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# Determinants of Y-Shaped Agility Test in Basketball Players

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**Abstract:** Y-shaped agility test is a reactive agility test that includes both sensory and motor components. However, there is a lack of information about the contribution of these components to reactive agility in basketball players. Therefore, this study investigates: (i) the relationship between Y-shaped agility performance and reaction speed, sprint speed, change of direction speed, muscle strength, and (ii) determinants of this reactive agility test. Eleven male basketball players performed a Y-shaped agility test, 5 m and 20 m sprints, a 505 Agility test, squat, countermovement and drop jumps, and simple and two-choice reaction time tests. The results revealed a significant relationship between the time in Y-shaped agility test and 5 m sprint time (r = 0.795, $p = 0.003$, $R^2 = 0.632$), 20 m sprint time (r = 0.676, $p = 0.022$, $R^2 = 0.457$), and reactive strength index (r = −0.619, $p = 0.042$, $R^2 = 0.383$), but not with simple and choice-based reaction times. These findings indicate that performance in the Y-shaped agility test is more profoundly determined by a motor rather than a sensory component. This may be ascribed to the structure of a predominantly velocity-oriented Y-shaped agility test with a small contribution of responses to visual stimuli. The adaptation of basketball players to training aimed at increasing speed and strength may also play a role. The structure of the Y-shaped agility test should be modified so as to better reflect the sensory component of reactive agility and more sensitively reveal within- and between-group differences.

**Keywords:** change of direction; motor component; reactive agility; reactive strength; sensory component; sprint speed

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## 1. Introduction

Agility is defined as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" and is considered to be important for many sports [1]. Some authors also use this term when the rapid movement of the body does not involve a reaction to a stimulus and the task is pre-planned [2,3]. Nowadays, it usually denotes a change of direction speed (CODS), which is an independent ability with only a small aspect of agility performance [4]. The common variance among the change of direction speed test and agility test was only 10%, suggesting that they are measuring distinct qualities [1]. The term "reactive agility" was created to make a clear distinction between the pre-planned change of direction speed and agility, including the perceptual and decision- making element [1,5,6].

In the first model indicating factors determining reactive agility, the change of direction speed was one of the two main components. The second component consists of the perceptual and decision-making factors [7]. Later, this model was modified and agility in invasion sports was determined by the cognitive, physical, and technical aspects [4]. The cognitive component included decision-making and accuracy (visual scanning, anticipation, pattern recognition), and the physical component replaced the change of direction speed; however, its subfactors remained almost unchanged (straight sprinting speed, leg muscle qualities as strength, power, and reactive strength). The primary model was supplemented by the technical component, which was the subcomponent of change of direction speed in the previous model [4]. However, no study to date has investigated the contribution of the technical component to reactive agility because of the difficulty of doing so. Most studies have assessed only the motor component (physical factors) and fewer have assessed the sensory component (perceptual and decision-making factors) of reactive agility [1,6–10].

Invasion sports involve several changes of direction and most of them include responses to stimuli, either movement of an opponent, teammate, or ball [4]. These types of sports include basketball, in which reactive agility is one of the most important factors of performance [9,11]. To test reactive agility, the task must include some external stimuli to stress athletes' visual scanning and decision-making capacities [12]. It has also been shown that ability to react to an external stimulus is an effective method of differentiating the skill levels of athletes [4]. The most common model used is a Y-shaped agility test, in which athletes receive a stimulus that requires them to complete a 45° cut to the left or right [12]. It is usually used for basketball players as well [11,13]. This test is characterized by a non-stop running scenario and relatively small directional change (45°) with a total running distance of 10 m (5 m forward + 5 m forward after directional change). Therefore, it is considered a velocity-oriented test [14]. The sensory or perceptual and decision-making aspect was expressed by the reaction to only one visual stimulus with two possible responses (left or right). There are several more reactive agility tests which differ in structure, e.g., shorter running distance or higher number of stimuli [15–17]. It was found that the number of possible responses affects the reaction time [18]. Compared to these types of tests, the Y-shaped agility test represents the motor rather than the sensory component.

Although all reactive agility tests consist of sensory and motor components, less is known about their contribution to reactive agility in basketball players. Whereas several studies have investigated the relationship between the reactive agility performance and parameters of motor abilities [11,15,16] from the practical and theoretical point of view, it could be of interest to know about the contribution of both components to reactive agility. Therefore, the aim of this study is (1) to investigate the relationship between Y-shaped agility performance and sprint, change of direction speed, reaction speed, and muscle strength and (2) to specify the determinants of Y-shaped agility performance in basketball players.

