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Original Investigation

Development, reliability and performance level discriminative validity of a new badminton-specific reactive agility test

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Purpose: The main aim of this study was to develop a reliable and ecologically valid badminton-specific reactive agility test that would provide researchers and practitioners with an easy-to-use instrument to assess both the motor and cognitive aspects of agility performance.
Methods: Sample of N=41 young badminton players (age 15.72 ± 1.11 yrs) from different performance levels (*High* (N_1=12), *Average* (N_2=14), *Low* (N_3=15) was subjected to the newly developed badminton-specific reactive agility test (BSARAT) and four tests that had previously proven to be reliable and valid in badminton practice.
Results: The newly constructed badminton-specific "Reactive Agility Test" (BSARAT) showed a very high internal consistency between trials (Cronbach's alpha α= .97) and a high repeatability of the results (Intraclass Correlation Coefficient ICC= .877). The factor analysis showed high correlation with the same latent dimension extracted from established generic and badminton-specific agility tests (factor structure coefficient = -.94), clearly indicating adequate construct validity. Furthermore, the between-subjects ANOVA revealed successful main effect for performance level (significance $P< .001$; (partial) eta squared (η_p^2= .29). The post-hoc analysis with Bonferroni correction showed significant pairwise differences between the groups of *High* and *Low* performance levels, as was the case for all tests in the test battery.
Conclusions: To summarise, the BSARAT is a reliable, ecologically valid and easy-to-use badminton-specific test that has the potential to become a more feasible and practical alternative to existing reactive agility tests.

Keywords: racket sports, motor abilities, performance evaluation, competitive success

Introduction

Due to the need for sudden acceleration, deceleration and change of direction (CODs), agility has been recognised as a critical component of physical performance in all racket sports[1]. The scientific literature defines agility as the ability to change direction quickly and precisely [2-6]. However, such a definition does not take into account the fundamental fact that changes in direction in sport usually occur in response to a sport-specific stimulus. Therefore, Sheppard and Young[7], defined agility as rapid movement of the whole body with a change in speed or direction in response to an external stimulus. It is also reasonable to assume that the assessment of agility under sport-specific conditions should mostly provide an appropriate profile of agility as an important ability in all sports games[8,9].
There is a growing scientific debate as to whether specific agility tests that include a sport-specific stimulus are more appropriate and better suited than generic, pre-planned agility tests[10]. Testing agility under sport-specific conditions with an external stimulus could/should better represent the type of agility that players are confronted with during points in racket sports. This arises from the requirement for the athlete to accelerate, decelerate and change direction rapidly in response to various external stimuli in certain match situations.
Players receive information primarily as a visual signal from the incoming ball/shuttle (i.e. speed, direction, rotation and trajectory) and from the movement of the opposing player, so their movements are non-linear and multidirectional[11, 12]. In order to successfully return the ball, players not only have to perform fast sport-specific movements, but also react correctly to the respective stimulus[1]. Consequently, agility in racket sports cannot be considered a physical skill[13] alone, as the process of reacting to the opponent's actions during points in racket sports involves a combination of specific motor, cognitive and technical skills[14,15]. It is therefore reasonable to hypothesise that an agility test should replicate real-life game situations as closely as possible in order to create the most realistic and comprehensive profile of agility performance during a badminton game. This includes the reaction to a stimulus, the inclusion of the racket and the badminton-specific footwork.

In contrast to some other racket sports, where reliable and valid sport-specific tests of reactive agility have not yet been successfully used or are only just being developed[1,11], specific tests of reactive agility have been used in badminton for some time and show reliable and valid results. The two badminton-specific speed and agility tests – Badminton Speed Test – BST[16] and Badcamp[17,18] - were developed with the aim of imitating sport-specific game situations, using badminton-specific movement patterns and incorporating a cognitive component "reaction to a stimulus" by randomly assigning the direction of movement using lights[16-18]. Although some specific reactive agility tests have already been successfully used in badminton, the main objective of this study was to develop a badminton-specific reactive agility test that is more feasible than the existing tests for conducting tests or training sessions. The new test does not require any special technical equipment and utilises the existing characteristics of the badminton court to perform the test.

