Development of an agility test for badminton players and assessment of its validity, reliability, and specificity

LUIZ DE FRANÇA BAHIA LOUREIRO JR. & PAULO BARBOSA DE FREITAS

Graduate Program in Human Moviment Sciences, Cruzeiro do Sul University, São Paulo - Brazil

Keywords: *badminton, agility, perceptual task, validity, reliability, testing*

Introduction

Agility is one of most important physical capacities for sport performance. It is generically defined as the ability to move the whole-body as fast as possible with change of direction. However, in most sports fast whole-body movement is preceded by the selection of where to run. Hence, in sports successful performance depends not only on the time spent to move the body from point A to point B (movement time) but also on the athlete's ability to quickly and effectively define the direction he/she should run. This decision is based on neural information processing that has some sequential steps: the ability to correctly detect relevant changes in environmental signs and/or in motor gestures from an opponent or opponents, motor response selection and planning, and response execution. Some sport scientists suggest that these processes required to make a decision should be considered in the agility classifications (Chelladura, 1976; Young, James & Montgomery, 2002; Sheppard & Young, 2006).

Some testing protocols have been created to evaluate agility in sports taking into consideration perceptual aspects. For instance, scientists interested in agility assessment in open skill sports such as netball (Farrow, Young & Bruce, 2005), Australian football (Sheppard et al., 2006; Veale, Pearce, & Carlson, 2010; Young, Willey, 2010), rugby (Gabbett & Benton, 2009), and tennis (Monte & Monte, 2007) included perceptual and decision making elements on their testing protocols. In these tests, the athletes need to move their body and change its direction according to a visual stimulus presented. However, the equipment used in these tests consists in expensive devices such as movement sensors, high definition cameras and video presentation, which could make them inviable to be used in the field by coaches and athletic trainers.

Badminton is a racket sport with open and very fast actions. One of the players' aims during the game is to put the shuttlecock out of reach of the opponent at the different points of the court by using, for example, high speed strikes (Tsai & Chang, 1998; Jaitner & Gawin, 2010). Thus, to be competitive in badminton, players should be able to move quickly towards a proper position that allows them to intercept and, at the same time, to attack the shuttlecock and it depends on their ability to rapidly define where to run, which in turn rely on their perceptual and decision making capacity and on their ability to move their body as fast as possible. In a recent study with Brazilian badminton players we compared experts and non-experts players in a reactive task that involved pointing targets on a touchscreen monitor (Loureiro Jr. & de Freitas, 2012). The participants were asked to release a small push button pressed with the index fingertip of the dominant hand as soon as a target appeared on the touchscreen, move their arm towards the target, and touch it as accurately as possible. The results revealed that experts had shorter reaction times then non-experts, but found no differences in movement time (i.e. time between the push button release and the screen touch) as well as in accuracy level. These results showed that the time required to process visual information could be an important factor to distinguish performance level of badminton players.

Some studies sought to adapt specific movements performed by badminton players on the court in new tests to evaluate athletes of this sport (Hugues & Bopf, 2005; Walklate & O'Brien, Paton, Young, 2009), but their protocols are only able to measure movement time because the directions of displacements are previously known by the players. Thus, the uncertainty aspect typical of the open sports has been neglected in these tests. To our knowledge, there is no test that links specific badminton movements and the effect of uncertainty in performance. Therefore, the aims of this research project were (1) to develop a new agility test that assess both the perceptual and motor capacity, (2) to examine the test's concurrent and construct validity and its test-retest reliability, and (3) to evaluate the specificity of this test to badminton players. To reach the two last aims we performed two studies as described below.

Method

Sample

To assess concurrent validity, construct validity, and test-retest reliability we selected 43 badminton players (29 male and 14 females) who were participating in a Brazilian championship tournament. The players were between 17 and 32 years-old and all had at least two years of experience in badminton and participation in regional and national tournaments. To assess specificity, we recruited 64 young athletes between 14 and 16 years-old who were engaged in 4 different sports: badminton; tennis; collective sports (volleyball and basketball); and track and field. Hence, 16 athletes (8 males and 8 females) from each sport modality participated in this part of the study. All participants had at least 1 year of experience in official competitions. Before being tested the players or their guardians signed the informed consent form approved by the Research Ethics Committee of the Universidade Cruzeiro do Sul, São Paulo, Brazil.