The Y-shaped agility test has been used in many studies for basketball players [11,13]. Regarding the structure of the Y-shaped agility test (velocity-oriented with two-choice reaction to visual stimuli), a higher contribution of the motor component to the performance in this test can be assumed. However, the sensory component also plays an important role in basketball, therefore the importance of both components may be expected.

## 2. Materials and Methods

### *2.1. Participants*

Eleven competitive male basketball players volunteered to participate in this study (20.0 ± 2.0, 186.0 ± 4.1 cm, 79.4 ± 8.9 kg). The inclusion criteria have been reduced due to COVID-19 restrictions to: healthy young male players (from 18 to 25 years), who are active in basketball, i.e., train at least three times per week and regularly participate in a basketball league. Players who have had injuries in the last six months or whose years of experiences were fewer than five were excluded from this study. They play matches regularly in the first and second-highest league in Slovakia and on average train four times per week and play one match. The smaller number of training units per week was due to COVID-19 restrictions, which were valid in a given period of time. These basketball players have 9.3 ± 3.0 years of experience. All participants were informed of the procedures and the main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation as stated in the Helsinki Declaration and its later amendments.

### *2.2. Experimental Procedure*

This is cross-sectional correlation research. Prior to the testing, all participants performed a 10 min warm-up including light aerobic running and dynamic stretching exercises. Then they attended a familiarization session where the testing protocols were explained and the trial sets were carried out. Afterwards, they performed three various types of reaction time tests using Fitro Reaction Check (FiTRONiC, Bratislava, Slovakia) and Witty SEM (Microgate, Bolzano, Italy). After that, three types of jumps, measured by the diagnostic system OptoGait (Microgate, Bolzano, Italy), and sprint and change of direction speed tests, measured by the Witty system (Microgate, Bolzano, Italy), were carried out. All tests were performed in a sports hall with a Taraflex vinyl sports floor.

#### 2.2.1. Simple and Two-Choice Reaction Time Tests

Simple and two-choice reaction times were measured by the diagnostic system FiTRO Reaction Check in accordance with protocol [19]. This device consists of two pressure switches connected to a computer. The task of simple reaction time tests was to respond as fast as possible to either one visual stimulus (green circle on a white background) by pushing the switch positioned on the table. In the choice-based reaction time test, the participants had to decide and respond as fast as possible to two visual stimuli (a green circle and a red cross on a white background) and to press the corresponding switch. Both tests consisted of two trials with 20 responses. The result of these tests was the better time of the two trials.

#### 2.2.2. Reaction Time Test to Four Visual Stimuli

Reaction time to four visual stimuli was measured by the Witty SEM diagnostic system. Four light photocells were situated "in one line" on a table at a distance of 10 cm from each other. The task was to react as fast as possible with a dominant hand to photocells which lit up green. Other photocells showed different colours or no colour at all. A total of 20 visual reactions (four for each light photocell) with a generating time of one second were included in this test. The result was the total time taken from the better of two trials.

#### 2.2.3. Squat Jump (SJ)

Two squat jumps were performed with 15 s rest period between attempts to measure explosive strength without using elastic energy. This test involved the subject flexing their knees to approximately 90 degrees, maintaining the position for three seconds, and then jumping as high as possible while holding their hands on their hips. The participants were asked to land in a fully extended position, without hip, knee, or ankle flexion. The higher of two jumps was taken for further analysis [20].

#### 2.2.4. Countermovement Jump (CMJ)

The CMJ was performed under the same conditions but involved flexion of knees (at 90° angle) followed immediately by extension of legs to measure explosive strength using elastic energy. The jump was performed by holding hands on hips. The participants were asked to land in a fully extended position, without hip, knee, or ankle flexion. The higher of two jumps was recorded for further analysis [20].

#### 2.2.5. Drop Jump (DJ)

Drop jump was used to measure reactive strength and fast stretch-shortening cycle. The starting position was on a 30 cm-high box with hands placed on hips. The falls were carried out from the step without taking a run-up, falling, and rebounding as fast as possible with a minimum ground contact time. Participants were required to avoid more pronounced knee bending and kicking during the jump and land in a fully extended position, without hip, knee, or ankle flexion. The parameters, such as the height of a jump and the duration of contact, were measured. The higher reactive strength index (RSI—the ratio of the height and duration of contact) of two trials was taken for further analysis.