Before this newly developed agility test is put into practise, it should be tested on psychometric characteristics[17], as its reliability and validity should be evaluated alongside some of the existing general and badminton-specific agility tests. In addition, the test should be correlated with players' performance quality to see if it can be used to successfully differentiate players based on their performance level and thus serve as a predictor of players' future performance success.

Method

Participants

Prior to the study, the required sample size was calculated using the G*Power software (Bonn, Germany, Bonn BRD, University of Bonn). Using pooled estimators of variables describing outcomes in previously validated tests[19-21], a total sample size of 22 to 37 was found to be optimal for detecting significant effects with a type I error of α= .05 and a power of .80. A total of 41 youth badminton players (age 15.72 ± 1.11 yrs; body weight 57.02 ± 5.73 kg; body height 1.70 ± .14 m; BMI 19.70 ± 1.11 $kg \cdot m^{-2}$), 21 males and 20 females, participated in this study. The eligibility criteria required participants to have competed at national level in their age category and to have played badminton regularly for ≥4 years. Those who had suffered a musculoskeletal injury less than 6 months prior to the test were excluded. The criteria for determining the players' performance level took into account two factors, their ranking on the National Badminton Association ranking list for their age category and the expert assessment of their performance level by the national team coaches. The players were divided into 3 categories according to their performance level:

1. High - they achieved remarkable results in their age groups and were in the top 20% of players in their age group.
2. Average - they achieve average results in their age groups and are among the 20-50% of the most successful players in their age group.
3. Low - they achieve no notable results in their age categories and are among the 50% least successful players in their age group.

All participants were informed that they could withdraw from the study at any time without any explanation and consequences. The study was conducted in full compliance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee.

Variables

In this study, two general agility tests[22,23] and two already established badminton specific pre-planned agility tests[24-25] were observed together with the newly constructed Badminton-Specific Agility "Reactive Agility Test" (BSARAT). The tests are described as follows:

The **Multi Direction Agility "ABCD" (MDAABCD)** test, developed by Strel at al.[22], is a generic agility test that is very similar in duration and movement pattern (Figure 1A) to the other well-known and standardly used agility test in the scientific literature (T-TEST), which was first introduced by Pauole at al.[26].

The **"Steps To Side" Lateral Agility (STSLA)** test[23] measures lateral (left to right and vice versa) movement ability (Figure 1B). The test assesses lateral speed, agility, and body control. In terms of duration and movement pattern the test is essentially identical to the frequently used Edgren Side-Step Test[27].

The **Badminton-Specific Agility "Shuttle Run Test" (BSASRT)** presented by Hughes and Bopf[24] is an agility test that is performed on at a badminton court (Figure 1C). The test uses a predetermined movement pattern in which the players have to perform ten movements as quickly as possible across the entire width of the badminton court.

The **Badminton-Specific "On-court Agility Test" (BSAOAT)** presented by Hughes[25] is a badminton specific agility test that uses a predetermined movement pattern that aims to mimic typical movements of badminton players during the game and requires players to perform playing techniques at the marked points on the court (Figure 1D).

The **Badminton-Specific Agility "Reactive Agility Test" (BSARAT)** is a newly developed badminton-specific reactive agility test that simulates typical movement patterns performed by players in a badminton match (Figure 1E), while movement directions are pseudo-randomly assigned to players by a measurement official based on visual cues. This means that the test is not completely random, but it meets statistical criteria for randomness. Although there is no specific order in which the measurer directs the participants, it is mandatory that three out of six moves are made from the back of the playing field and three from the front. This ensures that the distance covered is equal for each participant. To achieve ecological validity, the test therefore includes not only specific multidirectional badminton movements and playing techniques, but also a cognitive response to a visual stimulus.

More detailed information on the tests that make up the test battery can be found in Table 1.

