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Reliability, Validity and Sensitivity of Newly Developed Tennis-Specific Reactive Agility Tests

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Abstract: Agility is one of the motor skills on which success in tennis performance depends, and the aim of this research was the development and validation of a new test for assessing preplanned and reactive agility in young tennis players. The sample of respondents comprised 50 young competitors with an average age of 12.34 ± 1.22 years who were ranked up to 50th in the national tennis association ranking and up to 300th in the international Tennis Europe ranking. Agility variables were measured with newly constructed tests for the assessment of preplanned agility (CODS) and reactive agility (RAG), which were constructed in such a way that subjects imitated specific movements in tennis. It can be concluded that the newly constructed tests of preplanned agility (CODS) and reactive agility (RAG) have a high degree of reliability. Additionally, the assumption that the reliability will be slightly higher for preplanned agility tests (CA = 0.92 and 0.92; ICC = 0.86 and 0.82) than for reactive agility tests (CA = 0.90 and 0, 89; ICC = 0.74 and 0.72) was proven to be accurate. The results also showed that the tests have satisfactory validity. Thus, the results of both tests show a good correlation (p = 0.6 and p = 0.55) with the T-test of agility. It can be noted that all measurements, that is, all results, are normally distributed and that the values of skewness and kurtosis are within acceptable limits. We can confirm satisfactory sensitivity and their applicability to the sample of young tennis players. In conclusion, the results of this research confirmed the hypothesis and showed that the newly constructed agility tests have extremely good metric characteristics, especially the reactive agility test. Thus, this paper proposed a new procedure for the assessment of preplanned and reactive agility in young tennis players, which will significantly improve and advance the existing procedures, and make the results more reliable and precise.

Keywords: agility; speed; young tennis players; reliability; validity; sensitivity

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1. Introduction

Agility is considered one of the most important abilities for success in many sports, including tennis [1]. It is defined as a rapid whole-body movement with change of velocity and/or direction in response to a stimulus [2,3]. The great impact of agility on the achievement of top sports results has been confirmed in numerous studies [3–5]. There are two relatively independent manifested forms of agility. The first is nonreactive or preplanned agility (change of direction speed-CODS), which is characterized by a change in the direction of movement that is already known in advance; that is, it is planned, and the players do not need to react to a specific stimulus. The second form of agility is reactive or unplanned agility (Reactive agility-RAG), which includes a cognitive component, i.e., observation and decision-making factors [6–8].

In tennis, players very often change the direction of movement, so planned and reactive agility are considered extremely important motor dimensions [9,10]. Despite the importance of agility in tennis, there is very little scientific research that has dealt with this motor dimension, especially in specific conditions. An underlying problem in this lack of research is the lack of adequate tests; therefore, there has been an increasingly

pronounced trend of constructing and validating new ones. To date, agility in tennis has mostly been measured with standardized basic tests, but this research will offer a new specific agility test. Studies whose primary goal is the construction of new sport-specific tests for agility assessment are usually based on the modification of already existing basic agility tests such as "*T*-test", "505 test", or the "Spider drill test" [11]. The disadvantage is that all the aforementioned tests were created to measure agility in which changes in the direction of movement are planned in advance. That is another important reason why is it necessary to develop a sport-specific test that assesses reactive agility, which is key to success in tennis. Reactive agility is manifested in conditions when a person needs to perform an agile movement structure but in such a way that it must react to some kind of stimulus. Most often in the area of reactive agility, the stimulus is actually a visual stimulus, which is completely clear because athletes perform agile movements based on the visual observations of either the opponent's movement or the trajectory of the ball. So, from this it can be concluded how reactive agility includes a cognitive component, i.e., the factors of observation and enactment of a decision to some stimulus that cannot be assessed by older agility tests. Everything mentioned above leads to the conclusion that the newly constructed test in this research will be able to better and more precisely measure agility compared to already known basic tests. For the newly constructed test to be usable it must have good metric characteristics, and this primarily refers to reliability and validity [11]. Sports-specific tests provide more detailed information about the real state of those traits and abilities that ultimately ensure the success of the player at the top level of competition [12]. Additionally, such tests always better describe the efficiency of the player's motor skills related to technical performance than is the case with basic tests [13]. In previous years, the specificity of sports conditioned an increasing number of developed protocols for assessing preplanned and reactive agility that include movements characteristic of a particular sport. In their research, Sekulić et al. developed a reliable and valid test for assessing predicted and reactive agility in futsal players on a sample of 30 subjects [6,10,12]. In addition to futsal, protocols have been developed for validating specific tests to assess planned and reactive agility on a sample of soccer players [13,14] and basketball players [15].

