheppard et al. [65] checked the inter-rater reliability of the RA test comparing the results achieved by the players on two different days, with two different testers. Results showed no significant differences between the two raters (r = 0.90).

Most of the tests using these methods used a Y-shape with a change of direction at either 45 [41,71-73] or ~90º [10,24,25,27,28,56-59,65], with all of them showing a high ICC (range = 0.79-0.99). Despite the greater specificity of this stimulus, the movement and decision making in all these tests is relatively simple, with only two possibilities to change direction (i.e., to the left or right) in reaction to four possible scenarios displayed by the tester, two of them resulting in a change of direction movement to the right gate, and the other two resulting in a change of direction to the left gate. The tester displayed one of four possible scenarios for the athlete to react to; however, the athletes did not explicitly know this. All possibilities involved steps of approximately 0.5 m and were presented in a random order that was different for each athlete: 1) step forward with right foot and change direction to the left, 2) step forward with the left foot and change of direction to the right, 3) step forward with the right foot, then left, and change of direction to the right and, 4) step forward with the left foot, then right, and change of direction to the left [65]. This kind of test has been the most commonly used and has been shown to be reliable in a test-retest design (ICC = 0.79-0.99), between different testers (r = 0.90), in decision accuracy (ICC = 0.93) and in decision time (ICC = 0.95). Furthermore, the assessment of the decision accuracy in the test is especially important to assess how many times players choose the correct option rather than guessing. The use of a specific stimulus like the movement of another human may provide athletes with vital kinematic information relating to posture, position and movements of an opponent while they are still moving. In turn, this may assist in faster decision-making and improve the subsequent motor response [59].

Drake et al. [14] and Holding et al. [33] used a more realistic 1 vs. 1 situation to evaluate agility, in an open situation involving a real attacker and defender, with opposite goals. The attacker was instructed to cross a marked line without being touched by the defender, and the defender's role was to prevent the attacker from scoring. Holding et al. [32,33] used the total time spent for the defender's and the attacker to cross the line, and only considered attempts valid when both players crossed the same exit gate, reporting moderate reliability in a test-retest design (ICC = 0.64). In contrast, Drake et al. [14] gave a score to the attacker and the defender depending on the success rate of the action finding a high inter-rater reliability (ICC = 0.82-0.92).

Those tests which present human movements as a stimulus, show a more realistic and specific stimulus to the sporting context and also report high reliability. One of the potential reasons for this high reliability could be related to the simplicity of the test. It would be interesting to create more complex versions with a higher number of possible outcomes to get closer to the real context of competition and subsequently determine if reliability remains acceptable. Also, in order to control the variability of test results, it is important to find a way to control the presentation time of the stimulus by controlling the decision time of the athlete, taking into account the difference between the first tester’s movement to which the athlete has to react to, and the first movement in the same direction made by the athlete.

Video stimulus

The studies that use a video stimulus are less frequent in this review [9,19,26,31,62,69,74]. All tests included the use of video, carrying it out by recording a certain number of actions of an athlete, to which the player doing the test must respond, usually from a defensive perspective. Again, with Y-shape tests commonly employed, test-retest reliability was high (ICC = 0.81-0.83). In the first study that used a response to a video stimulus [19] performed by rugby players, athletes had to respond from a defensive role to a pass made by an attacker to the left or right. Despite a high reliability reported for this test (ICC = 0.83), the ability of challenging the perceptive ability of high-level players through the few scenarios presented with a possible response was considered questionable. To resolve this issue, Serpell et al. [62] and Henry et al. [30,31] introduced a greater variability of stimuli, including the possibility of feinting by the player on the video and a higher number of situations to which respond. The goal of the player doing the test was to cross the gate in a defensive reaction to the movement by the player on the video, and showed a high test-retest reliability (ICC = 0.81-0.82). For its part, Young et al. [74] compared in a Y-shape test, the reaction to a specific sporting stimulus (an attacker's movement) and the reaction to a non-specific stimulus (an arrow) in elite and sub-elite Australian Football players. In both tests, a very low test-retest reliability was reported, being lower in the agility test in response to an arrow (ICC = 0.10) than in response to an opponent (ICC = 0.33). Although speculative, this may be due to the necessity of needing a greater familiarization time with the test by the players. Finally, Bullock et al. [9] created the reactive motor skill test (RMST) for soccer players in which the speed, the passing ability, and the RA were evaluated as a whole. Reactive agility was the final part of the test, in which all players (after the passing ability component), had to react by taking on the role of a defender to the movement of a player dribbling the ball to the left or the right. When considered as a whole, test-retest reliability showed acceptable variability (CV = 2.4%) with a CV of 2.3% reported for the RA component, specifically.

When considering the available body of evidence, all RA tests reported high test-retest reliability, so the use of a human stimulus may potentially be considered more advantageous than using a light stimulus, given the greater accessibility and ecological validity of using human subjects. However, future research should consider the creation of new test that includes more resulting scenarios, with higher complexity in the decision-making process for athletes, especially considering the importance of the cognitive component of agility performance.

Validity of the tests

Different performance levels

All studies included in this review, with the exception of one [23], show faster agility times for players of a higher performance level (mean = 6.4% faster, range = 2.1-18.2%) [19,22,29,30,38,44,58,61,65,71,73,74] compared with players of a lower performance level. We found the exception to be a study by Gabbett et al. [23], who showed no significant differences were found between starters and non-starter players, which may potentially be explained by the high level of all players in the sample. Notwithstanding, only better results were found on the response accuracy of the agility test with a better performance of the starter players (2.5% better, ES = 0.29); however, no significant differences between group was evident.

When assessing agility, the evaluation of total time, decision time, the accuracy of the decision, and the movement time is important for practitioners, because of obviating them could lead to the misinterpretation of key aspects in the results [22], for example, the non-inclusion of the assessment of decision accuracy could promote athletes guess one option rather than choosing the correct one. In addition, it can give us clues about the reason why there is a faster or slower test performance and about a player's weaknesses in terms of movement speed or decision times [25]. Gabbett et al. [25] used this information to differentiate players in four groups according to the results of movement time and decision time. Consequently, results created a combination of categories of ‘fast and slow’ thinkers, and ‘fast and slow’ movers, which provided useful information to coaches in relation to the specific weaknesses of each player. Collectively, all studies included found a faster decision time (mean = 23.2%, range = 10.2-48.0%), and better decision accuracy (mean = 9.3%, range = 2.5-21.0%) in those groups of a higher performance level [25,26,58,22]. This may be because players of a higher performing level are able to take out relevant information and postural cues to give a faster response to any kind of stimulus that may warrant a specific decision (e.g., human or light stimulus).

Seven studies used planned and non-planned agility tests to evaluate the discriminatory validity of the test between different performance level. These studies found no significant differences in planned agility tests between levels, but a higher performance in non-planned agility tests in the players competing at a higher level [19,25,38,58,61,62,65]. This may be due to the team sports player's need to constantly adjust their movements to situations that arise during matches, such as the movement of an opponent, the ball or their teammates, highlighting the importance of the cognitive processes during such actions. Scanlan et al. [58] suggest that anticipation, visual scanning, pattern recognition and situational knowledge should be central factors to distinguish between different the performance level of players, and a key consideration for team selection in team sport athletes. The only study which found significant differences between different group-levels in planned agility tests was Green et al. [29], finding that club level rugby players were faster in change of direction speed (ES = 2.23) and in reactive agility test (ES = 1.14) than academy players.