Methodology

All tests were carried out on a badminton court in a hall. The participants wore sportswear as for regular training sessions or competitions. The indoor temperature was 19°-23°C with constant humidity. All participants brought their own badminton rackets to the tests in order to perform the badminton-specific agility tests. Before the test, one of the authors of this study demonstrated the performance of each test to the participants. All participants then completed up to 10 minutes of low-intensity warm-up training. For all tests, three trials were conducted with 2-3 minutes of rest between trials and a ten-minute recovery period between the different tests. Participants were allowed to perform one low-intensity trial. Although some potentially confounding factors, such as the previous night's sleep, can affect cognitive performance[28], which is especially important for the specific reactive agility test (BSARAT), they were not taken into consideration in this research, but could be considered in future studies.

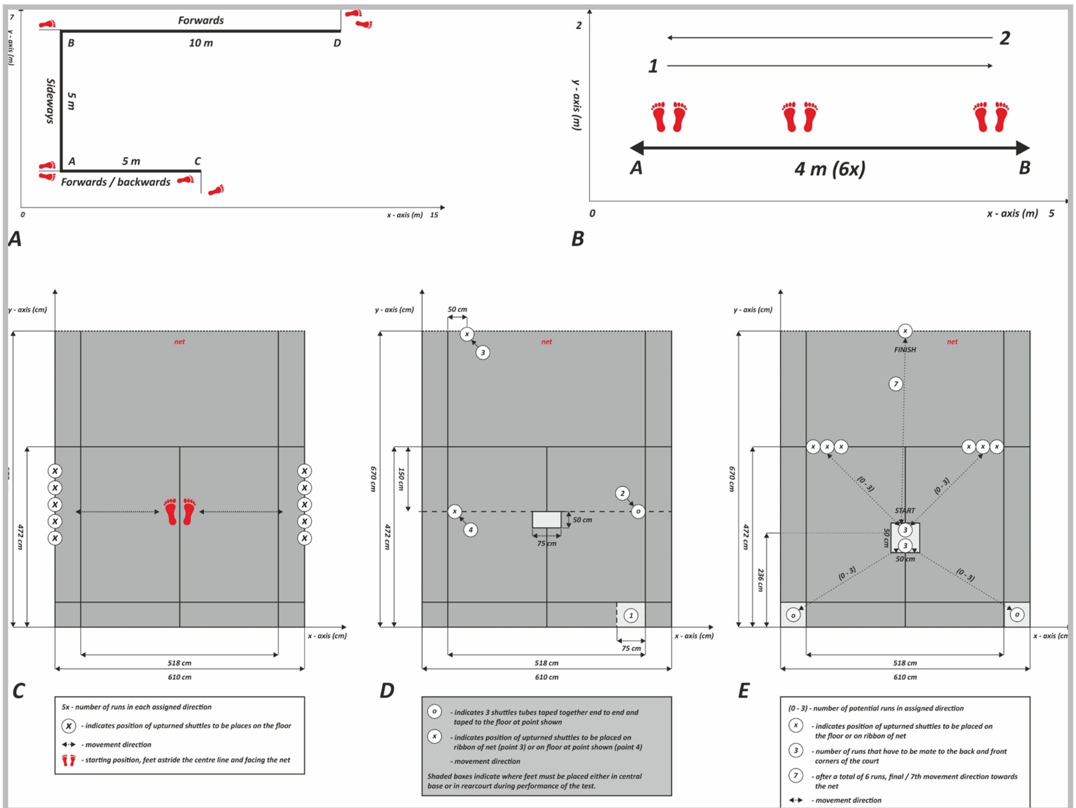

Figure 1. Test setups: Multi Direction Agility "ABCD" (MDAABCD) (A), "Steps To Side" Lateral agility (STSLA) (B), Badminton-Specific Agility "Shuttle Run Test" (BSASRT) (C), Badminton-Specific Agility "On-court Agility Test" (BSAOAT) (D), Badminton-Specific Agility "Reactive Agility Test" (BSARAT) (E).

Table 1. Agility tests comprising the test battery, categorised according to the type of agility measured and the requirements for the correct performance of the test.