For concurrent validity we tested 43 badminton players (29 males and 11 females, mean ±SD, 20.97 ± 4.2 years-old). For construct validity we tested 30 players allocated in two groups. In the first group we selected 15 expert players (EXP, 11 males and 6 females, 21.15 ± 3.16 years-old) based on the criteria that these players should be currently playing in the national elite class and should have already played for the Brazilian national team. In the second group we selected 15 non-expert players (NEP, 11 males and 6 females, 22.64 ± 5.6 years-old) who play in lower or intermediate class and who never had served the Brazilian national team. We selected 15 players of NEP group based on the criteria of matching the players of this group with the EXP group in terms of sex, age, body weight, and height. For the test-retest reliability assessment we selected 21 players (15 males and 6 females, 21.06 ± 3.6 years-old) who could be tested twice in two different days.

Testing setup

The test is performed in a rectangular area with 5.6m in length by 4.2m in width, which approximately corresponds to the measures of the singles badminton court (Fig 1A). At the exact center of this area is the center of a smaller rectangle with 0,7m in length and 1,4m in width, which is the starting position of the test. This starting position area is divided into two squares with 0,7m of side (Fig 1E).

Six targets composed of inflatable 1.2 m tall cone-shaped towers, with circular base and top measuring 0.2 m and 0.1m in diameter, respectively (Fig 1D) where placed on top of the four corners of the larger rectangle and at the middle points of the larger side of this rectangle, aligned with its central point. The towers have within its base an attached compartment where was inserted disc weights. These weights were placed in the basis to maintain the towers in a vertical position after they had been touched.

A light panel measuring 0.67m by 0.52m, scaling 1:10 to a half of the singles badminton court was placed 0.5 m in front of the larger rectangle on top of an adjustable tripod. This panel had 6 flashing arrows, each one measuring 0.15 m, formed by a circuit of 43 high glossy yellow LEDs and that are pointing to 6 points of the panel (Fig 1B). Each arrow corresponded to a target and indicated the direction the athlete should run. The arrows pointing upward corresponded to the targets positioned in front of the starting position, the arrows pointing downward corresponded to the targets positioned behind the starting position and the arrows pointing laterally corresponded to the targets positioned on the middle of the area. Behind the panel there were 6 potentiometers linked with each arrow to adjust the brightness of LEDs according to environmental luminosity. The panel height should be adjusted to the height of the participant. The middle arrows should be aligned with eye of the participant.

Connected with the panel there was a microcontroller (MICROCHIP, model PIC32MX) programmed in C++ language to control the sequence of the arrows lighting and to record the time to complete the test. Sixty arrow lighting sequences were determined and stored in the microcontroller. Those sequences lit the 6 arrows with no arrow repetition. The order of the sequences was randomized and very logical sequences (i.e. 1,2,3,4,5,6 or 6,5,4,3,2,1) were not programmed. An automatic chronometer is linked and also controlled by the microcontroller. The chronometer starts when the tested individual touches the push button switch for the first time and stops immediately after the 7th touch on the switch. This push button switch measuring 0.13 m in diameter (Fig 1C) was connected with the microcontroller and was used to control the arrows' lighting sequence. This switch was placed on top of support from the middle of the rectangular starting position limit (Fig 1E). More details of this support can be found in Fig 2.