Other studies have evaluated the difference between two groups of different performance level in an agility test in response to a specific (human) or non-specific (light) stimulus [44,74]. Results concluded that the non-specific stimulus was unable to find significant differences between groups; however, significant differences were found between groups in the use of a human stimulus, with the higher-level group obtaining better results. Young et al. [74] used a video stimulus, to differentiate the performance between reacting to an arrow that pointed in a given direction or to an attacking player, using Australian football players. For the arrow condition, no differences were evident between groups, but in the agility test in reaction to an opposition athlete, elite players performed better than secondary school players [74]. Similarly, Morland et al. [44] used two different tests; one in reaction to a light stimulus and another one in reaction to a human stimulus, representing an opponent. Better performance was seen from the higher level players in the test involving a human stimulus; however, no significant differences were seen between groups during the light stimulus test.

These results bring out a greater ability to anticipate an opponent's action through the observation of postural cues of higher-level players [58,73], that probably cannot be obtained through the use of general or non-specific stimulus such as lights or arrows. Even so, other studies that use a general stimulus (light) also reported improved test scores in players of a higher competitive level [29,38,61,62]. It is worth noting however, that none of these studies reported metrics such as decision time, decision accuracy or movement time, which likely ignores some of the reasoning for faster agility times.

Most of the tests used to evaluate agility use fairly stable surroundings, where there is small variety of stimuli to respond to and only a few chances of response. Henry et al. [30] wanted to introduce the evaluation of more complex surroundings and a greater variability of stimuli by including a response to a video of an opponent feinting (or not). They found a very large difference between feint and non-feint agility test performance (ES = 3.06), finding worse results in the feint-agility test performance in comparison to the non-feint agility test. It was suggested that this could be due to a greater cognitive complexity in the test. That said, in both tests, enhanced performance was found in the higher performance group who were 5.5% faster in feint trials (ES=0.52) and 2.1% faster in non-feint trials (ES = 0.47). In addition, the same group also showed faster decision times, being 10.2% faster in feint trials (ES = 0.59) and 12.0% faster in non-feint trials (ES = 0.73), showing less loss of performance in the feint agility test than lower-skilled players. Nevertheless, lower performance level players were slightly faster in the inter-response interval between the first and the second decisions in reaction to the feint movement, probably as a result of a faster first decision and in consequence of a greater time running in an incorrect direction. As a result, the authors concluded that the result of a better performance in the non-feint agility test was due to shorter decision times of the higher skill level group; and in the feint agility test, shorter movement time accounts for most of this [30].

It is generally accepted that an agility test can distinguish between performance levels in all team sports. The majority of these studies used rugby players, finding a better result in the agility test by the higher performing group [22,23,25,29,62], but the same results were found in studies carried out on Australian football [30,65,73,74], soccer [3,21,49,71], basketball [38,58,61], hockey [44], netball [19], softball [26] and handball [67]. It seems to make sense due to the intermittent nature of these sports, in which players are constantly involved in high-intensity game actions where they must respond to a very complex game situations depending on the position of teammates, adversaries and ball.

Different age categories

Some studies have assessed the discriminatory validity of agility tests by distinguishing between different age groups [3,21,49,62], and all of these studies found that older and more experienced athletes were faster than their younger counterparts. Serpell et al. [62] compared a Y-shaped video RA test between a first grade Australian National Rugby League group and an under-20 Australian National Youth Competition group. The senior group achieved faster perception and response times, with a mean negative value showing a higher anticipatory capacity, and a faster total time in the agility test than the junior group. Also, this study assessed a planned agility test, but no significant differences were evident between groups. When considering these data, it has been proposed that differences in agility performance between older and younger athletes can be attributed to perception and response time. Furthermore, it is suggested that players who perform at a higher level are able to identify key kinematic cues earlier; thus, having a quicker reaction [19,25,26,30,38,44,58,62,71,73,74].

Fiorilli et al. [21] also used a Y-shaped agility test but in response to a light stimulus, and compared the test performance between 4 different age groups (under-12, under-14, under-16 and under-18) finding improved test performance in older age groups, being the under-18 group faster in all agility test than the other age categories. They also included the measure of the REAC-INDEX, understood as the difference between the results of a Y-shaped reactive agility test minus the planned Y-shaped test, which showed that the under-18 group had a better index than younger groups. The under-12 group was slower in both tests, and had a significantly higher value than the other age groups for the REAC-INDEX. Unsurprisingly, this is likely due to the lower physical development and sport-specific experience of the younger groups: an inexperienced technique and lack of movement strategies [21]. Furthermore, the under-18 group were able to distinguish and respond better to unpredictable game situations with a faster perception and decision time and a better and more stable technique to changes of direction; thus, obtaining better results [21,71]. Moreover, it was shown that correlations between COD and agility were larger in younger athletes ($r=0.61$, $p<0.01$ in under-14 group), but may progressively decreases with age ($r=0.31$ in the under-18 group) [21]. It shows a low and non-significant correlation in the under-18 group, which suggests that when athletes reach physical maturation and proficient soccer experience, change of direction speed and reactive agility represent independent skills, highlighting the importance of cognitive factors [21].

Pojskic et al. [49] compared a "Stop'n'Go" agility test between under-17 and under-19 groups and also found the older group was faster in the agility test. These differences were not found in jumping, sprinting or reactive strength tests. Consequently, these results may suggest that differences can be due to the higher expertise and a longer involvement in structured soccer training from the under-19 group (9.3 vs 11.9 years of training). Finally, only one of the studies included dribbling a ball during the agility test [3] comparing between four ages groups (under-10, under-12, under-14 and under-16) and measured the total time to completion between groups. Results showed progressively faster times in older groups supported by the greater visual tracking capability of the more experienced group and the greater dependency on visual feedback at increased speeds during dribbling [3].

As seen in this review, agility tests are also able to distinguish between different age groups; older and experienced players are typically able to achieve superior results in agility tests than their younger and less experienced counterparts. However, one limitation of many studies is the use of a light as the response stimulus. This aspect can reduce the advantage of the more experienced athletes, because it does not let them use specific cues associated with the sport to anticipate and react faster [7,38]. Furthermore, the lack of information about the decision time, movement time and decision accuracy of agility tests makes it difficult to determine if better test performance is because of better perception and response capacity, or because of a higher performance in the motor task itself. Future research should include specific stimuli and more information about decision time, movement time and decision accuracy to extract as much information during the testing and training process as possible.

Team vs individual athletes

Sekulic et al. [60] compared male and female athletes divided into two different groups: one formed by athletes involved in agility saturated sports (such as team, combat and racket sports); and another one formed by athletes involved in non-agility saturated sports (such as track sports, swimming and gymnastics). The agility test used was a "Stop'n'Go" agility test in which athletes had to respond to five light stimuli with five different changes of direction. The results for male athletes were somewhat expected; those involved in team sports achieved a better performance than those who were not. The reason for such differences could be the constant involvement in perception and reactive actions in team sports. Nevertheless, there were not significant differences between those women involved in agility saturated sports and non-agility saturated sports. But, when analyzing the results of the test, they found that if they shortened the duration of the agility test results to the first three courses instead of the five courses that compose the initial test, they were then able to find a significant difference between both groups, with a mean of 6.71 seconds for team sport athletes vs. a mean of 7.55 achieved by non-team sports athletes (ES = -0.88, p = 0.03). They suggest that the higher influence of other physical factors (e.g., anaerobic lactate capacity) may have confounded the results, and potentially had a greater influence than the decision making capacities. Following that suggestion, they propose to reduce the duration of the test to a better assessment of agility in female athletes; thus, reducing the influence of this other physical factors in the results achieved in the test.

