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Reliability and validity of a novel agility measurement device for badminton players

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ABSTRACT

The validity and reliability of a novel badminton agility test was examined by making comparisons with previously established agility tests, namely the T-test and Illinois test. The participants were active high-level badminton players (*n* = 36) and active non-badminton players (*n* = 33). The participants performed three tests to assess agility: (a) T-test, (b) Illinois test, and (c) the novel badminton agility test (BAT). Independent samples *t* test was used to compare mean scores and paired-samples *t* test for the differences between pre- and post-tests. Intraclass correlation coefficient (*ICC*), paired samples *t* test and Bland-Altman plot were used to test the reliability of the agility measurements. The level of agreement between the tests was analyzed by using Cohen's Kappa (κ) and Pearson's *r*. Concurrent validity was tested by dispersion plot and coefficient of determination. Construct validity was assessed by independent samples *t* test. According to the results, it was found that BAT had a good level of agreement with T-test and Illinois test. BAT was found to be a discriminative test for the badminton and non-badminton players. BAT was strongly correlated to T-test but the correlation to IAT was stronger. Construct and concurrent validity of BAT were found to be high and reliability assessments revealed satisfactory results. It was found that agility assessment by using BAT could be appropriately done for the badminton players. BAT seems to be a valid and reliable agility measurement test for the badminton players, but not for the non-badminton players, and it has concurrent validity, construct validity, and relibility.

Keywords: Assessment, racquet sports, speed, evaluation, test.

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INTRODUCTION

Identifying and developing the physical characteristics of the athletes are always of great concern for coaches/trainers (Pauole et al., 2000) and athletic talents were evaluated by using physical performance tests (Chu and Vermeil, 1983). There are numerous tests available to measure performances such as cardiovascular endurance, power, strength, flexibility and agility. Professionals (coaches, trainers, physiologists, etc.) use performance tests to assess athletes' performances and the effects of the training sessions. There is no standard test battery that is suitable for any sport but many test are commonly used in diffent types of sports. Cooper's 12 min walk/run test is a widely used test to assess aerobic endurance, for instance.

Badminton is a net game, in which players try to beat their opponents by dropping the shuttlecock onto their courts. Badminton requires endurance, power, speed, and agility. Agility is very important in badminton since the speed of the shuttlecock can reach at a speed of 118 $m \cdot sec^{-1}$. As the shuttlecock has high post-impact speed, the opponent will have a very limited reaction time, while he tries to make quick reactive movements to send the shuttlecock back to the opponent's court (King et al., 2020) and this means that players may have less than one second to react and return the shuttlecock (Abernethy et al., 2012). A badminton player is expected to move fast and change direction quickly for many times to earn the serve, thus, to earn the point. The number of rallies in badminton may extended to 150 in top level competitions and the players have to move quickly to an unexpected spot in the court. Having such an important role in returning the shuttlecock for many times, players' agility is the key to success in badminton.

Agility is defined as the ability to produce power and to change the movement direction rapidly (Haj-Sassi et al., 2011; Young et al., 2002) but it also has a cognitive dimension and it is related to the the decision-making speed of the player (Young and Willey, 2010). In most of the sports competitions, the speed of the athlete is important but the ability to decide and change the direction of movement is as important as the speed. So, if a task involves some sort of preplanned actions, they are proposed to be considered not agility but change of direction (Loureiro and Freitas, 2016).

There are some tests to assess agility levels of the athletes in many sports such as netball (Farrow et al., 2005), tennis (Monte and Monte, 2007), and rugby (Gabbett and Benton, 2009). Although there are many sports-specific agility tests, most of the agility tests used to assess badminton players' agility levels are not suitable to reflect the players' on-court movements. General agility test protocols have standard tasks and paths to cover by running fast but it is not similar to the players' movements in badminton as they have to reach different corners of the court in an unknown order. Although the general tests give a clue for the players' levels of agility, a more specific agility test for the badminton players is needed.

There is a badminton-specific agility test, called Badcamp, but it has many physical components that have to be set up prior to testing. It requires six inflatable towers, each 120 cm tall. A center push-button with an iron supportive leg and an LED panel. The system runs by a microcontroller which has 6 preprogrammed sequences of directions. It was stated by the authors that the system could be assembled for about $300 and the system could be set up on the court in about ten mins (Loureiro and Freitas, 2016).