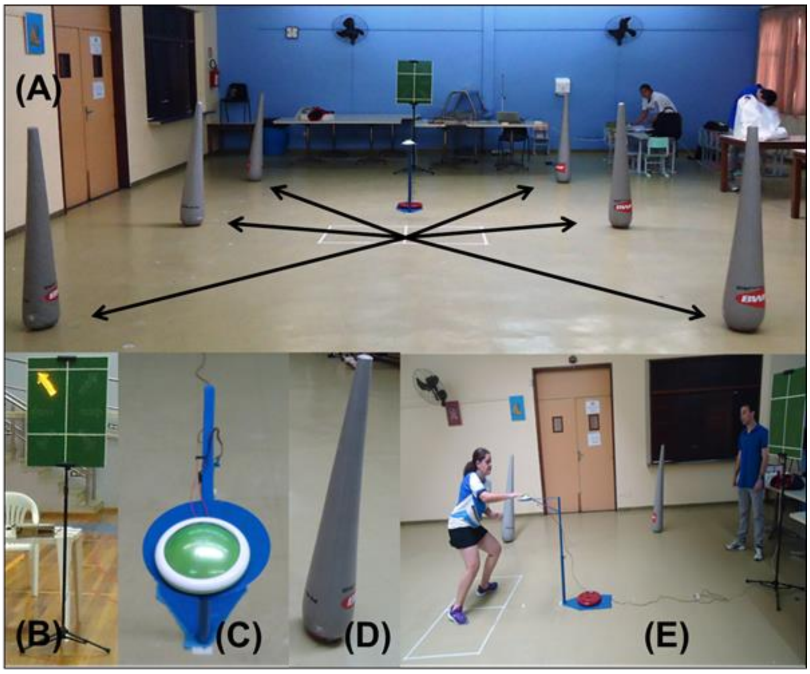

Fig. 1: (A) The general view of the data collection space and the apparatuses used. (B) The panel presenting the running direction. (C) The push switch used to control the target displaying sequence and the time to perform the task. (D) The target used. (E) The participant in the initial position and beginning the test.

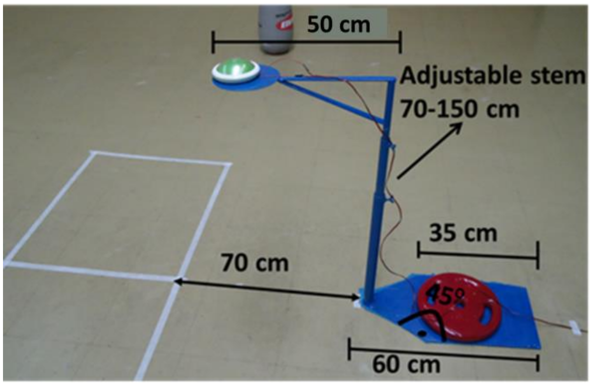

Fig. 2: Switch support should be aligned with umbilicus of the participant

Test execution

Prior testing care should be taken to ensure maximum and safe performance. The floor surface should not be slippery, participants should warm them up just before the test using typical warm up procedure, and they need to use comfortable and stable shoes, similar the ones they use in practice and competition. The test should be explained and demonstrated step by step to the participants by experimenter.

Initially, the participant was required to stay in the start position area (Fig. 1A-E), with the left foot on the left and the right on the right of middle line centered at the rectangular area on the court's center. The experimenter gives the warning signals speaking: - "Be as fast as you can" and "start when you wish". The test starts when the participant is ready and presses the switch for the first time, lighting the first arrow up. As soon as the first arrow is on the participant should run towards the corresponding target, touches it and, immediately, goes back to the starting position area, placing his/her feet on each side of the central line of the small rectangular area, and presses the switch again. The second switch pressing lights the second target, indicating the new target that should be touched. The test ends when the participant finishes touching all six targets and presses the switch for the 7^{th} time. The time recording starts at the first switch touch and ends at the last (i.e., 7^{th}) switch touch just after the individual reach the 6^{th} target.

Each participant performs the test three times with at least of 1 minute of resting between trials and the shortest time was considered for analysis. Before the first valid trial, each participant performed the test at moderate speed to familiarize with the task. If the participant committed errors in any part of the test, the trial was stopped and repeated. The experimenter should consider the following errors in order to require the participants to repeat the trial: (a) touching the switch before the feet are in the correct position (i.e. it was allowed to step in the lines of the rectangular area, but each foot should be visibly in each side of the line that divides the starting position rectangular area), (b) running towards the wrong target, (3) running towards the target and does not touch it, and (4) touching the switch or one of the targets with the non-dominant hand.