NAME OF THE TEST (ABBREVIATION)	TYPE OF AGILITY	SPACE & EQUIPEMENT	MEASUREMENT REQUIREMENTS	TASK DESCRIPTION
Multi-Directional Agility "ABCD" (MDA"ABCD")	Generic pre-planned multidirectional COD	Flat open space with hard surface, with a minimum size of 15×7m & Adhesive tape and stopwatch	1 measurer, stands at point D, checks the correct execution of the test and measures the time Time measured in 1/10 of a second / Three measured attempts	The starting position is at point A. The participant covers the distance from A to B and back with sidesteps, sprints forward to point C and backwards to A, sidesteps to point B and concludes with a sprint run to point D
"Steps To Side" Lateral agility (STSLA)	Generic pre-planned lateral COD	Flat open space with hard surface, with a minimum size of 5×2m & Adhesive tape and stopwatch	1 measurer, stands in front of the participants, checks the correct execution of the test and measures the time Time measured in 1/10 of a second / Three measured attempts	The starting position is at point A. The participant takes sidesteps to the right until right foot crosses the right outer line at point B and then takes sidesteps back to A. The test is completed when the participant crosses the start/finish line at point A for the 3rd time

Badminton - Specific Agility "Shuttle Run Test" (BSA"SRT")	Badminton -specific pre-planned lateral COD	Indoor badminton court & Adhesive tape, stopwatch, 10 shuttles, badminton racket.	1 measurer, stands at the centre line, checks the correct execution of the test and measures the time. Time measured in 1/10 of a second / Three measured attempts	The starting position is on the centre line, with each foot on its own side of the line and the participant facing the net. At the start command, the participant moves laterally around the court with the racket in hand using badminton-specific movements. With each lateral movement, the participant hits one shuttle after the other until all ten shuttles have been hit from the side lines of the court. The test ends when the participant has hit all 10 shuttles and returns to the centre line.
Badminton - Specific Agility "On-court Agility Test" (BSA"OAT")	Badminton-specific pre-planned multidirectional COD	Indoor badminton court & Adhesive tape, stopwatch, 4 shuttles, 3 shuttle tubes, badminton racket.	1 measurer, stands at the centre line, checks the correct execution of the test and measures the time. Time measured in 1/10 of a second / Three measured attempts / The test is invalid if the 'shots' are not performed correctly *(e.g. if the participant turns away from the net or if the participant gains an advantage by not placing a foot in the centre box)*	The starting position is in a rectangle/box measuring 75 x 50 cm, 150 cm behind the short service line, which is centred on the centre line and marked with tape. The participant moves from the centre box in the middle of the court to the ends of the court in the order 1-4 in the following sequence: MOVEMENT 1 – executing an overhead shot, placing at least one foot in the back box; MOVEMENT 2 - touching the top of the three stationary shuttle tubes with the racket; MOVEMENT 3 - executing a net kill shot by hitting a shuttle placed on the backhand side, 150 cm from the short service line; MOVEMENT 4 - touching the shuttle on the ground. After each movement, the player must return to the centre box and place at least one foot in the box before moving on to the next point. To complete the test, participants must repeat the same sequence twice (8 movements in total).
Badminton - Specific Agility "Reactive Agility Test" (BSA"RAT")	Badminton-specific multidirectional reactive agility	Indoor badminton court & Adhesive tape, stopwatch, 7 shuttles, badminton racket.	1 measurer, stands in front of a participant at the centre of the court close to the net, assigns the direction of movement, checks the correct execution of the test and measures the time. Time measured in 1/10 of a second / Three measured attempt / The test is invalid if the 'shots' are not performed correctly	The starting position is a 50 x 50 cm, square/box centred on the centre line in the middle of the participant's half of the badminton court and marked with tape. The participant moves from the centre box in a direction randomly assigned (visually and vocally) by the measuring official. If the direction indicated points to one of the sides at the front of the court, the participant's task is to knock over one of the shuttles placed at the short service line on each side of the court, at a distance of 5, 10 and 15 cm from the singles side line. If the target direction is towards one of the back sides of the court, the participant moves backwards from the centre of the court and performs an overhead shot (without shuttle), with at least one foot placed inside the rectangle bounded by the court lines in the extreme right/left part of the court. There is no specific order in which the measurer instructs the participants. The only important thing is that the three moves are made from the back of the playing field and the three moves from the front. After the last (sixth) move, the participant returns to the centre of the court for the last time and runs to the net to execute the net-kill shot, by hitting out the last shuttle that was initially placed on the top of the net. The time stops.