Therefore, it seems that agility might differentiate between team sports players and individual sports players due to reasons such as: a constant interaction with the environment, and different game situations and a necessary readjustment of the movement depending on the game stimuli to which they must respond, such as the position of teammates, opponents or ball. However, until now we have only found one study assessing this difference; thus, further research in this regard is suggested.

In conclusion, agility tests have shown a good reliability irrespective of the type of stimulus used. The advantage of using lights is the increase of the reliability due to the control of the moment when the stimulus appears, however, it is presented as a non-specific stimulus. Seems better to use either a video representing an opposing player's action, or to use a researcher or player simulating an opponent. In this case, the main disadvantage of the video stimulus is that it is shown in 2D, which causes a loss of movement information and postural hints that we do obtain using a real opponent. So, the use of a human stimulus seems to be the more valid ecological stimulus for the evaluation of the agility test.

Many studies have shown the performance difference between a pre-planned agility test and a non-planned agility test, showing them to be different abilities. However, most agility tests occur in fairly simple contexts, in which there is only one stimulus and there are only two possible responses (left or right), such as the extended Y-shaped agility test. In recent years, tests have been evolving and "Stop'n'Go" agility tests have been created, being tests where there are back-and-forth races needing the response to more than one stimulus, and more complex surroundings have been created, such as the use of feints during the opponent's action to which respond. Nevertheless, it is still necessary to create new tests, with a greater number of possible responses, and through using specific stimuli.

To assess agility is also important to consider the decision time, movement time and decision accuracy in order to have more data to give us clues to know why there is a higher or lower performance in the test, differentiating between a possible cognitive response, motor response or both. More research is necessary to find new reliable methods to determine and evaluate the perception and response time, since some methods are presented as subjective or not duplicable. Additionally, an appropriate time of familiarization with the test might be needed to avoid a misinterpretation of the results.

Agility tests have also shown a great discriminatory ability between performance levels and age groups: the higher the performance level and sports experience, the better the tests results obtained. Those differences tend to be clearer when the stimulus to which athletes respond to is more specific, so that players with greater experience or higher level are able to perceive postural clues and anticipate movement, giving much faster decision times.

PRACTICAL APPLICATIONS

Strength and conditioning coaches have to consider the inclusion of the evaluation of reactive agility, as it is a determinant capacity in team sports performance, taking into account not only the movement time, but also the decision time and decision accuracy in order to know the influence of the cognitive factors in the results of the test. Moreover, the inclusion of specific training of agility in reaction to a specific stimulus additionally to change of direction speed training, seems crucial to improve team sports performance as it has been proved to be different abilities. Finally, the difficulty of the cognitive task has to be adapted to the level of performance and the experience of players, trying to develop more complex and specific surroundings in higher level athletes to really challenge their perception and decision-making abilities.

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REFERENCES

1. Abernethy B, Thomas KT, Thomas JT. Strategies for improving understanding of motor expertise [or mistakes we have made and things we have learned!!]. In: Cognitive issues in motor expertise. Vol 102; 1993:317-356.
2. Barrow HM, McGee R, Tristschler K. Practical Measurement in Physical Education and Sport. Lea & Febiger; 1989.
3. Bekris E, Gissis I, Kounalakis S. The dribbling agility test as a potential tool for evaluating the dribbling skill in young soccer players. Res Sport Med. 2018;26(4):425-435.

4. Benvenuti C, Minganti C, Condello G, Capranica L, Tessitore A. Agility assessment in female futsal and soccer players. Medicina (Kaunas). 2010;46(6):415-420.
5. Bloomfield J, Polman R, O'Donogue P, McNaughton L. Effective speed and agility conditioning methodology for random intermittent dynamic type sports. J Strength Cond Res. 2007; 21(4):1093-1100.
6. Born DP, Zinner C, Düking P, Sperlich B. Multi-directional sprint training improves change-of-direction speed and reactive agility in young highly trained soccer players. J Sport Sci Med. 2016;15(2):314-319.
7. Bruce L, Farrow D, Raynor A, Mann D. But I can't pass that far! The influence of motor skill on decision making. Psychol Sport Exerc. 2012;13(2):152-161.
8. Brughelli M, Cronin J, Levin G, Chaouachi A. Understanding Change of Direction Ability in Sport: A Review of Resistance Training Studies. Sport Med. 2008;38(12):1045-1063.
9. Bullock W, Panchuk D, Broatch J, Christian R, Stepto NK. An integrative test of agility, speed and skill in soccer: Effects of exercise. J Sci Med Sport. 2012;15(5):431-436.
10. Chaalali A, Rouissi M, Chtara M, et al. Agility training in young elite soccer players: promising results compared to change of direction drills. Biol Sport. 2016;33(4):345-351.
11. Cochrane DJ. The effect of acute vibration exercise on short-distance sprinting and reactive agility. J Sport Sci Med. 2013;12(3):497-501.
12. Čoh M, Vodičar J, Žvan M, et al. Are Change-of-Direction Speed and Reactive Agility Independent Skills Even When Using the Same Movement Pattern? J Strength Cond Res. 2018;32(7):1929-1936.
13. Docherty D, Wenger HA, Neary P. Time-Motion Analysis Related to the Physiological Demands of Rugby. J Hum Mov Stud. 1988; 14:269-277.
14. Drake D, Kennedy R, Davis J, Godfrey M, MacLeod S, Davis A. A Step towards a Field Based Agility Test in Team Sports. Int J Sport Exerc Med. 2017;3(6):1-7.
15. Draper JA, Lancaster MG. The 505 test: A test for agility in the horizontal plane. Aust J Sci Med Sport. 1985; 17(1):15-18.

16. Düking P, Born DP, Sperlich B. The speedcourt: Reliability, usefulness, and validity of a new method to determine change-of-direction speed. Int J Sports Physiol Perform. 2016;11(1):130-134.
17. Edwards S, Austin AP, Bird SP. The role of the trunk control in athletic performance of a reactive change-of-direction task. J Strength Cond Res. 2017;31(1):126-139.
18. Engelbrecht L, Terblanche E, Welman KE. Video-based perceptual training as a method to improve reactive agility performance in rugby union players. Int J Sport Sci Coach. 2016;11(6):799-809.
19. Farrow D, Young WB, Bruce L. The development of a test of reactive agility fot netball: A new methodology. J Sci Med Sport. 2005;8(1):52-60.
20. Fiorilli G, Iuliano E, Mitrotasios M, et al. Are change of direction speed and reactive agility useful for determining the optimal field position for young soccer players? J Sport Sci Med. 2017;16(2):247-253.
21. Fiorilli G, Mitrotasios M, Iuliano E, et al. Agility and change of direction in soccer: differences according to the player ages. J Sport Med Phys Fit. 2017;57(12):1597-1604.
22. Gabbett T, Benton D. Reactive agility of rugby league players. J Sci Med Sport. 2009;12(1):212-214.
23. Gabbett TJ, Jenkins DG, Abernethy B. Relative importance of physiological, anthropometric, and skill qualities to team selection in professional rugby league. J Sports Sci. 2011;29(13):1453-1461.
24. Gabbett TJ, Jenkins DG, Abernethy B. Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players. J Sports Sci. 2011;29(15):1655-1664.
25. Gabbett TJ, Kelly JN, Sheppard JM. Speed, change of direction speed, and reactive agility of rugby league players. J Strength Cond Res. 2008; 22(1):174-181.
26. Gabbett T, Rubinoff M, Thorburn L, Farrow D. Testing and Training Anticipation Skills in Softball Fielders. Int J Sports Sci Coach. 2007;2(1):15-24.