Validity and reliability testing procedures

The athletes performed the Badcamp test and shuttle run test on the 1^{st} day of the tournament. Firstly, the players performed the Badcamp and 5 minutes after the end of this test they performed the shuttle run agility test. The shuttle run test consists of running a distance of 5 m in a straight line and going back to start positions for 5 times in a row. The athletes performed two trials and the shortest time was used in the analyses (Adam, Klissouras, Ravazzolo, Reson, & Tuxworth, 1988). Twenty-one badminton players who remained competing and was not injured during the first day of competition performed the tests again on the next day. They performed the test either before their matches or 2 hours after the last one to avoid fatigue effects. The data collected on the 1^{st} day were used for concurrent validity and construct validity assessment. The data collect on the 2^{nd} day were used to assess test-retest reliability.

Specificity testing procedures

The athletes performed the Badcamp test and shuttle run test in a single session, 5 minutes apart. All the tests were applied at their training location and always before the training session.

Statistical analyses

Data distribution were individually assessed for each testing situation: concurrent validity, construct validity, test-retest reliability, and specificity. Data used to test concurrent validity were not normally distributed and, therefore, we performed a non-parametric correlation test (Spearman's Rho) to test the relationship between the performance in Badcamp and Shuttle run. However, data used to test construct validity had normal distribution. Thus, one-way analysis of variance (ANOVA) was employed to test the difference between expert and non-expert badminton players in the Badcamp.

Data used to assess Badcamp test-retest reliability also presented non-normal distribution. Therefore, to assess the relationship between the performances in Badcamp in the first day and in the second day of testing we used Spearman's Rho correlation test and to examine if the performance in the first day was similar to the performance in the second day of testing we carried out a Wilcoxon Signed-Rank test. Finally, data used to test Badcamp's specificity presented normal distribution for both Badcamp and Shuttle run and, consequently, we ran two one-way ANOVA, one for Badcamp e other for Shuttle run. Tests post hoc with Bonferroni corrections were used to assess individual difference between sport modalities. For all test performed alpha level was set at 0.05. We used SPSS statistical package (IBM SPSS, version 19) to perform the analyses.

Results

Fig. 3 depicts a dispersion plot with each point showing each player performance in Badcamp (x axis) and in Shuttle run (y axis). For concurrent validity Spearman's rho test revealed a statistically significant correlation between the performances of badminton players in Badcamp and Shuttle run (ρ= 0.83, $p < 0.001$).

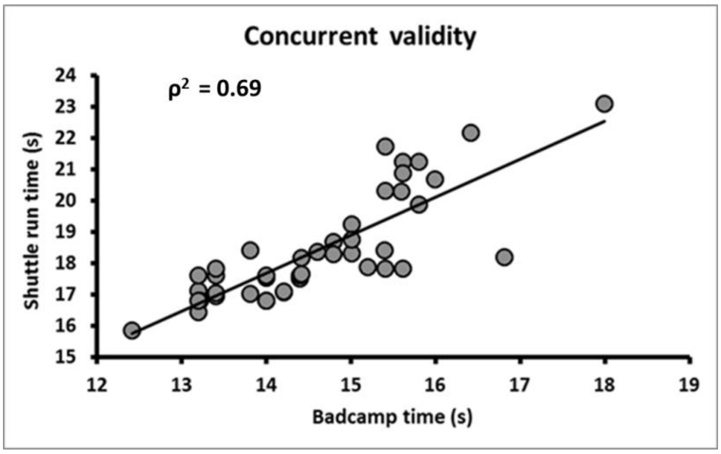

Fig. 3: Relationship between the performance in Badcamp and Shuttle run time.