#### 2.2.6. Sprints of 20 m and 5 m

The participants started their attempts from a standing position, 50 cm behind the starting line. They performed two trials of 20 m-long sprints including a split time at 5 m with two minutes break between the trials. The width of the gates was 1.5 m with a height of 1.2 m. The task was to accelerate to maximum speed in a straight line over a 20 m distance. The better sprint time of two trials was taken for further analysis.

#### 2.2.7. The 505 Agility Test

The 505 Agility test was used to measure CODS ability. It uses one single 180° change of direction—a movement which often occurs in team sports. Therefore, this test is suitable for measuring CODS ability in team sports players [21] and basketball players, too [22,23]. The task was to accelerate to maximum speed towards the 15 m line (first pair of timing gates), turn on the right or left leg, and sprint back 5 m through the same gates. During the turn, the participants must not touch their inside hand down on the floor, but they must touch the "turn-around line", putting their foot on or across this line. The recorded time included only 5 m of running before and after the change of direction. The participants performed two trials (right and left turn) and the better time was taken for further analysis.

#### 2.2.8. Y-Shaped Agility Test

A Y-shaped agility test, as a reactive agility test, was used in this study. This assessment is reliable and valid [11,12]. This test seems to be appropriate for basketball players and can differentiate between semi-professional and amateur performance levels [11]. The Witty light-based timing system was used to record the time and set the reactive conditions. The width of the gates was 1.5 m with a height of 1.2 m. The participants began 50 cm behind the start line and ran maximally in a 5 m straight sprint. Then they performed the change of direction task as quickly as possible with a 45° cut to the left or to the right side followed by a 5 m-long sprint to the finish gates. As a stimulus, the green arrow was used to dictate the direction. It appeared with a delay of approximately 40–45 ms after passing the starting gate. Three trials were performed, and the best time was taken for further analysis.

### *2.3. Statistical Analyses*

All statistical analyses were computed in the statistical program IBM SPSS for Windows (version 22.0, Inc., Chicago, IL, USA). Prior to the selection of statistical methods, the Shapiro–Wilk test for homogeneity of variance revealed that the data were normally distributed ($p$-value ranged from 0.304 to 0.979). The standardized measure of the dispersion of probability distribution was checked via a coefficient of variations (CV). Pearson correlation coefficient was used to find the relationship between the performance in the Y-shaped agility test and sprint, change of direction speed, reaction speed, and parameters of muscle strength. The correlation is considered as trivial ($r < 0.1$), small ($0.1 \leq r < 0.3$), moderate ($0.3 \leq r < 0.5$), large ($0.5 \leq r < 0.7$), very large ($0.7 \leq r < 0.9$), and perfect ($0.9 \leq r < 1$) [24]. Simple linear regression analysis (enter method) was used to establish the significant predictors of the dependent variable (Y-shaped agility performance) from independent variables (reaction, speed, and muscle strength parameters). The coefficient of determination ($R^2$) computed as a square of r was used to indicate how much of the total variation in the dependent variable, can be explained by the independent variable. The level of significance was set at $p < 0.05$.

The G*Power 3.1 analysis was used to check the required sample size. An a priori sample size estimate for an alpha level of 0.05 with an effect size of 0.71 (calculated from $R^2 = 0.5$) and a power of 0.80 was calculated. The sample size of 13 participants appeared to be necessary to detect the relationship between Y-shaped agility performance and the variables measured. However, the number of participants in this study was slightly below the limit due to COVID-19 restrictions. Many of them did not meet the inclusion criteria at that time (they did not train and play matches regularly). A post hoc sample size analysis for an alpha level 0.05 with an effect size of 0.71 (calculated from $R^2$ = 0.5) and a sample size of 11 participants dropped the power to 0.75.

## 3. Results

Test results used in this study and the coefficient of variation are shown in Table 1. The reaction time tests reflect the sensory component, sprints, and change of direction speed test, and jump tests reflect the motor component of the Y-shaped agility test.