Statistical analysis

The data of all trials were presented as mean ± standard deviation. The Kolmogorov-Smirnov test with Lilliefors correction was used to determine deviations from the normal distribution. To establish internal consistency Cronbach alpha (α) was used to determine internal consistency. The intraclass correlation coefficient (ICC) was calculated as a measure of test-retest reliability and repeatability. As suggested by Koo and Li[29], an ICC of < .50 was indicated as poor, between .50 - .75 as moderate, .75 - .90 as good, and > .90 is considered excellent. To determine the construct validity of the BSARAT, an exploratory factor analysis was conducted for all tests using the principal component factor extraction method. Finally, to determine the discriminant validity of the generic and badminton-specific agility tests used in relation to performance level, a one-way between-subjects ANOVA, with a post-hoc Bonferroni correction was performed, while the (partial) eta-squared (η_p^2) was used as a measure of effect size, which was interpreted as small if < .06, moderate if ≥ .06 and < .14, and large if ≥ .14. The between-subjects t-test was used to examine the significance of differences between genders in all categories. Type one error was set to α=5%. All statistical calculations were performed using the Statistica 14.0.0.15 data analysis software system (TIBCO Software Inc., 2020).

Results

The descriptive statistical parameters between trials for each of the tests performed are shown in Table 2. Using the Kolmogorov-Smirnov test with Lilliefors correction, no significant deviations from a normal distribution were found for all observed variables and in all observed performance categories (P> .20). In addition, the t-test between the test subjects did not reveal any significant differences between the genders in any of the tests (P> .05), which is why the sample was treated as homogeneous for the subsequent analyses.

Test-retest reliability

The raw data showed that a learning effect between the trials has certainly occurred, as reflected in the relatively small differences in the mean values between the trials. (Table 2).

Table 2. Mean ± standard deviation (M ± SD) and reliability measures of the used generic and badminton-specific agility tests.

	Trial 1 (M ± SD)	Trial 2 (M ± SD)	Trial 3 (M ± SD)	ICC	α	KS-p
MDA“ABCD”	11.17±1.17	10.79±0.97	10.79±0.97	.89	.97	> .20
STSLA	09.38±1.20	9.02±1.31	9.12±1.37	.91	.98	> .20
BSA„SRT“	17.44±2.85	17.15±3.26	16.73±2.92	.79	.97	> .20
BSA„OAT“	19.63±2.92	18.81±2.74	18.05±2.46	.88	.93	> .20
BSA”RAT”	17.92±2.30	17.40±2.14	17.08±2.22	.88	.97	> .20

Note. MDA“ABCD” - Multi Direction Agility “ABCD”, STSLA - “Steps To Side” Lateral agility, BSA“SRT“ - Badminton-Specific Agility „Shuttle Run Test“, BSA“OAT“ - Badminton-Specific Agility „On-court Agility Test“, BSA“RAT“ - Badminton-Specific Agility „Reactive Agility Test“, Intraclass corelation coefficient (ICC), Cronbach alpha (α); significance of Kolmogorov-Smirnov-test (KS-p).

The Cronbach's alpha values (Table 2) showed a very high internal consistency of the participants’ position on the measurement scale between trials for all variables (α ranged from .93 - .98). In addition, the ICC ranged from .79 for the specific badminton lateral agility test (BSASRT), which is considered a good agreement of the measurement results, to .91 for the generic lateral agility test (STSLA), which according to Koo and Li[29] is an indicator of excellent repeatability of the measurement results. The newly developed BSARAT showed (Table 2) a very high internal consistency between the trials (α = .97) and a “good” repeatability of the measurement results (ICC = .877).

The results of a one-way ANOVA conducted with the aim of determining the discriminant validity of the newly designed agility test and the entire test battery in relation to the three categories of performance level of young badminton players showed significant differences within all tests (Table 3).