To assess construct validity we compared the performance of expert and non-expert players in the Badcamp test. One-way ANOVA revealed that expert players performed the test in shorter times than non-expert players (14.01 ± 1.01s and 15.58 ± 0.92s, respectively) [$F(1, 29)$= 19.77, $p<$ 0.01].

Fig. 4 depicts a dispersion plot with each point showing each player performance in Badcamp during test (x axis) and during the retest (y axis). To evaluate test-retest reliability firstly a Spearman's rho correlation test was performed and the result revealed a very strong positive relationship between test and retest performance (ρ=0.92, $p < 0.001$). In addition, we compared the performance in Badcamp during the test and during the retest and the results revealed no difference between the performance in both sessions (Z = -1.72, $p > 0.05$) with14.31 ± 1.29s for test vs. 14.12 ± 1.14s for retest.

Fig. 5 shows the mean values of the performance in Badcamp (left panel) and in Shuttle run (right panel) presented by athletes from different sports. One-way ANOVA revealed significant main effect of group for the time to complete the Badcamp test [$F(3, 63)$= 26.81, $p <$0.001] and for the time to complete the Shuttle run test [$F(3, 63)$= 4.1, $p < 0.01$]. The post-hoc tests showed that in Badcamp test badminton players had shorter times than collective sports players, tennis players, and track and field athletes. Collective sports players did not differ significantly from tennis players but had shorter times than track and field athletes ($p < 0.01$) and tennis players had shorter times than track and field athletes ($p < 0.01$). In shuttle run post hoc tests showed that badminton, collective sports and tennis players had similar performance, furthermore badminton and tennis players were significantly different than track and field athletes (19.38 ±10 s, $p < 0.01$).