27. Gabbett TJ, Sheppard JM, Pritchard-Peschek KR, Leveritt MD, Aldred MJ. Influence of closed skill and open skill warm-ups on the performance of speed, change of direction speed, vertical jump, and reactive agility in team sport athletes. J Strength Cond Res. 2008;22(5):1413-1415.

28. Gabbett TJ, Ullah S, Jenkins D, Abernethy B. Skill qualities as risk factors for contact injury in professional rugby league players. J Sports Sci. 2012;30(13):1421-1427.

29. Green BS, Blake C, Caulfield BM. A valid field test protocol of linear speed and agility in rugby union. J Strength Cond Res. 2011;25(5):1256-1262.

30. Henry G, Dawson B, Lay B, Young W. Effects of a feint on reactive agility performance. J Sports Sci. 2012;30(8):787-795.

31. Henry G, Lay B, Young WB. Validity of a Reactive Agility Test for Australian Football. Int J Sports Physiol Perform. 2011;6(4):534-545.

32. Holding R, Meir RA, Zhou S. Assessing response time reliability in a simple 1-v-1 defensive scenario relevant to rugby football. J Aust Strength Cond. 2014;22(5):111-115.

33. Holding R, Meir R, Zhou S. Can Previewing Sport-Specific Video Influence Reactive-Agility Response Time? Int J Sports Physiol Perform. 2017;12(2):224-229.

34. Hopkins WG, Marshall SW, Batterham A;, Hanin J (2009). Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 41:3-13.

35. Johnson BL, Nelson JK. Practical Measurements for Evaluation in Physical Education. Minneapolis: Burgess; 1969.

36. Keogh JWL, Weber CL, Dalton CT. Evaluation of Anthropometrix, Physiological, and Skill-Related Tests for Talent Identification in Female Field Hockey. Can J Appl Physiol. 2003; 28(3):397-409.

37. Little T, Williams AG. Specificity of acceleration, Maximum Speed, and Agility in Professional Soccer Players. J Strength Cond Res. 2005;19(1):76-78.

38. Lockie RG, Jeffriess MD, McGann TS, Callaghan SJ, Schultz AB. Planned and Reactive Agility Performance in Semiprofessional and Amateur Basketball Players. Int J Sports Physiol Perform. 2014;9(5):766-771.

39. Mathews DK. Measurement in Physical Education. 5th ed. W.B. Saunders; 1978.
40. Matlák J, Tihanyi J, Rácz L. Relationship between Reactive Agility and Change of Direction Speed in Amateur Soccer Players. J Strength Cond Res. 2016;30(6):1547-1552.
41. Meir R, Holding R, Hetherington J. Impact of the Two-Handed Rugby Ball Carry on Change of Direction Speed and Reactive Agility: Implications for Sport Specific Testing. Int J Sports Sci Coach. 2014;9(5):1181-1190.
42. Meir R, Newton R, Curtis, E, Fardell M, Butler B. Physical Fitness Qualities of Professional Rugby League Football Players: Determination of Positional Differences. J Strength Cond Res. 2001; 15:450-458.
43. Moher D. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. Ann Intern Med. 2013;151(4):264.
44. Morland B, Bottoms L, Sinclair J, Bourne N. Can change of direction speed and reactive agility differentiate female hockey players? Int J Perform Anal Sport. 2013;13(2):510-521.
45. Mujika I, Santiesteban J, Impellizzeri FM, Castagna C. Fitness determinants of success in men's and women's football. J Sports Sci. 2009; 27(2):107-114.
46. Nimmerichter A, Weber N, Wirth K, Haller A. Effects of Video-Based Visual Training on Decision-Making and Reactive Agility in Adolescent Football Players. Sports. 2016;4(1):1; https://doi.org/10.3390/sports4010001.
47. Oliver JL, Meyers RW. Reliability and Generality of Measures of Acceleration, Planned Agility, and Reactive Agility. Int J Sports Physiol Perform. 2009;4:345-354.
48. Paul DJ, Gabbett TJ, Nassis GP. Agility in Team Sports: Testing, Training and Factors Affecting Performance. Sport Med. 2015;46(3):421-442.
49. Pojskic H, Åslin E, Krolo A, et al. Importance of reactive agility and change of direction speed in differentiating performance levels in junior soccer players: Reliability and validity of newly developed soccer-specific tests. Front Physiol. 2018;9(MAY):1-11.
50. Portney, L and Waltkins, M. Foundations of Clinical Research:Application to Practice (2nd ed.). Upper Saddle River, NJ: Prentice Hall, 2000.

51. Rauter S, Simenko J, Zvan M, et al. Analysis of reactive agility and change-of-direction speed between soccer players and physical education students. Hum Mov. 2018;2018(2):68-74.

52. Reilly T., Williams AM, Nevill A, Franks A. A multidisciplinary approach to talent identification in soccer. J Sports Sci. 2000; 18:695-702.

53. Salaj S, Markovic G. Specificity of jumping, sprinting, and quick change-of-direction motor abilities. J Strength Cond Res. 2001; 25:1249-1255.

54. Sattler T, Šajber D. Change of Direction Speed and Reactive Agility Performance - the Reliability of a Newly Constructed Measuring Protocols: A Brief Report. Kinesiol Slov. 2015;21(2):31-38.

55. Sattler T, Sekulić D, Spasić M, et al. Analysis of the Association between Motor and Anthropometric Variables with Change of Direction Speed and Reactive Agility Performance. J Hum Kinet. 2015;47(1):137-145.

56. Scanlan A, Humphries B, Tucker PS, Dalbo V. The influence of physical and cognitive factors on reactive agility performance in men basketball players. J Sports Sci. 2013;32(4):367-374.

57. Scanlan AT, Tucker PS, Dalbo VJ. A comparison of linear Speed, closed-skill agility, and open-skill agility qualities between backcourt and frontcourt adult semiprofessional male basketball players. J Strength Cond Res. 2014;28(5):1319-1327.

58. Scanlan AT, Tucker PS, Dalbo VJ. The importance of open- and closed-skill agility for team selection of adult male basketball players. J Sport Med Phys Fit. 2015;55 (5):390-396.

59. Scanlan AT, Wen N, Kidcaff AP, Berkelmans DM, Tucker PS, Dalbo VJ. Generic and sport-specific reactive agility tests assess different qualities in court-based team sport athletes. J Sports Med Phys Fitness. 2014;56(3):206-213.

60. Sekulic D, Krolo A, Spasic M, Uljevic O, Peric M. The development of a new Stop'n'go reactive-agility test. J Strength Cond Res. 2014;28(11):3306-3312.