The post-hoc Bonferroni correction was applied to gain additional insight into the structure of the differences obtained. The results show that in the BSARAT test, as in all other agility tests in the test battery, there are significant differences between the *High* and *Low* level players. In addition, significant differences were also found between the *Medium* and *Low* levels in the BSASRT and BSAOAT.

Furthermore, the results of the exploratory factor analysis (Table 3) showed that a significant latent dimension was extracted that explained 84% of the common variance of the test battery. All five agility tests that made up the test battery loaded highly on a common factor, with the lowest projection to the common factor of .87 shown by the BSASRT and the highest projection of .96 by the BSAOAT. The newly designed BSARAT has the second highest projection to the common factor of .94, only a fraction lower than the BSAOAT test, which it most closely resembles structurally.

Discussion

Agility is undoubtedly a very important ability in badminton. Competitive badminton players need to be able to make quick, multidirectional movements to put themselves in the best possible position to hit the ball, enabling them to hit a technically successful shot[24, 30]. Therefore, the development of appropriate tests to assess and monitor development at different stages of a player's career is an important task for coaches and sports scientists involved in badminton training and research. However, before a newly constructed test is used in practise, its measurement properties should be tested[17] and compared with some already validated and frequently used general and

Table 3. Differences in test results between the players group categorised according to their competitive performance level, values expressed as M ± SD, except for sex (M/W ratio).

AGILITY TESTS	COMPETITIVE PERFORMANCE LEVEL			ANOVA			Factor Analysis
	1. High (n_1 = 12)	2. Average (n_2 = 14)	3. Low (n_3 = 15)	F	*P*	η_p^2	Factor
MDA"ABCD"	10.49^3±0.98	10.72±0.95	11.44±0.80	4.14	.02	.18	-.88
STSLA	8.63^3±1.17	8.93±1.14	9.84±1.20	4.00	.03	.17	-.93
BSA„SRT"	15.48^3±2.20	16.34^3±2.10	19.12±2.15	7.69	< .001	.29	-.87
BSA„OAT"	17.13^3±2.08	18.42^3±1.76	20.57±2.24	7.91	< .001	.29	-.96
BSA"RAT"	15.92^3±1.81	17.44±1.89	18.74±1.90	7.58	< .001	.29	-.94
Age	14.61±3.01	14.65±1.48	14.30±2.36	.48	.62	.02	
Hight	170.42±13.01	167.21±10.53	169.03±13.06	.32	.60	.14	
Sex (M/W)	7/5	7/7	7/8				

Note. MDA"ABCD" - Multi Direction Agility "ABCD", STSLA - "Steps To Side" Lateral agility, BSA"SRT" - Badminton-Specific Agility „Shuttle Run Test", BSA"OAT" - Badminton-Specific Agility „On-court Agility Test", BSA"RAT" - Badminton-Specific Agility „Reactive Agility Test"; ANOVA F value (F), statistical significance (p), partial eta squared (η_p^2), 3- significantly different from *Low* performance level, correlations of the tests with the main component of factor analysis (Factor).

badminton-specific agility tests. Test-retest reliability is the most important prerequisite for the repeatability and reproducibility of tests. It is a measure of the stability of the results and indicates the extent to which the results can be distinguished from one another despite measurement errors[31]. Since both intra-subject and inter-subject reliability are important indicators of the overall quality of the test, various measures of reliability were used in this study to determine the inter-subject and intra-subject reliability of the new test. The results of the newly designed BSARAT showed (Table 2) a very high inter-subject reliability, as high values of the Cronbach's alpha coefficient (α= .97) prove that the participants actually maintained their relative position on the measurement scale compared to other test participants during repeated measurements. In view of the results of the reliability measures presented above, it is not unexpected that the ICC, which reflects both intra-subject and inter-subject reliability, has slightly lower values than the Cronbach's alpha coefficient. However, the ICC values obtained in the BSARAT (.88) can be considered moderate to high according to the standards proposed by Koo and Li[29]. At the same time, these ICC values proved to be identical to the other badminton-specific agility test (e.g. BSAOAT), to which it is structurally most similar within the test battery used. Overall, it can be concluded that the newly designed reactive agility test for measuring specific badminton agility (BSARAT) is ecologically valid and has a very high internal consistency between the tests as well as satisfactory repeatability.