Since agility is one of the motor skills on which the success in tennis performance depends, the aim of this research was to develop and validate a new test for assessing preplanned and reactive agility in young tennis players. The assumption was that the newly constructed test would be reliable and valid and as such would be applicable to the sample of young tennis players. Using the newly constructed test, it should be possible to systematically develop training methods, as well as diagnostics, to enable tennis players to develop better and faster towards the top level of tennis.

2. Materials and Methods

2.1. Participants

Participants included in this study were 50 young tennis players with an average age of 12.34 ± 1.22 years, height 156.7 ± 12.85 cm and weighing 45.87 ± 8.87 kg ranked up to 50th in the national Tennis Federation ranking and up to 300th in the international Tennis Europe rankings. G-Power program was used to estimate the appropriate number of subjects (version 3.1.9.2; Heinrich Heine University, Dusseldorf, Germany). To participate in the study, all subjects had to meet the criteria that they were healthy, physically active players who trained at least three times a week and compete in regional, national, or international tournaments. The research was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Kinesiology of the University of Zagreb (protocol code 34; date of approval 13 December 2021). All participants were informed about the subject and goal of the study, and the subjects and their parents gave written consent to participate. The complete testing protocol was explained to them in detail with special emphasis on the fact that study requires certain additional effort

and presents a risk of injury that is the same as during the standard training process or competition.

2.2. Measurements

Agility variables were measured with newly constructed tests for the assessment of preplanned agility (CODS) and reactive agility (RAG). The tests were measured using the Sportreact system (Sportreact, Zagreb, Croatia). The generic tennis agility test *T*-test was used to validate the mentioned tests. The *T*-test is considered the gold standard for measuring agility in tennis and includes forward, sideways and backward sprints.

2.3. Study Design and Procedure

The preplanned agility (CODS) and reactive agility (RAG) tests were constructed in such a way that the examinees imitated specific movements in tennis (Figure 1). The examinees start from a predetermined starting line in both tests. At the moment when the infrared signal (IR1) located next to the starting line is interrupted by the "split step", the time starts to be measured and one of the two lights (L1 or L2) lights up. The participant should recognize which light has turned on, run with an overstepping and lateral technique to the side to the stand with a ball placed on it (S1 or S2) and hit the aforementioned ball forehand or backhand in front of the body with enough force that the ball hits the ground. After playing the shot, the player should return as quickly as possible to the device in front of the starting line and interrupt the infrared signal (IR2) again, which ends the measurement. In the preplanned agility test (CODS), the subjects know in advance which light will turn on; that is, they can plan in advance to run and play forehand or backhand shots. Each test was performed nine times, and for further processing, the mean measured value of both tests was taken [14].

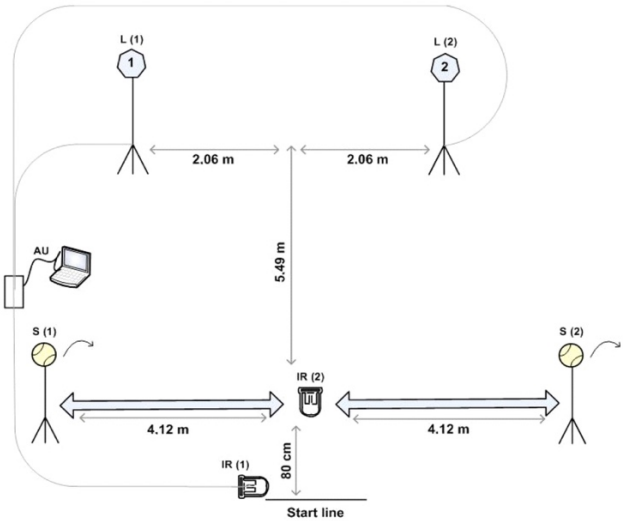

Figure 1. CODS and RAG test.