61. Sekulic D, Pehar M, Krolo A, et al. Evaluation of Basketball-Specific Agility: Applicability of Preplanned and Nonplanned Agility Performances for Differentiating Playing Positions and Playing Levels. J Strength Cond Res. 2017;31(8):2278-2288.
62. Serpell BG, Ford M, Young WB. The Development of a New Test of Agility for Rugby League. J Strength Cond Res. 2010;(27):3270-3277.
63. Services UD of H and H. Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. Bethesda, MD Natl Institutes Heal Dep Heal Hum Serv. 2014.
64. Sheppard J, Young W. Agility literature review: Classifications, training and testing. J Sports Sci. 1985; https://doi.org/10.1080/02640410500457109
65. Sheppard JM, Young WB, Doyle TLA, Sheppard TA, Newton RU. An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. J Sci Med Sport. 2006;9(4):342-349.
66. Simonek J, Horicka P, Hianik J. Differences in pre-planned agility and reactive agility performance in sport games. Acta Gymnica. 2016;46(2):68-73.
67. Spasic M, Krolo A, Zenic N, Delextrat A, Sekulic D. Reactive agility performance in handball; development and evaluation of a sport-specific measurement protocol. J Sport Sci Med. 2015;14(3):501-506.
68. Spiteri T, Newton RU, Nimphius S. Neuromuscular strategies contributing to faster multidirectional agility performance. J Electromyogr Kinesiol. 2015;25(4):629-636.
69. Spiteri T, Nimphus S, Hart NH, Specos C, Sheppard JM, Newton RU. Contribution of Strength characteristics to change of direction and agility performance in female basketball athletes. J Strength Cond Res. 2014;28(9):2415-2423.
70. Thomas JT, Nelson JK, Silverman SJ. Research Methods in Physical Activity. 7th ed. Kinetics H; 2015.
71. Trecroci A, Longo S, Perri E, Iaia FM, Alberti G. Field-based physical performance of elite and sub-elite middle-adolescent soccer players. Res Sport Med. 2018;27(1):60-71.

72. Trecroci A, Milanović Z, Rossi A, Broggi M, Formenti D, Alberti G. Agility profile in sub-elite under-11 soccer players: is SAQ training adequate to improve sprint, change of direction speed and reactive agility performance? Res Sport Med. 2016;24(4):331-340.

73. Veale JP, Pearce AJ, Carlson JS. Reliability and validity of a reactive agility test for australian football. Int J Sports Physiol Perform. 2010;5(2):239-248.

74. Young WB, Farrow D, Pyne D, McGregor W, Handke T. Validity and Reliability of Agility Tests in Junior Australian Football Players. 2011;25(12):3399-3403.

75. Young WB; James R, Montgomery I. Is muscle power related to running speed with change of direction? J Sports Med Phys Fitness. 2002;42:282-288.