The aim of this study was to design and build a novel badminton agility testing system which was easy to set up and highly reliable and valid.

MATERIALS AND METHODS

Subjects

Thirty-six active male badminton players (age: 21.58 ± 2.12 yrs; height: 177.73 ± 5.05 cm; weight: 69.98 ± 5.75 kg) and thirty-three non-badminton players (age: 21.82 ± 2.76 yrs; height: 175.72±4.83 cm; weight: 67.56 ± 8.26 kg) participated in this study. Non-badminton players were active futsal, soccer and handball players with an experience of at least 10 years. The participants declared no history of musculoskeletal problems or injuries occurred in 6 months. This study was approved by Hitit University Non-Interventional Researches Ethics Committee (2019-77) and the experimental procedure complied with the Declaration of Helsinki. The participants performed the tests twice as the pre- and post-tests. The participants provided informed consent before the tests. The active badminton players had at least 10 years of badminton experience.

Data collection and test protocols

The athletes performed three agility tests in 3 nonconsecutive days. Each test was performed in a day by providing enough rest time between trials. The athletes wore sporting suits and sports shoes. The tests were held in the same sports hall between 09:00 a.m. and 11:00 a.m. on the testing days.

T-test

T-test was applied to the athletes as the first agility test. The athletes were asked to complete the T-test protocol as described by Semenick (1990). Three trials with full recovery rests between trials were performed and the best time was recorded. Time was kept by using an electronic timing system with two photoelectric sensors.

Illinois agility test

Illinois agility test (IAT) was conducted as the second agility test. After the athletes prepared and were ready, the test was performed as described by Amiri-Khorasani et al. (2010). The athletes performed the test three times and resting periods given were enough for full recovery. The performance times were measured by using an electronic timing system and the best time was recorded.

Badminton agility test

Badminton agility test (BAT) was held by using a testing device that was designed and produced by the researcher. The device consisted of one main control unit (MCU) and two photoelectric sensors (PES). MCU had an ATmega328p (5 V, 16 MHz) microprocessor that was coded by using Arduino. There were two cold white light-emitting diodes (LED) placed on the left and right sides of the MCU's front panel. The sensors were placed on the badminton court's forehand and backhand sides of the frontcourt. Each sensor was placed 30 cm apart from the net and the left sensor was placed 70 cm away from the left side line for doubles and the right sensor was 70 cm away from the left side line for doubles (Figure 1).

A center mark cylinder (12-shuttlecock box) was placed at the intersection of the center line and the short service line (Figure 2). The athlete was set at the middle of the court right behind the center marker cylinder with each foot in either service court. When the device was set to start, both of the LEDs were turned on. When ready, the athlete moved and reached to either of the PES by