2.4. Statistical Analysis

Based on the collected data, the hypothesis was tested. The obtained data were processed in Statistica 13 for the Windows operating system and in Microsoft Excel 2013 (Palo Alto, CA, USA). Parameters that were calculated for quantitative variables consist of: arithmetic mean (AS), standard deviation (SD), minimum score (MIN), maximum score (MAX), measure of asymmetry (skewness) and measure of flatness (kurtosis). The normality of the distribution was tested with the Kolmogorov–Smirnov test. The reliability of the test was checked by calculating the Cronbach's alpha (CA) parameter and the intraclass correlation coefficient (ICC). The validity of the test was carried out through a set of correlation analyses, by calculating the Pearson's correlation coefficient. A set of factor analyzes with varimax rotation was calculated to determine the existence of latent

dimensions and finally define the construct validity of the test. All conclusions are drawn at the level of statistical error of 5%.

3. Results

3.1. Reliability

Table 1 shows the reliability parameters for the newly constructed tests of planned agility (CODS) and reactive agility (RAG) in tennis.

Table 1. Reliability of CODS and RAG tests.

	CA (α)	**ICC**
CODS (R)	0.92	0.86
CODS (L)	0.92	0.82
RAG (R)	0.90	0.74
RAG (L)	0.89	0.72

CODS (R)—preplanned agility test to the right side; CODS (L)—preplanned agility test to the left side; RAG (R)—reactive agility test to the right side; RAG (L)—reactive agility test to the left side; CA—Cronbach Alpha reliability coefficient; ICC—intraclass correlation coefficient.

Based on the obtained results presented in Table 1, it can be concluded that the newly constructed tests of preplanned agility (CODS) and reactive agility (RAG) have a high degree of reliability. We also assumed that the reliability would be slightly higher for the preplanned agility tests (CA = 0.92 and 0.92; ICC = 0.86 and 0.82) than for the reactive agility tests (CA = 0.90 and 0,89; ICC = 0.74 and 0.72).

3.2. Validity

Table 2 shows the validity parameters for the newly constructed tests of preplanned agility (CODS) and reactive agility (RAG) in tennis. The validity of the test was carried out through a set of correlation analyses, by calculating the Pearson correlation coefficient, and the tennis agility *T*-test, which is considered the gold standard for measuring agility in tennis, was used to compare the results.

Table 2. Validity of CODS and RAG tests.

	***T*-TEST (AM)**
CODS (AM)	$p = 0.55$
RAG (AM)	$p = 0.60$

CODS (AM)—arithmetic mean of preplanned agility test results; RAG (AM)—arithmetic mean of reactive agility test results; *T*-TEST (AM)—arithmetic mean of *T*-test agility test results; *p*—statistically significant association between tests.

Based on the obtained results presented in Table 2, it can be concluded that the newly constructed tests of preplanned agility (CODS) and reactive agility (RAG) have satisfactory validity. The results of both tests show good correlation ($p = 0.6$ and $p = 0.55$) with the agility *T*-test. This confirms the assumption that subjects who achieve better results on tests of preplanned agility (CODS) and reactive agility (RAG) will, with a high probability, achieve better results on the *T*-test of agility.

3.3. Sensitivity

Table 3 shows the descriptive parameters for the newly constructed tests of preplanned agility (CODS) and reactive agility (RAG) in tennis. The following were calculated: arithmetic mean (AM), standard deviation (SD), minimum score (MIN), maximum score (MAX), measure of asymmetry (SKEW) and measure of flatness (KURT) and the maximum difference between the values of the Kolmogorov–Smirnov test (MAX D).

Table 3. Descriptive parameters for CODS and RAG tests.

	AM	SD	MIN	MAX	SKEW	KURT	MAX D
CODS (R)	3.18	0.21	2.77	3.42	0.81	0.25	0.15
CODS (L)	3.18	0.16	2.83	3.79	0.65	0.60	0.12
RAG (R)	3.36	0.23	2.94	4.17	0.80	1.75	0.13
RAG (L)	3.37	0.23	2.96	4.04	0.73	0.93	0.12

According to the obtained results, it can be noted that all results are normally distributed. It is noticeable that there are no significant differences between the obtained normal distributions of the results given that none of the obtained values on the Kolmogorov–Smirnov test exceeds the limit value. Skewness and kurtosis values are also within acceptable limits. Therefore, based on the results shown in Table 3, we can speak about the satisfactory sensitivity of these newly constructed tests and their applicability to a sample of young tennis players.