Minor fluctuations in the test results in repeated measurements can be explained primarily by learning effects, which are reflected in the systematic improvement in the results achieved by the participants between test trials. This pattern occurred across the entire test battery, which is not surprising given that each participant performed these tests for the first time. This indicates that a mandatory familiarisation session should become a standard part of the testing protocol, and that, in addition to the existing low-intensity trial, a full-intensity practice trial should also be conducted before baseline testing.

In comparison to the results of previous studies, the test-retest reliability of the newly developed reactive agility test (BSARAT) has been shown to be very consistent with the other commonly used badminton-specific speed and agility tests: BST[16], BSST[32] and Badcamp[17], all of which showed good to excellent test-retest reliability, and better than that of the MDCT[33] and MRSAB[34], both of which showed moderate reliability.

Construct validity of the newly designed test

The results of the exploratory factor analysis showed that all five speed and agility tests that formed the test battery projected highly onto the common factor (Table 3.). Since only one latent dimension was extracted, explaining 84% of the common variance of the test battery used, it can be assumed that the tests used measure the same construct to a significant extent. It was also shown that the BSARAT together with the BSAOAT had the highest projection on the common factor (.94 and .96). It is evident that the more complex badminton-specific agility tests, which use multidirectional movement patterns and are designed to simulate the badminton player's movement and shot execution in real play, explain more variance of the common latent dimension than the general or simpler specific agility tests used in this study.

Although the BSARAT is a reactive agility test, designed to measure both the cognitive and physical aspects of agility, and the BSAOAT test, designed to cover only the physical side of agility as a COD test, is hypothesised to measure two theoretically different aspects of agility (pre-planned and reactive), their contribution to explaining the common variance is almost identical. The hypothesis that there are differences in measurement characteristics between pre-planned and reactive badminton-specific agility tests was not supported in the case of this research study and for this sample of participants. These results strongly suggest that all five tests, whether reactive or pre-planned, measure a nearly identical physical construct in this population. If the newly designed BSARAT is considered separately, it demonstrates high factorial validity compared to established and validated generic and badminton-specific

agility tests, as it has a high projection (.94) on the common latent dimension, which can be predominantly explained by the badminton-specific agility tests.
The results of the one-way ANOVA, which was conducted with the aim of determining the discriminative validity of the tests used in relation to the three competition-specific performance categories, showed (Table 3.) significant differences between the three groups of players and their performance in all generic and badminton-specific agility tests. To gain additional insight into the structure of the differences found, a post-hoc Bonferroni correction was performed. The results showed that for the new BSARAT test, as for all other agility tests in the test battery, the differences between players with *High* (1st category) and *Low* performance levels (3rd category) were significant. In the two badminton-specific agility tests (BSASRT; BSAOAT), significant differences were also found between the players with an *Average* level (2nd category) and the players with a *Low* level (3rd category). Although these differences were not significant in the other tests that make up the test battery, a clear trend in favour of the more successful players can be seen in the mean values. No significant differences were found between the high-level players (1st category) and the average-level players (2nd category) in any of the tests used, although the differences between the categories are evident from the average results of the tests.
The results obtained show that the BSARAT can differentiate young badminton players in terms of their competitive performance, as was also the case with all other agility tests that formed the test battery. This study did not find that different generic and badminton-specific agility tests discriminated significantly differently between players in terms of their competitive performance. The results are consistent with other studies that assessed the discriminative ability of agility tests in badminton. The two commonly used badminton-specific tests, the BSST[32] and the Badcamp[17-18], showed significantly better performance in higher level players, as did the partially specific MRSAB[34] and the non-specific “505 Agility Test”[35], which also showed better performance in higher level players. Relating the results to those of the few other studies in racket sports that examined the ability to discriminate between agility test scores and player performance level, two of the rare tennis studies on this topic[36,37] also found better performance on the tennis-specific agility test among higher-level male youth tennis players.
It can be concluded that the BSARAT is an ecologically valid and reliable instrument that, together with the other general and badminton-specific agility tests used in this study, can be considered useful for predicting the competitive performance of young badminton players.