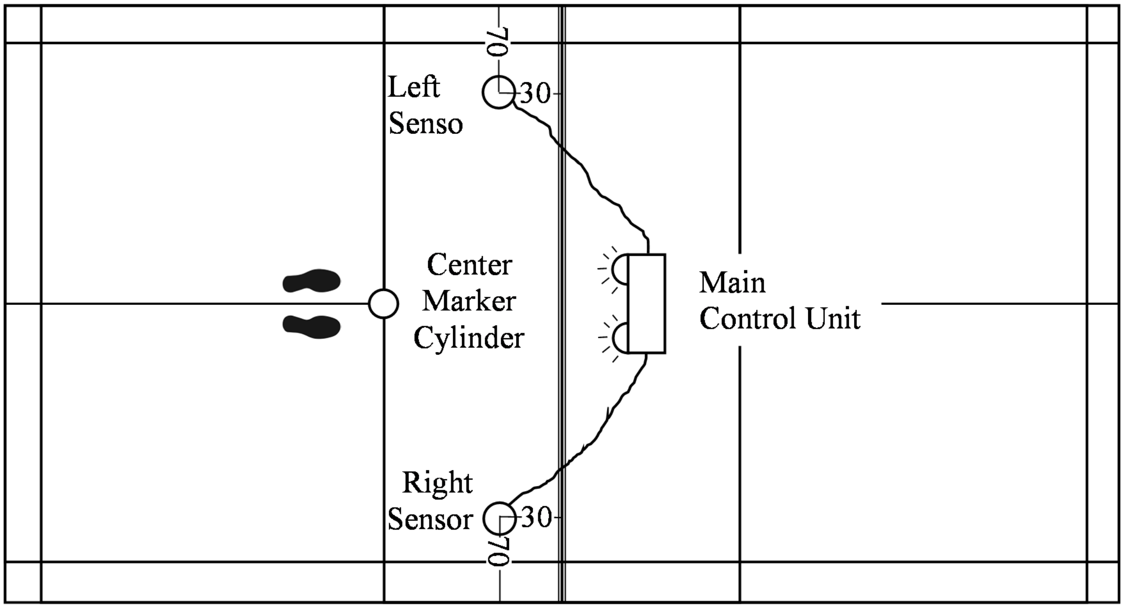

Figure 1. BAT device setting diagram.

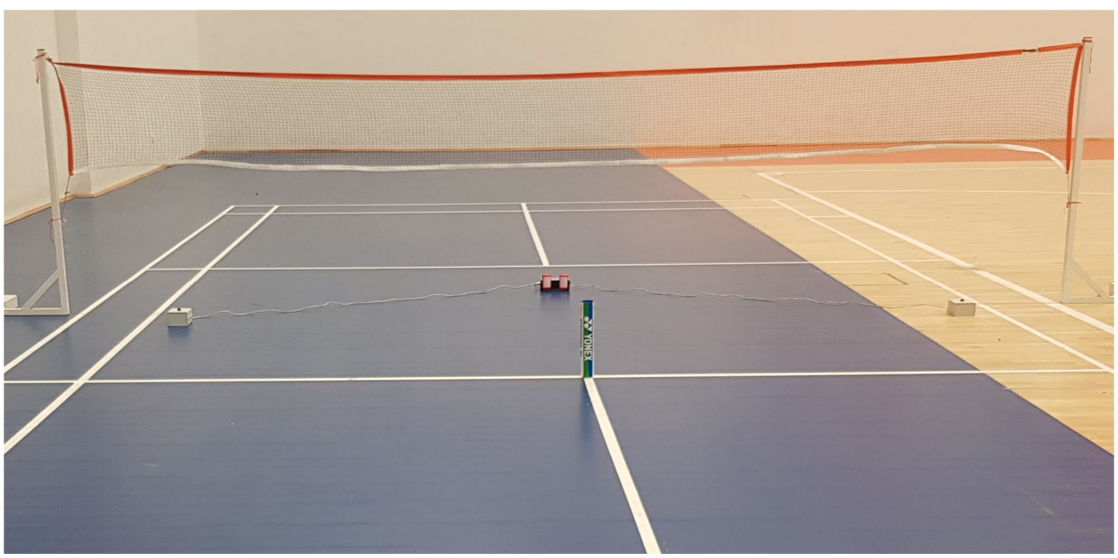

Figure 2. BAT device setting on court.

his/her racquet hand closer than 20 cm. Following a successful movement, the LED on the corresponding side was turned off. After the LED turned off, the athlete aimed to get to the center of the court as soon as possible since he/she does not know which LED would turn on next.

During the movement of the athlete, the next LED was randomly decided by the MCU and it was turned on (Figure 3). When the athlete saw the LED was on, he/she aimed to get to the corresponding PES as fast as possible. If he/she was not at the center of the court when the LED was on, he/she could reach to the sensor before he/she turned back to the center but the athlete was not allowed to shorten the path by running between the center marker cylinder and the net. The score was the number of successful repetitions. The test lasted for 30 s and the number of the LEDs turned off was recorded as the score. BAT was performed three times with enough rests for full recovery between sets and the highest score was recorded as the performance of the athlete.

The testing device is very compact and easy to set up. The device can be built under $30 and very affordable when compared to the other digital and electronic