4. Discussion

With the development of sports science, an increasing number of studies appeared that were concerned with determining the reliability of tests for the assessment of preplanned and reactive agility. Most often, these are sport-specific tests, which by their structure try to get as close as possible to certain situations within the chosen sport. Such research was conducted with samples of Australian football players [16], rugby players [17], netball players [18], basketball players [9,15], soccer player [13,14,19], futsal players [6,10,12,20]. Common to all the mentioned studies is that relatively high reliability of the analyzed tests was obtained, which makes the results obtained here expected. There is an advantage in the application of sport-specific tests compared with tests of a general character in the fact that during their performance, there are demands for knowledge of the technique of the individual sport, or specific movement structures for that sport [21]. Based on the above, the assumption is that sport-specific tests give a better insight into the actual state of sports form, and enable the differentiation of athletes on the basis of small differences that exist in them at the top level of competition. An additional difficulty in the application of sport-specific tests is the fact that they have not been systematically researched, so lack of them is evident both for tennis and other sports. What is important to emphasize is that the new tests were mainly based on the modification of already existing basic tests of agility such as "*T*-test", "505 test", "Spider drill test", and the disadvantage of such tests is that the changes of direction of movements were planned in advance [11]. From this, it can be concluded that the newly constructed test will be able to better and more precisely measure agility compared to already known basic tests.

In this research, the newly constructed tests showed extremely good metric characteristics. The high reliability of the tests can be attributed to the relatively short duration of the tests and their relatively simple execution. If we compare the results obtained here with each other, we can notice that the reliability obtained in the preplanned activity test (CA = 0.92 and 0.92; ICC = 0.86 and 0.82) is slightly higher than in the reactive agility test (CA = 0, 90 and 0.89; ICC = 0.74 and 0.72). The same trend of decreased reliability in the reactive component compared with preplanned agility was confirmed in the research of Sekulić et al., who aimed to construct a sport-specific test for assessing agility in basketball [9]. The reasons for the greater reliability of preplanned agility tests come down to the simple fact that such tests are less susceptible to error during execution. In tests of reactive agility, due to the greater demand on reaction speed, a greater number of errors occur in the form of violation of movement technique and incorrect selection of sides, which in itself leads to a decrease in the reliability of the test. Regardless of the fact that the reliability of the reactive agility test is somewhat weaker than that of preplanned agility, the results are still very satisfactory and show that the test as such will be applicable to a sample of

young tennis players. The mentioned qualities are not easily and quickly trained, which makes reactive agility more complex and difficult to perform. Therefore, an athlete who possesses high-quality visual space scanning and anticipation will achieve better results on reactive agility tests [3]. This phenomenon has already been described in the literature in other sports. For example, Foretić et al. found differentially weak results on specific tests of reactive agility in young soccer players [22]. Pehar et al. showed the difference between preplanned and reactive agility in professional basketball players in all playing positions [23], and in the research of reactive agility on male and female handball players, it was determined that both genders achieve weaker results in the reactive agility test [24].

This study has a number of limitations that will be discussed below. Firstly, the subjects involved in this study were highly selected youth tennis players in a very sensitive and crucial developmental phase. Secondly, we did not evaluate the quality of the movement of the participants, which could influence movement performance; thirdly, we did not have the possibility to look at the mental and physical fatigue that may have occurred during the testing process, which could have potentially affected the most effective movement execution.

In summary, the present study confirmed that the newly constructed agility tests have good metric characteristics, especially the reactive agility test. Our findings provide useful information for coaches to create a wide range of tennis-specific situations to test proper movement, especially for their player's reactive agility. Therefore, the measurement of the reactive agility is suggested in the testing session of junior tennis players.

5. Conclusions

The results of this research confirmed the hypothesis and showed that the newly constructed agility tests have extremely good metric characteristics, especially the reactive agility test. This study proposed a new procedure for the assessment of preplanned and reactive agility in young tennis players, which will significantly improve and advance the existing procedures and make the results more reliable and precise. The shortcoming of this research is that the newly constructed tests were conducted with a convenient sample of subjects under controlled conditions, and the results might have been different if the tests had been conducted on a different sample of participants or in different conditions. The aim of future research should be to conduct tests with subjects of different genders and different competition categories in order to obtain the best and most precise data that would enable an even greater practical and scientific contribution.

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Data Availability Statement: Data available on request.

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