**Table 1.** Descriptive statistics of basketball players test performance.

| Test | Mean ± SD | CV |
|---|---|---|
| 5 m sprint time (s) | 1.1 ± 0.1 | 9.1% |
| 20 m sprint time (s) | 3.2 ± 0.1 | 3.1% |
| Time in the Y-shaped agility test (s) | 2.0 ± 0.1 | 5.0% |
| Time in the 505 Agility test (s) | 2.3 ± 0.1 | 4.3% |
| Simple reaction time (ms) | 298.1 ± 11.5 | 3.9% |
| Two-choice reaction time (ms) | 425.6 ± 24.2 | 5.7% |
| Reaction time to four visual stimuli (s) | 26.3 ± 0.6 | 2.3% |
| Squat jump height (cm) | 34.3 ± 4.8 | 14.0% |
| Countermovement jump height (cm) | 40.8 ± 4.2 | 10.3% |
| RSI in the drop jump (cm.ms$^{-1}$) | 1.6 ± 0.3 | 17.2% |

Note. SD—standard deviation, CV—coefficient of variation.

The Y-shaped agility performance significantly correlated with times in the 5 m-long sprint and 20 m-long sprint (r = 0.795** and r = 0.676*, respectively) and RSI in the drop jump (r = −0.619*). The time in the Y-shaped agility test did not correlate with any other variables measured; however, the relationship between the time in the Y-shaped agility test and simple reaction time indicated a large effect size (r = 0.566) (Table 2).

**Table 2.** Relationship between Y-shaped agility performance and sprint, change of direction speed, reaction speed, and muscle strength parameters in basketball players.

| Y-Shaped Agility Performance | *r* | *p* |
|---|---|---|
| 5 m sprint time | 0.795 | 0.003 |
| 20 m sprint time | 0.676 | 0.022 |
| Time in the 505 Agility test | 0.280 | 0.404 |
| Simple reaction time | 0.566 | 0.069 |
| Two-choice reaction time | −0.350 | 0.292 |
| Reaction time to four visual stimuli | 0.437 | 0.179 |
| Squat jump height | 0.103 | 0.764 |
| Countermovement jump height | 0.007 | 0.985 |
| RSI in the drop jump | −0.619 | 0.042 |

Note. *r*—Pearson coefficient of correlation, *p*—probability value.

The simple linear regression analysis revealed that sprint speed for 5 m ($F_{(1,9)}$ = 15.439, $p$ = 0.003) followed by sprint speed for 20 m ($F_{(1,9)}$ = 7.593, $p$ = 0.022), and RSI ($F_{(1,9)}$ = 5.579, $p$ = 0.042) were significant predictors of Y-shaped agility performance. The results of the regression analysis are displayed in Table 3.

**Table 3.** Linear regression analysis for Y-shaped agility performance.

| Y-Shaped Agility Performance | β | SE | $R^2$ | $p$ |
|---|---|---|---|---|
| 5 m sprint time | 0.795 | 0.051 | 0.632 | 0.003 |
| 20 m sprint time | 0.676 | 0.062 | 0.457 | 0.022 |
| Time in the 505 Agility test | 0.280 | 0.080 | 0.078 | 0.404 |
| Simple reaction time | 0.566 | 0.069 | 0.320 | 0.069 |
| Two-choice reaction time | −0.350 | 0.078 | 0.122 | 0.292 |
| Reaction time to four visual stimuli | 0.437 | 0.075 | 0.191 | 0.179 |
| Squat jump height | 0.103 | 0.083 | 0.011 | 0.764 |
| Countermovement jump height | 0.007 | 0.084 | 0.000 | 0.985 |
| RSI in the drop jump | −0.619 | 0.066 | 0.383 | 0.042 |

Note. B—standardized regression coefficient, SE—standard error, $R^2$—coefficient of determination, $p$—probability value.

Based on simple linear regression analysis and coefficients of determination, Y-shaped agility performance was determined by sprint speed for 5 m and 20 m (63.2% and 45.7%, respectively) and reactive strength in the drop jump (38.3%).