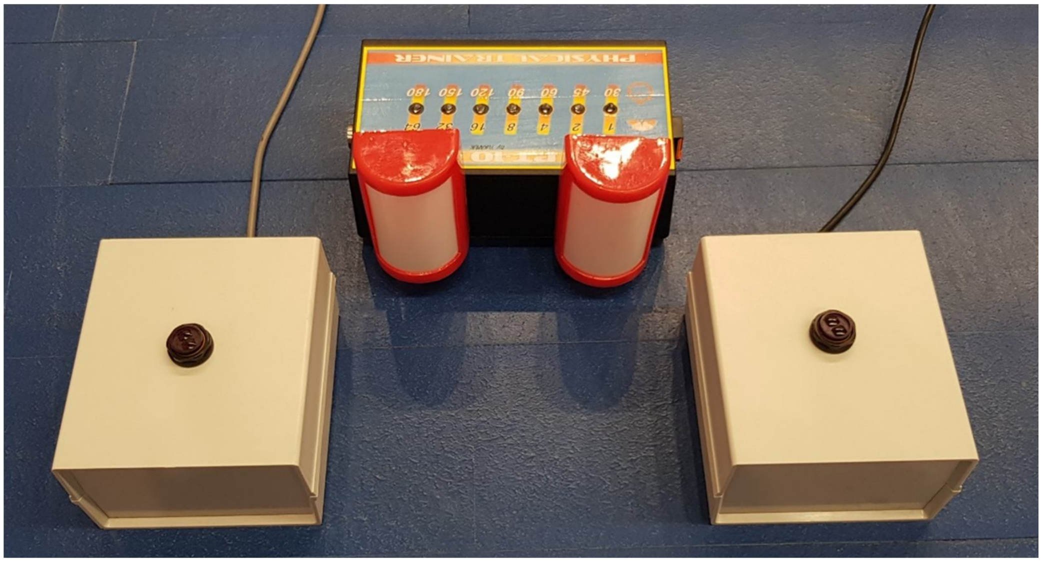

Figure 3. Main control unit and photoelectric sensors.

measurement devices available. The device was assembled and the Arduino was coded by the author. The source code and Arduino diagram can be shared on request.

Statistical analysis

Statistical analysis was performed using SPSS 25.0 (IBM Corp., USA) software. Descriptives were given as mean±standard deviation (*SD*) where appropriate and confidence intervals (*CI*) were calculated at 95%. Normality of the data was tested by using Shapiro-Wilk and it was found that the data were normally distributed ($p > .05$). Comparisons of mean scores were made by using independent samples *t*-test for the differences between agility tests and paired-samples *t*-test for the differences between pre- and post-tests. Intraclass correlation coefficient (*ICC*) and Pearson's *r* were used to test the reliability of the agility measurements. Pearson's *r* was computed between the BAT and the other agility tests, and partial correlations were also computed to obtain estimates of criterion validity. The level of agreement between the tests was analyzed by using Cohen's Kappa (κ) and Pearson's *r*. The statistical significance level was set at $p < .05$ for the statistical analysis used.

RESULTS

Descriptives for the badminton players and non-badminton players are presented in Table 1. There were no significant differences in age, height, weight, BMI, T-test and IAT between badminton and non-badminton players according to the independent samples *t* test results ($p > .05$). The only difference between the athletes was in BAT scores ($p < .01$). Badminton players' performance (15.75 ± 3.15 reps) was significantly better than the non-badminton players performance (11.55 ± 2.46 reps).

The participants' mean differences in agility tests are given in Table 2, where the results of the reliability analysis are shown. Badminton players' *ICC* and Pearson's *r* were between .91 and .98 which were pretty high. Pre- and post-test scores were highly correlated and there were no statistically significant difference between pre- and post-tests. Non-badminton players' *ICC* and Pearson's *r* values were also high and between .90 and .97, but BAT results did not reveal a correlation as strong as the badminton players had. The *ICC* was as low as .78 and Pearson's *r* was .64.

Cohen's kappa and correlation analysis results are provided in Table 3. As shown in the table, BAT has a high level of agreement with IAT (κ = .997; $p < .01$) and T-test (κ = .900; $p < .01$). Pearson's *r* is also pretty high for the badminton players ($r = -.917$; $p < .01$ and $r = -.832$; $p < .01$; respectively). Non-badminton players' level of agreement between BAT and T-test was not good (κ = .571; $p = .031$). Illinois test had the same level of agreement (κ = .571; $p = .018$). The correlation between BAT and the other agility tests for the non-badminton players were low ($r = -.380$; $p = .012$ for the T-test and $r = -.606$; $p = .008$ for IAT).

The concurrent validity of the BAT was inspected in Figure 4. The dispersion plot for BAT and T-test was presented in Figure 4a, and Figure 4b depicted the dispersion between BAT and IAT of the badminton players. In both figures, BAT was seen to have negative correlations with the agility tests used. The best-fit line

Table 1. Descriptive statistics.