Figure 1. Flow-diagram of study identification and exclusion process

Table 1. Study characteristics regarding the reliability of the agility test

Table 2. Study characteristics regarding the validity of the agility test

Figure 1

Click here to access/download;Figure;Figure 1.jpg

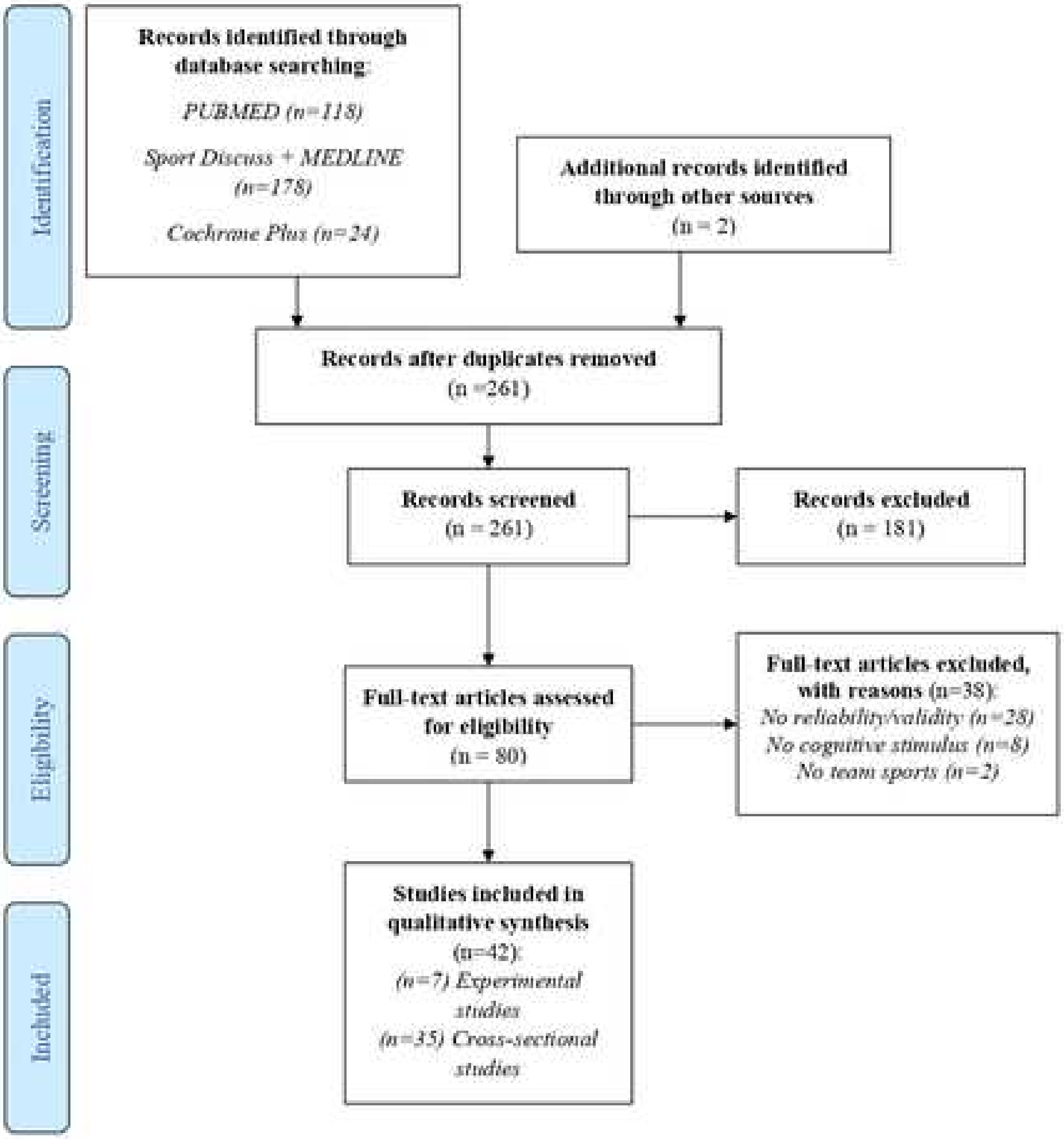

Table 1

Table 1. Study characteristics regarding the reliability of the agility test

Study	**QA**	**Population**					**TEST**					**Results**
Autor		***n***	***G***	***Age***	***Sport***	***Level***	***Description***	***Stimuli***	***nº CoD***	***d(m)***	**(°)**	***Reliability***
Bekris et al. (2018) [17]	6*	500	M	U16 U14 U12 U10	Soccer	Local	A 7x7 square area. In the center of the big square, another small square. Athlete started inside of the central square and had to run to the lit gate with the ball and go to the central square to go to the next lit gate 8 times.	Light	16	≈60m	≠	ICC=0.90
Benvenuti et al. (2010) [18]	4*	30	F	23±6	Futsal and soccer	Regional	Four lights placed at the corners of a 7.5x7.5 square. Players had to react to 6 light stimuli.	Light	12	≈51m	≠	ICC=0.80
Born et al. (2016) [45]	15**	19	M	14 ± 0.6	Soccer	High level youth	SpeedCourt (11). The court had 9 plates forming a square. The player had to touch a sequence of 11 contact plates.	Light	9	≈35m	10°-180°	r=0.94 CV=2.51
Bullock et al. (2012) [19]	8**	42	M	18.5 ± 3.5	Soccer	High level amateur	Reactive motor skill test including 5 m. speed, a passing task and reactive agility in response to a video	Video	1	≈20m	45°	TT (CV=2.4%) RAT (CV=2.3%)
Chaalali et al. (2016) [46]	17**	32	M	14.5 ± 0.9	Soccer	National league	Y-shaped agility test in reaction to the tester movement. It was done with and without ball dribbling.	Human	1	≈8-9m	≈ 90°	RAT (ICC=0.867, CV=1.99%, SEM=0.018) RATball (ICC=0.861, CV=2.03%, SEM=0.027)
Cochrane (2013) [62]	16**	8	F	20 ± 1.2	Netball	High level	Y-shaped agility test in reaction to a light stimulus.	Light	1	≈5m	45°	ICC=0.863 CV=7.1%
Čoh et al. (2018) [55]	5*	45 31	M F	21.2 ±1.78 20.6 ± 1.27	Team sports athletes	college level	Four ≠ RA test in reaction to a light stimulus: 1- Frontal: 6 possibilities to CoD in an open square C. 2- Universal: CoD to lateral (90°), and diagonal (45°). 3- Semi-circular: semi-circle. 4- Lateral: CoD to 90º at right or left	Light	8 a 12	≈30-40m	≠	ICC=0.81-0.85
Drake et al. (2017) [20]	3*	28	M	19,3± 2,2	Rugby	Professional	1v1 agility test. In a square 12x12m. There were an attacker and a defender, one opposite the other. Attacker had to ground the ball in the defensive line, while the defender tried to tackle him. The outcome result is measured by an observational score.	Human	≠	≈12m	≠	CI=0.816-0.917 (inter-rater reliability)
Duking et al. (2016) [21]	4*	30	F M	19 ± 3	Handball Soccer	4th National league 2nd National League	SpeedCourt (SC 8, 15, 43). The court had 9 plates forming a square. Athlete started at the central plate and had to run and touch with their toe the illuminated plate over 8, 15 or 43 times (depending on the test)	Light	8 a 43	≈25m-140m	≠	SC8 TT (ICC=0.86, CV=2.6%) SC15 TT (ICC=0.86, CV=2.4%) SC43 TT (ICC=0.79, CV=2.7%)

Farrow et al. (2005) [22]	4*	32	M	19.5 ± 0.79 16.4 ± 1.94 28.1 ± 2.58	Netball	Australian Institute of Sport National and Talent Identification Club level	Y-shaped agility test in reaction to a video. It started with a 4 m. side-step to left follow by 2 m. to the right. Then they had to sprint forward for 1m approx. and react to the stimulus shown in the video.	Video	3	≈11m	45°, 90°	ICC=0.83
Gabbett et al. (2007) [23]	4*	10	M	19 ± 1	Softball	State	Reaction to a video of a batter with stops at different moments of the video. Player had to move where s/he thought the ball was going.	Video	≠	NR	≠	DA (ICC=0.74, TEM=3.3%) DT (ICC=0.99, TEM=4.7%)
Gabbett et al. (2008) [63]	13**	14	M F	16.3 ± 0.7	Basketball	Scholarship	Y-shaped agility test in reaction to the tester movement.	Human	1	≈8-9m	≈ 90°	ICC=0.88 TEM=0.05
Gabbett et al. (2008) [12]	5*	42	M	23.6 ± 5.3	Rugby	First Grade Second Grade	Y-shaped agility test in reaction to a tester movement.	Human	1	≈8-9m	≈ 90°	MT (ICC=0.92) DT (ICC=0.95) RA (ICC=0.93)
Gabbett et al. (2011) [42]	6*	58	M	23.8 ±3.8	Rugby	National league	Y-shaped agility test in reaction to the tester movement.	Human	1	≈8-9m	≈ 90°	DA (ICC=0.93, TEM=3.9%) DT (ICC=0.95, TEM=7.8%)
Gabbett et al. (2012) [64]	5*	66	M	23 ± 4	Rugby	Professional	Y-shaped agility test in reaction to the tester movement.	Human	1	≈8-9m	≈ 90°	DA (ICC=0.93, TEM=3.9%) DT (ICC=0.95, TEM=7.8%) PR (ICC=0.8, TEM=9.3%) PP (ICC=0.85, TEM=8.7%)
Green et al. (2011) [24]	4*	28	M	19±1.3 19±1,67	Rugby	Academy group Club level	Y-shaped agility test in reaction to a light stimulus.	Light	1	≈10m	45°	ICC=0,88
Henry et al. (2011) [33]	2*	42	M	18±1 18±0	Australian football & Non-footballer	National League Amateur	Y-shaped agility test in reaction to a light or a video.	Video or light	1	≈11m	45°	RAT video (ICC=0.81, CV=1.4%) Intra rater DT (ICC=0.98, CV=5.2%)
Holding et al. (2017) [47]	17**	30	M	14,6 ± 1.09	Rugby	U-15 & U-17 National	1v1 agility test. In a 9x6m rectangle. An attacker and a defender, one opposite the other. Attacker had to move when he wanted to cross to right or left lateral line.	Human	≠	≈10m	≠	ICC=0.638 CV=16%-19.9%
Lockie et al. (2014) [34]	14*	10 10	M	21.4 ± 3.13 23.2 ± 4.66	Basketball	Semi-professional Amateur	Y-shaped agility test in reaction to a light stimulus.	Light	1	≈10m	45°	RATL-RATR (r=0.59)
Meir et al. (2014) [65]	4*	14	M	22.5 ±2.1	Rugby	Amateur	Y-shaped agility test in reaction to the tester movement. The athlete had to move to the opposite gate where the tester was moving with or without carrying a ball.	Human	1	≈20m	45°	ICC=0.79-0.92 TEM=0.04-0.08