## 4. Discussion

Y-shaped agility test performance under reactive conditions significantly correlated with the time in the 5 m-long and 20 m-long sprints and RSI in drop jump in male basketball players. These findings are in agreement with other studies, in which the time in the Y-shaped agility test was associated with the 10 m sprint time in physically active males [12] and amateur and semiprofessional basketball players [11]. It may be ascribed to the structure of this reactive agility test, which is considered velocity-oriented with non-stop running. The biggest part of this test is a function of linear running and this makes it difficult to identify COD ability similar to the 505 Agility test [25]. It includes 5 + 5 m forward running with a 45° change in direction to the left or the right side with a two-choice reaction to a visual stimulus. This angle does not require more pronounced breaking phases which result in a lower speed loss [14]. In these types of change of direction speed similar to linear sprint speed, short contact time with the ground is needed [26,27]. Although the reactive strength is associated with the short contact time, it may explain the significant relationship between the time in the Y-shaped agility test and RSI in the drop jump. The relevance of reactive strength can likely be explained by the physical demands of the technique used to change direction because the push-offs involve a fast stretch-shortening cycle [7]. However, the movement techniques and strength qualities required for the COD tests can be different to those required for reactive agility [28]. Therefore, this is a new finding, as previous studies showed only the relationship between RSI and change of direction speed without reaction to visual stimuli [4,29].

Y-shaped agility performance was determined mainly by the sprint speed for 5 m (63.2%), followed by the sprint speed for 20 m (45.7%) and reactive strength (38.3%) in basketball players. It is obvious that the motor component plays a more important role in the Y-shaped agility performance compared to the sensory component. This may be attributed to the structure of the Y-shaped agility test, which included running for longer distances with a two-choice reaction to one visual stimulus. Higher between-group differences between basketball players (lower and higher levels of performance) can be assumed to indicate the different levels of motor preparation (e.g., players with a lower level of performance put emphasis on the motor component rather than sport-specific stimuli), which may affect the results in terms of the different contributions to reactive agility performance. However, in this case, the variability in motor parameters among basketball players (running speed, muscle strength) was lower. The retrospective analysis showed that their training load was focused mainly on sport-specific stimuli due to the ongoing accelerated competition period. Although players came from several clubs, the difference in their motor preparation at that time was lower than 10%.

Nevertheless, the contribution of perceptual and decision-making factors cannot be completely excluded due to a large effect size of the Y-shaped agility performance with the simple reaction time. It can be expected that the reactive conditions with higher demands on decision-making (a higher number of possible responses and/or a higher number of stimuli) would have resulted in a higher contribution of the sensory component to reactive agility. This could more sensitively differentiate between athletes´ performances and detect even slight changes after the training intervention.

The findings of this study completed the deterministic model of reactive agility created by Young et al. and Sheppard et al. [1,7] and expanded this knowledge to basketball players, as well as handball players in our previous study [30]. Despite some similarities between these two team sports, slight differences in determinants of Y-shaped agility performance were obtained. The highest percentual contribution to the performance in this test was recorded by the sprint speed for 20 m followed by the change of direction speed and reactive strength in handball players, whereas in basketball players it was mainly the sprint speed for a short distance (5 m), followed by the longer distance (20 m) and the reactive strength. It seems that determinants of reactive agility differ in players of various types of sports [31].

The relatively high variation in players´ levels of sports performance, without taking into account variations in team game positions and the low sample size, can be considered as the main limitation of this study. Therefore, it is not possible to make inferences applying to the entire population of male basketball players. For future research, it would be interesting to extend this knowledge to sports with shorter running distances as well (e.g., badminton or tennis) and longer running distances (e.g., soccer) and to compare their demands on sensory components, too.

## 5. Conclusions

The Y-shaped agility performance under reactive conditions is associated with the 5 m and 20 m sprint times and reactive strength index in basketball players. Performance in this test was mainly determined by motor abilities, i.e., linear sprint speed for 5 m (63.2%) followed by 20 m sprint speed (45.7%) and reactive strength (38.3%). However, it is not determined by sensory functions expressed by the simple and choice-based reaction times.

The higher contribution of the motor compared to the sensory component to Y-shaped agility performance may be attributed to the structure of this reactive agility test. It is considered a velocity-oriented test that includes a two-choice reaction to one visual stimulus. The training stimuli of these basketball players probably consist of pre-planned changes of direction speed rather than changes of direction speed in reaction to visual stimuli. Nonetheless, game situations in sports games become more dynamic and faster, which makes higher demands on the perceptual and decision-making component of reactive agility skills as well. Therefore, the structure of the reactive agility test should be modified to better reflect the sensory component. For example, by including a higher number of stimuli or possible responses while eliminating the movement distance. This could increase the specificity of the test to differentiate between athletes´ performances more sensitively and to evaluate the effectiveness of the training program.

From a practical point of view, it could be interesting to create a new reactive agility test which could differentiate athletes of various sports and the demands on sensory and motor components of reactive agility.

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