Variables	Badminton players (*n*=36)		Non-badminton players (*n* = 33)		*p*
	Mean ± *SD*	95% *CI*	Mean ± *SD*	95% *CI*	
Age (year)	21.58 ± 2.12	17.42-25.74	21.82 ± 2.76	16.41-27.23	.69
Height (cm)	177.73 ± 5.05	167.83-187.63	175.72 ± 4.83	166.23-185.17	.10
Weight (kg)	69.98 ± 5.75	58.71-81.25	67.56 ± 8.26	51.37-83.75	.16
BMI ($kg.m^{-2}$)	22.15 ± 1.49	19.23-25.07	21.87 ± 2.49	16.99-26.75	.57
T-Test (sec)	10.21 ± 0.42	9.39-11.03	10.39 ± 0.51	9.39-11.39	.10
IAT (sec)	15.65 ± 0.48	14.71-16.59	15.61 ± 0.45	14.73-16.49	.68
BAT (rep)	15.75 ± 3.15	9.58-21.92	11.55 ± 2.46	6.73-16.37	.00*

* $p < .01$.

Table 2. Reliability analysis of agility performance tests.

Group	Test and retest	Mean difference (95% *CI*)	*ICC* (A, 1)	Pearson's *r*	*p*
Badminton players	T-Test	0.024 ± 0.16 (*-0.29 – 0.34*)	.96	.94	.38
	IAT	0.022 ± 0.20 (*-0.37 – 0.41*)	.95	.91	.51
	BAT	0.028 ± 0.65 (*-1.25 – 1.30*)	.98	.98	.80
Non-badminton players	T-Test	0.032 ± 0.15 (*-0.26 – 0.35*)	.97	.95	.23
	IAT	0.024 ± 0.19 (*-0.35 – 0.40*)	.94	.90	.48
	BAT	0.424 ± 2.15 (*-3.79 – 4.64*)	.78	.64	.27

Table 3. Pearson's correlation and Cohen's Kappa test results.

Groups	Tests		T-test	Illinois agility
Badminton players	BAT	Cohen's κ	.900	.997
		p	.000	.000
		Pearson's *r*	-.832	-.917
		p	.000	.000
Non-badminton players	BAT	Cohen's κ	.571	.571
		p	.031	.018
		Pearson's *r*	-.380	-.606
		p	.012	.008

and the linear equation revealed the relationships of BAT with the T-test and the Illinois test. The coefficients of determination (r^2) were also presented on the figures and the results revealed a strong and negative relationships between the performances in BAT and both T-test ($r = .90$, $p < .01$) and IAT ($r = .997$, $p < .01$). Figure 4c presented the dispersion plot for BAT and T-test while Figure 4d was for the dispersion plot for BAT and IAT of the non-badminton players. The coefficients of determination for the non-badminton players were low ($r^2 = .14$ for the T-test and $r^2 = .37$ for the IAT).

Test-retest reliability was tested by using Bland-Altman plot test. Intraclass correlation coefficient was found to be very high (ICC = .947, 95% *CI* = .915 to .967). Paired samples *t* test results showed no significant differences between test (13.74 ± 3.53) and retest (13.96 ± 3.46) performances ($t_{68} = -1.157$, $p = .251$). Bland-Altman plot was also created to assess test-retest reliability visually. Figure 5 shows that all values but two are within the limits of agreement.

Construct validity of the BAT was inspected by analyzing the differences between the badminton players' and non-badminton players' performances by using independent samples *t* test. Badminton players' performances (15.76 ± 3.14) were significantly ($t_{67} = 6.018$, $p < .01$) higher than non-badminton players'