Oliver & Meyers (2009) [26]	3*	17	M	20.3 ± 0.7	rugby, hockey, soccer, athletics, racket sports	Students	Y-shaped agility test in reaction to a light stimulus. Athlete can run to the left, to the right or straight.	Light	1	≈10m	45°	CV=3 % (CI 2.5–3.7)
Pojskic et al. (2018) [36]	6*	10 10	M	17 ± 0.9	Soccer	U-19 top class U-17 top class	Y-shaped with 4 possible CoD (45º y 90º). Athlete had to assess which cone was lit, run to that particular cone, kick the ball placed at the top of the cone, and return to the start line over 5 times in response to 5 light stimuli.	Light	20	≈40m	45°, 90° y 180°	ICC=0.7-0.88 CV=3.66-6.14%
Sattler et al. (2015) [41]	3*	39 34	M F	21.9 ± 1.9	agility-saturated sports	college level	Y-shaped with 4 possible CoD (45º y 90º) to right or to the left. The athlete had to assess which cone was lit, run to that particular cone, touch the top of it with their preferred hand, and return to the start line over 3 times in response to 3 light stimuli.	Light	12	≈24m	45°, 90° y 180°	ICC=0.81 ICC=0.84
Scanlan et al. (2013) [40]	6*	12	M	25.9 ± 6.7	Basketball	State level	Y-shaped agility test in reaction to the tester movement.	Human	1	≈7m	≈ 90°	ICC=0.89-0.99; CV=1.9-2% Tester rater video (ICC=1, CV=0.69%)
Scanlan et al. (2014) [54]	6*	12	M	25±9	Basketball	Semi-professional	Y-shaped agility test in reaction to the tester movement.	Human	1	≈7m	≈ 90°	ICC=0.89-0.99 CV=1.9-2%
Scanlan et al. (2014) [66]	6*	12	M	25.9 ± 6.7	Basketball	Semi professional	RAT light: Y-shaped agility test in reaction to a light stimulus. RAT opponent: Y-shaped agility test in reaction to a tester movement.	Light Human	1	≈7m	≈ 90°	ICC=0.81-0.91, CV=2.9-5% NR
Scanlan et al. (2015) [37]	5*	12	M	25.9 ± 6.7	Basketball	State level Starters (HPL) State level Non-starters (LPL)	Y-shaped agility test in reaction to the tester movement.	Human	1	≈7m	≈ 90°	ICC=0.89-0.99; CV=1.9-2% Tester rater video (ICC=1, CV=0.69%)
Sekulic et al. (2014) [27]	5*	57	F M	18-24	Team sports Non-team sports	Agility satured sports Non-agility satured sports	Y-shaped with 4 posible CoD (45º y 90º) to the right or to left. Athlete had to assess which cone was lit, run to that particular cone, touch the top of it with their preferred hand, and return to the start line over 2-5 times.	Light	8 a 20	≈16-40m	45°, 90° y 180°	Male ICC=0.81, CV=4% Women ICC=0.86, CV=4%
Sekulic et al. (2017) [67]	5*	58 52	M	21.58 ± 3.92	Basketball	Professional Semi-professional	Y-shaped agility test in reaction to a light stimulus. Player had to go to the lit cone, rebound the ball placed at the top of the cone and return to the start line as quickly as possible.	Light	3	≈8m	45°	Intrasession: ICC dom=0.86, CV=5.2%; ICC nond=0.85, CV=5% Intersession: ICC dom=0.88, CV=5.6%; ICC nond=0.81, CV=5.4%
Serpell et al. (2010) [68]	3*	30	M	NR	Rugby	National league National Youth Competition	Y-shaped agility test in reaction to a video. Athletes were instructed to react to the video as they would in a typical game situation if playing the role of a defender.	Video	1	≈10m	45°	TT (ICC=0.82) PRT (ICC=0.31) Confidence rating (ICC=0.50)

Sheppard et al. (2006) [28]	4*	38	M	21.8± 3.2	Australian football	National league Reserve league	Y-shaped agility test in reaction to the tester movement.	Human	1	≈8-9m	≈ 90°	ICC=0.878 intra-rater tester (r=0.904)
Spasic et al. (2015) [29]	4*	23 26	F M	25.14 ± 3.71 26.9 ± 4.2	Handball	National league	T-shaped (90º) to right or to the left. The athlete had to assess which cone was lit, run to that particular cone, touch the top of it with their preferred hand, and return to the start line over 3 times in response to 3 light stimuli.	Light	12	≈33m	90°	ICC=0.9, CV=2.4% ICC=0.85, CV=3%
Spiteri et al. (2014) [16]	6*	12	F	24.25 ± 2.55	Basketball	Professional	Y-shaped agility test in reaction to a video while dribbling the ball.	Video	2	≈14m	45°	ICC=0.81 CV=3.3%
Trecroci et al. (2016) [48]	14**	39	M	10.5 ± 0.30 10.7 ± 0.21	Soccer	U11 sub-elite U11 sub-elite (CG)	Y-shaped agility test in reaction to the tester movement.	Human	1	≈11m	45°	ICC=0.85
Trecroci et al. (2018) [38]	5*	20 20	M	15.36 ± 0.54 15.28 ± 0.60	Soccer	U-16 Elite U-16 Sub-Elite	Y-shaped agility test in reaction to the tester movement.	Human	1	≈11m	45°	ICC=0.87, CV=95% CV=2%, SEM=0.02s
Veale et al. (2010) [30]	4*	20	M	17.44 ± 0.55	Australian football	U-18 Elite	Y-shaped agility test in response to a tester movement. Athlete had to move to the same gate where the tester was moving and then continue to the end of next gate in front of it.	Human	2	≈12m	45°	r=0.91
Young et al. (2011) [39]	4*	35 15	M	15-17	Australian football	Elite junior Secondary school team	Y-shaped agility test in reaction to a video.	Video (arrow/ human)	1	≈8m	45°	Human (ICC=0.33, CV=2.7%) Arrows (ICC=0.10, CV=3.4%) Human-arrows (r=0.50)

***quality assessment tool for observational cohort and cross-sectional studies proposed by National Heart, Lung and Blood Insitute, ****quality assessment screening scoring proposed by Brughelli et al (60), **(º)** angle**, ATL** agility time left**, ATR** agility time right**, CI** confidence interval**, CoD** change of direction**, CV** coefficient of variation**, d** distance (m), **DA** decision accuracy**, dom** dominant**, DT** decision time**, F** female**, G** gender**, ICC** intraclass correlation coefficient, **M** male, **MT** movement time, **nond** non dominant, **PP** pattern prediction, **PR** pattern recall, **PRT** perception and response time, **r** Pearson correlation, **QA** quality assessment, **RA** response accuracy, **RAT** reactive agility test, **SEM** standard error of measurement, **TEM** typical error of measurement, **TT** total time*