Practical Applications

The newly designed (BSARAT) test proved to be a feasible test, suitable for regular use in various training and testing environments, without any special requirements for equipment from the test organisers. The test is designed to use the existing features of the badminton court and, in addition to standard badminton equipment (racket and shuttles), requires only a stopwatch and adhesive tape to mark a square in the centre of the court. Furthermore, only one measurer is needed to conduct the test. The fact that the newly designed test does not require sophisticated measuring equipment can also be seen as a disadvantage, as manual measurement of the test time is certainly less reliable than using photo cells. However, the potential measurement error should have been reduced by using the average of three trials.

Limitations Of The Study

The sample of examinees included both male and female participants, pooled into a single group, which may be a concern given the physiological differences between genders. However, the sample consisted of participants in early to mid-teen years (14–15 years), and the sex gap at this age is present but modest, much smaller than in later adolescence[38], which supports pooled analyses at this specific age. Moreover, sport-specific evidence relating to agility performance shows that agility changes little across the mid-teen years in males and plateaus earlier in females. Scoping reviews and longitudinal or age-group comparisons report relatively small between-group differences in agility around the mid-teen years, with larger divergences emerging later[2].
However, although the results have not shown significant differences in age and height within groups, with group sizes of n = 21 (males) and n = 20 (females), the statistical power to detect a true difference may still be insufficient. Therefore, this is noted as a limitation of the study.
Another limitation of the study is that the newly developed BSARAT test could significantly differentiate only between High and Low performance groups, but was unable to distinguish between High and Average level players. The authors believe that, as badminton is a highly technical sport, most competitive performance differences between excellent and solid players in late puberty to early adolescence are likely due to technical level rather than purely physical abilities. This suggests that physiological ceilings are less often the limiting factor in youth players than in elite senior players, compared with the players' technical proficiency[39]. Therefore, at this youth age and level of competition, technical-tactical factors are presumed to contribute more to differences in competitive performance than at higher levels of competition, where all players are more equally technically proficient and physical and cognitive abilities become the main differentiators. In short, as the level increases and all players are technically at a very high level, only then do physical and cognitive capacities become the main separators[40]. Supporting the presumption that this may be a characteristic of this specific sample is the fact that the same inability to distinguish excellent from solid players is observed in all other agility tests in the battery, regardless of whether they are generic or badminton-specific.

Conclusions

The new badminton-specific reactive agility test (BSARAT) was developed with the aim of providing badminton practitioners with an easy-to-use instrument to assess both the motor and cognitive aspects of agility performance in badminton players. The results of the study confirm the construct validity of the new test. Its test-retest reliability is also broadly in line with other commonly used badminton-specific speed and agility tests, with which the new test also shares the ability to successfully differentiate between badminton players of different performance levels.
Compared to the other badminton-specific reactive agility tests in use today, the greatest strength of the new test lies in its feasibility and practicality. The new BSARAT test requires no specialised technical equipment and minimal preparation time, making the test very practical for regular use.
Although the new test shows promising results and has the potential to be widely used in practise, new research studies,

preferably with more homogeneous samples of badminton players in terms of their gender and age, are certainly recommended to further determine the full potential of the test.

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Informed Consent Statement

Informed consent has been obtained from all subjects involved in the study.

Ethical Committee approval

Ethics Committee of the Faculty of Kinesiology University of Split (ID:2181-205-0205-22-024)

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Author-s contribution

Conceptualization, G.J., G.Mu., G.Ma., G.Y. and I.F.; methodology, G.J., G.Mu., I.F.; software, G.J.; formal analysis: G.J., G.Mu.; data curation, G.J., G.M.; writing—original draft preparation, G.J., G.Mu.; writing—review and editing, G.J., G.Mu., I.F. and G.Ma.; visualization, G.Mu. and I.F.; supervision, G.J. and G.Ma. All authors have read and agreed to the published version of the manuscript.

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