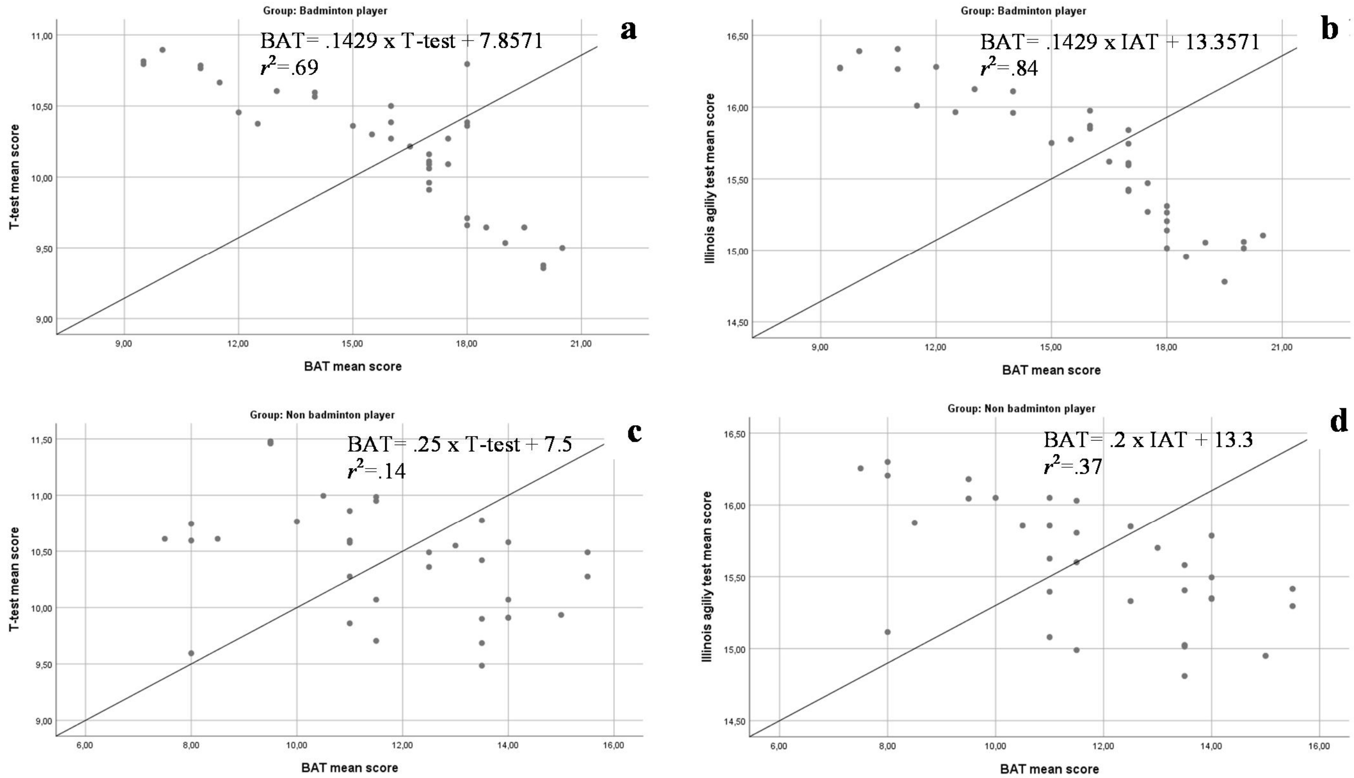

Figure 4. Dispersion plot for BAT with T-test and IAT.

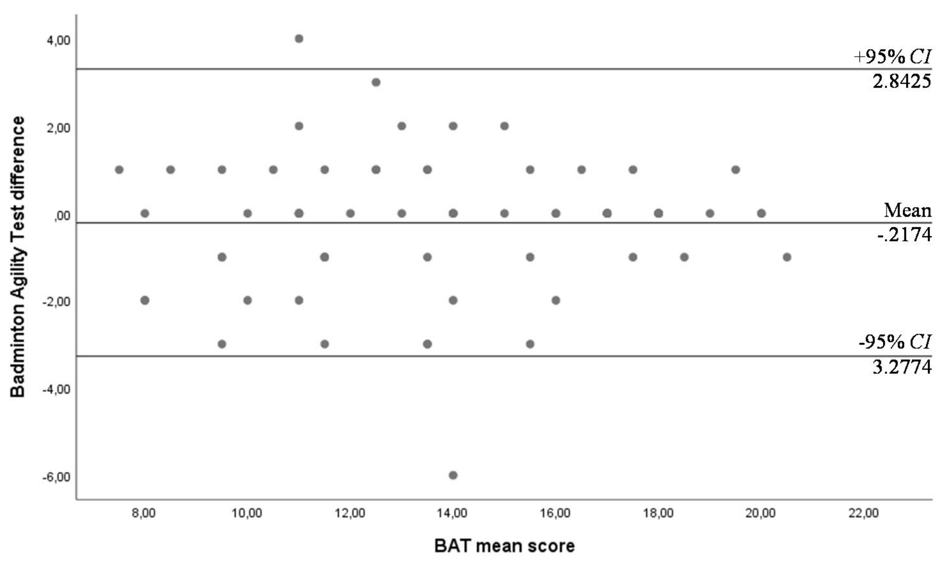

Figure 5. Analyzing the agreement between BAT test and retest by using Bland-Altman plot.

performances (11.76 ± 2.27).