Table 2

Table 1. Study characteristics regarding the validity of the agility test

Study	QA	Population					TEST					Results
Autor		***n***	***G***	***Age***	***Sport***	***Level***	***Shape***	***Stimuli***	***nº COD***	***d(m)***	***Angle***	***Validity***
Benvenuti et al. (2010) [18]	4*	30	F	23±6	Futsal and soccer	Regional	Square	Light	12	≈51 m	≠	AT: Futsal players 7.8% faster than soccer players (ES=1.6) DT: Futsal players 36.5% faster than soccer players (ES=2.4)
Bekris et al. (2018) [17]	6*	500	M	U16 U14 U12 U10	Soccer	Local Players	Square (with ball)	Light	16	≈60 m	≠	TT: U16 11.3% faster than U14 (ES=1.2) TT: U16 14.37% faster than U12 (ES=1.4) TT: U16 25.3% faster than U10 (ES=2.9)
Farrow et al. (2005) [22]	4*	32	M	19.5 ± 0.79 16.4 ± 1.94 28.1 ± 2.58	Netball	Australian Institute of Sport (HPL) National and Talent Identification (MPL) Club level (LPL)	Y-shape	Video	3	≈11 m	45°, 90°	HPL 0.8% faster than MPL (ES=0.25) HPL 6.8% faster than LPL (ES=2.07) MPL 6% faster than LPL (ES=2.29)
Fiorilli et al. (2017) [31]	6*	35 70 42 39	M	17.53±0.32 15.59 ± 0.39 13.38 ± 0.35 11.51 ± 0.48	Soccer	U18 (HPL) U16 (MPL1) U14 (MPL2) U12 (LPL)	Y-shape	Light	1	≈10 m	45°	AT: U18 were faster than U16 AT: U16 were faster than U14 AT: U14 were faster than U12
Gabbett & Benton (2009) [61]	1*	24 42	M	24.5± 4.2 23.6±5.3	Rugby	National league (HPL) Recreational (LPL)	Y-shape	Human	1	≈8-9m	≈ 90°	MT: HPL 8,2% faster than LPL (ES=1.39) DT: HPL 19.7% faster than LPL (ES=0.62) DA: HPL 7,7% better than LPL (ES=0.58)
Gabett et al. (2007) [23]	4*	21 10 9	M	19±1	Softball	National (HPL) State (MPL) Novice (LPL)	Free	Video	≠	NR	≠	DT: HPL 48% faster than MPL and LPL DA: HPL 4.9% faster than MPL DA: HPL 21%faster than LPL
Gabbett et al. (2008) [12]	5*	12 30	M	23.6 ± 5.3	Rugby	First Grade (HPL) Second Grade (LPL)	Y-shape	Human	1	≈8-9m	≈ 90°	MT: HPL 4,6% faster than LPL (ES=0.73) DT: HPL 29.3% faster than LPL (ES=0.54) DA: HPL 5.9% better than LPL (ES=0.34)
Gabbett et al. (2011) [32]	6*	86	M	23.3+3.8	Rugby	Professional (HPL) Semi-professional (LPL)	Y-shape	Human	1	≈8-9m	≈ 90°	DA: HPL 2.5% better than LPL (ES=0.29) DT: LPL 5,3% faster than HPL (ES=0.17)
Green et al. (2011) [24]	4*	28	M	19±1,3 19±1,67	Rugby	Academy group (HPL) Club level (LPL)	Y-shape	Light	1	≈10 m	45°	HPL 8.5% faster than LPL (ES=1.14)

Henry et al. (2012) [25]	3*	14 14	M	23+2 21+2	Australian football	Semi-professional (HPL) Amateur (LPL)	Y-shape	Video	1	≈11 m	45°	Feint AT: HPL 5,5% faster than LPL (ES=0.52) Feint DT1: HPL 10,2% faster than LPL (ES=0.59) Feint DT2: LPL 2% faster than HPL (ES=0.07) Feint MT: HPL 12% faster than LPL (ES=0.56) Non-feint AT: HPL 2,1% faster than LPL (ES=0.47) Non-feint DT1: HPL 12,4% faster than LPL (ES=0.73) Non-feint MT: LPL 2,5% faster than HPL (ES=0.34)
Lockie et al. (2014) [34]	5*	10 10	M	21.4 ± 3.13 23.2 ± 4.66	Basketball	Semi-professional (HPL) Amateur (LPL)	Y-shape	Light	1	≈10 m	45°	ATL: HPL 5,7% faster than LPL (ES=1.02) ATR: HPL 6,2% faster than LPL (ES=1.06)
Morland et al. (2013) [35]	4*	10 20	F	16.9 ± 0.7 17.0 ± 0.7	Hockey	Regional (HPL) School (LPL)	Y-shape	Light and human	1	≈12 m	45°	HPL 2,4% faster than LPL (ES=0.39) for light stimulus HPL 3% faster than LPL (ES=0.92) for specific stimulus
Pojskic et al. (2018) [36]	6*	10 10	M	17 ± 0.9	Soccer	U-19 top class (HPL) U-17 top class (LPL)	Y-shape	Light	20	≈40 m	45°, 90° y 180°	AG1: HPL 3'6% faster than LPL (ES=0.96) AG2: HPL 3% faster than LPL (ES=0.66) AG3: HPL 4,4% faster than LPL (ES=1.1)
Scanlan et al. (2015) [37]	5*	12	M	25.9 ± 6.7	Basketball	State level Starters (HPL) State level Non-starters (LPL)	Y-shape	Human	1	≈7m	≈ 90°	TT: HPL 8.3% faster than LPL (ES=1.65) RT: HPL 27.9% faster than LPL (ES=0.97) DT: HPL 24.3% faster than LPL (ES=1.14)
Sekulic et al. (2014) [27]	5*	57	F M	18-24	Team sports Non team sports	Agility saturated sports (HPL) Non agility saturated sports (LPL)	Y-shape	Light	8 a 20	≈16-40m	45°, 90° y 180°	M: HPL 5% faster than LPL (ES=0.75) F: HPL 2.9%faster than LPL (ES=0.39)
Sekulic et al. (2017) [67]	5*	58 52	M	21.58 ± 3.92	Basketball	Professional (HPL) Semi-professional (LPL)	Y-shape	Light	3	≈8m	45°	ATdom: HPL 4,9% faster than LPL (ES=0.6) ATnond: HPL 4,6% faster than LPL (ES=0.64)
Serpell et al. (2010) [68]	3*	30	M	NR	Rugby	National league (HPL) National Youth Competition (LPL)	Y-shape	Video	1	≈10 m	45°	TT: HPL 9.6% faster than LPL (ES=0.56) PRT: HPL 101% faster than LPL (ES=0.68)
Sheppard et al. (2006) [28]	4*	38	M	21.8±3.2	Australian football	National league (HPL) Reserve league (LPL)	Y-shape	Human	1	≈8-9m	≈ 90°	HPL 5.2% faster than LPL (ES=1.13)
Spasic et al. (2015) [29]	4*	23 26	F M	25.14 ± 3.71 26.9 ± 4.2	Handball	National league	T-shape	Light	12	≈33 m	90°	M: Defensive player 1.8% faster than offensive (ES=0.07) F: Offensive player 4.3% faster than defensive player (ES=0.49)

Treroci et al. (2018) [38]	5*	20 20	M	15.36 ± 0.54 15.28 ± 0.60	Soccer	U-16 Elite (HPL) U-16 Sub-Elite (LPL)	Y-shape	Human	1	≈11 m	45°	HPL 3.5%faster than LPL ES=0.81
Veale et al. (2010) [30]	4*	20 20 20	M	16.6 ± 0.5	Australian football	U-18 Elite (HPL) U-18 Sub-elite (MPG) Control group (LPL)	Y-shape	Human	2	≈12 m	45°	HPL 4.3% faster than MPL (ES=1.1) HPL 18.2% faster than LPL (ES=2.34) MPL 14.5% faster than LPL (ES=1.87)
Young et al. (2011) [39]	4*	35 15	M	15-17	Australian football	Elite junior (HPL) Secondary school team (LPL)	Y-shape	Video (arrow/ human)	1	≈8m	45°	AT human: HPL 8.5% faster than LPL (ES=2.59) AT arrows: 0% differences

quality assessment tool for observational cohort and cross-sectional studies proposed by National Heart, Lung and Blood Insitute, *****quality assessment screening scoring proposed by Brughelli et al (60), ***(º) *angle****, AT*** *agility time,* ***ATL*** *agility time left****, ATR*** *agility time right****, CoD*** *change of direction****, d*** *distance (m),* ***DA*** *decision accuracy****, dom*** *dominant****, DT*** *decision time****, ES*** *effect size,* ***F*** *female****, G*** *gender****, HPL*** *high performance level,* ***LPL*** *low performance level,* ***M*** *male,* ***MPL*** *medium performance level,* ***MT*** *movement time,* ***nond*** *non dominant,* ***PRT*** *perception and response time,* ***QA*** *quality assessment,* ***RT*** *response time,* ***TT*** *total time*