DISCUSSION

The current study was aimed to assess the reliability and validity of a novel badminton agility test and the results proved that BAT was strongly correlated to T-test but the correlation to IAT was stronger. Construct and concurrent validity of BAT were found to be high and reliability assessments revealed satisfactory results. It was found that agility assessment by using BAT could be appropriately done for the badminton players. Non-badminton players' were not as successful as the badminton players in BAT. Since the non-badminton players were active futsal, soccer and handball players, their agility levels were high according to the T-test and Illinois test results but their BAT performances were lower than the badminton players. As the T-test and IAT are used for general agility assessment, they have no sports-specific movements or no fundamentals are required. Badminton players did well in all three tests but non-badminton players were not good at BAT but the other two agility tests. The reason to this was thought that the movements required in BAT overlapped with the movements, especially footwork, occur in a regular badminton game but non-badminton players had no previous experience or training of these badminton-specific movements. In the general agility tests, no differences were found between badminton and non-badminton group. So, it can be told that BAT assessment was correctly classified the badminton players and non-badminton players but general agility test were not as sensitive as BAT.

General agility assessment can be done by using any agility test protocol but the question is how to measure the agility levels of the badminton players. BAT may offer an appropriate solution to this issue. BAT can also be used as a means of athlete selection tool as it can succesfully discriminate badminton players from the others. Reilly et al. (2000), reported that the results of an agility test would discriminate elite football players in a population when compared to the other field tests. Alternatively, Ooi et al. (2009) reported that there were no statistically significant differences in shuttle run or badminton-specific agility test scores by being elite or sub-elite players. The results of that study is not consistent with the results of the current study. The reason to this was thought to be that the current study compared badminton players and non-badminton players, but Ooi et al. compared only badminton players with different success levels (elite and sub-elite). Since all the subjects in that study were badminton players, the conflicting results might be emerged.

In the literature, many attempts to find the best agility test were found but there is still no agreement on the "gold standard" for agility assessment (Pauole et al., 2000). Some authors claim that T-test was the gold standard to assess change of direction (Hachana et al., 2013) or shuttle run agility test was the gold standard (Loureiro and Freitas, 2016) while some others voted for Illinos agility test (Reilly and Williams, 2003) or hexagon drill (Pauole et al., 2000). The reason for having many different opinions about which agility test was the best, may be due to the wide range of requirements. Some may need to have quick feet while some other need full body agility. General agility tests are easy to use and their application is very simple but these tests does not contain sports-specific movements that reflect the real actions in sports competitions (Loureiro et al., 2017). Because general agility tests cannot help in assessing specific sports-related agility, some new assessment tests were required. In some studies, athletes from a specific sport were evaluated and the results revealed that even in the same sport, positions would affect the agility levels. For example, according to a study conducted on basketball players, a significant difference was found between backcourt and frontcourt players' agility times (Scanlan et al., 2014). Agility was shown to have no strong relationship with linear sprint, leg strength or power (Salaj and Markovic, 2011).

Another reason that a general agility test requires a fixed movement sequence and no extra stimulus is given, the results of that agility does not differ by type of sport. Shuttle run was commonly used in badminton to improve agility of the athletes but reactive initiation training was found to be more effective in beginner level badminton players. It was previously reported that agility had a weak correlation with the regular agility protocols (Dong et al., 2018).

In BAT athletes need to be quick and able to perceive the signals fast. Perceiving the signal is a prerequisite to start moving the body. BAT includes many accelerations, decelarations, changes in directions and decision making (Young et al., 2002). It was previously reported that athletes with high skill levels were faster in agility tests the reason was thought that these athletes had shorter decision times (Young and Farrow, 2006). By having these attributes, BAT correctly discriminates badminton players from the other athletes. As the sequence of movements have infinite variations, learning effect cannot alter the athletes' BAT results.

Conclusion

BAT seems to be a valid and reliable agility measurement test for the badminton players as it has concurrent validity, construct validity, and relibility.

Conflict of Interest

The author declares no conflict of interest.

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