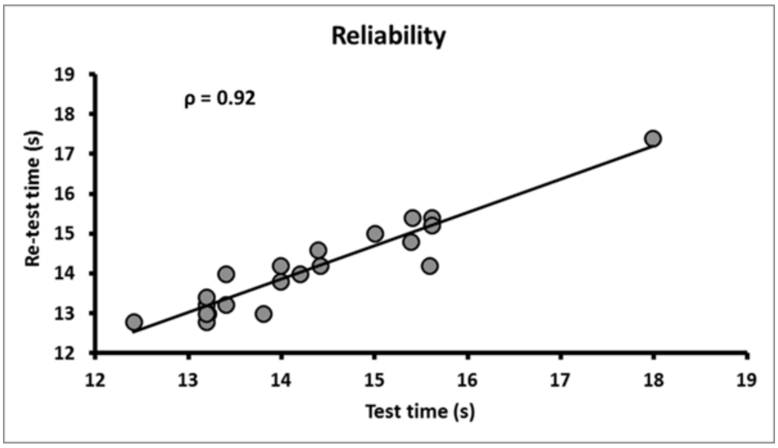

Fig. 4: Relationship between test and retest

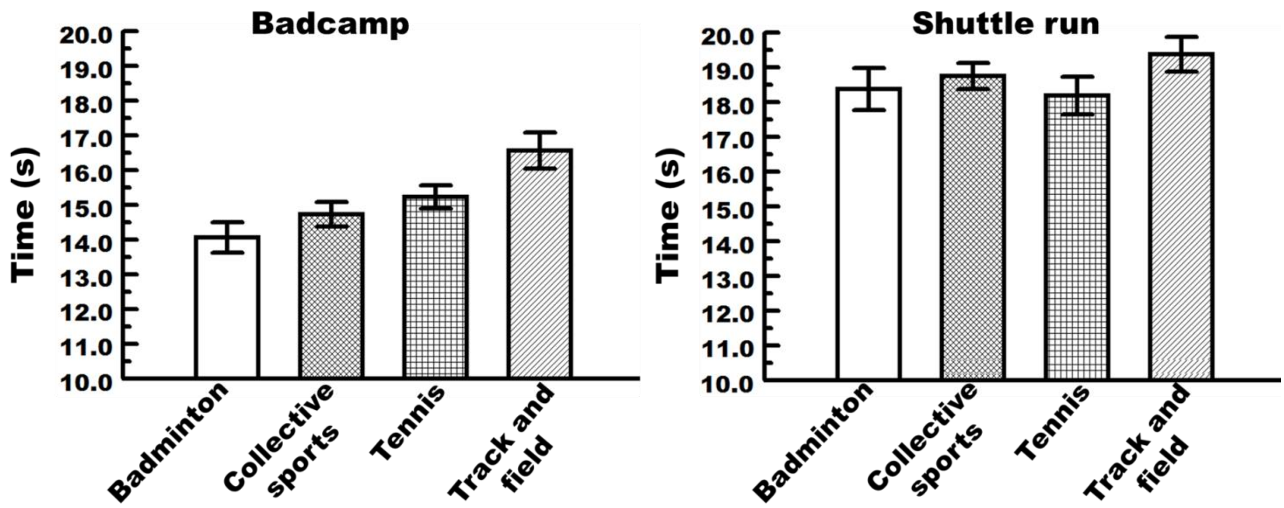

Fig. 5: Comparisons of badminton players with other sports athletes. In the left panel are the results of the Badcamp test, in right panel the results of the Shuttle run test. Error bars indicate standard deviation of the means.

Discussion

Results showed high relationship between Badcamp and shuttle run test ($\rho = 0.83$, $p < 0.001$), which proves the concurrent validity of Badcamp. Despite this high relationship, when the coefficient of determination is considered ($\rho^2 = .69$), one might consider that 69% of the variability in Badcamp have association with the performance in shuttle run but 31% have not. In both tests the individuals need to displace their bodies as fast as they can and simultaneously they should be able to accelerate and decelerate their bodies to change running direction. Hence, it is not surprising the performance in both tests shares some variance. However, there are two major differences between these tests that could account for the “unexplained variance”. The first is the uncertainty condition presented in Badcamp. While in shuttle run the players know in advance the direction they should run, in the Badcamp they have 6 options that will be determined by other entity immediately before running starts. Previous studies assessing netball players (Farrow, Young & Bruce, 2005) and basketball players (Scanlan, Tucker & Dalbo, 2014) revealed different test performance when measured by closed skill tests and open skill tests. For example, Farrow et al. (2005) were only able to identify differences between high level netball players and lower level players when they added a visual stimulus in the test that challenged the decision making of the participant. They also found a moderate relationship between tests ($r = 0.7$, $p < 0.05$), representing 50% common variance between the reactive and pre-planned conditions. Also, Scanlan et al. (2014) compared frontcourt basketball players and backcourt basketball players in a closed skill change of direction test and an open skill agility test. The results showed shorter times for frontcourt players then backcourt players, but found no differences between groups in the open skill agility test; hence the uncertain factor changes the assessed result.

The second feature that distinguishes the tests is the kind of movements. In Badcamp, participants move shorter distances then shuttle run. The total measuring of the diagonal line from center point to frontcourt and backcourt targets is 3.5 m each one, and 2.1m to each middle court target which require short and fast front strides, lateral strides, back strides, and lunges. The pivots are performed in angles of ≈ 50º having as the reference the starting position. In shuttle run, the distance of 5 m between lines requires forward and straight line displacements and all the pivots are performed in angles of 180º. These features require distinct physical demands from both tests (i.e. recruitment of different muscle groups), hence contributing to weaker relationship between tests data. For example, Sheppard & Young (2006) in their review about agility, cited two different studies (Young, James & Montgomery, 2002;) and (Negrete & Brophy, 2000) that evaluate relationship between change of direction speed and leg muscle strength and had two different results. The first cited study had low ($r = 0.36$) while the second study had moderate relationship ($r = 0.6$). They explain these different results by the use of distinct protocols to measure change of directions speed. Young et al. (2002) used a task involving some straight sprinting and changes of direction during sprinting, but Negrete & Brophy (2000) used a complex multi-directional task over short distances, similarly to badminton players' and soccer goalkeepers' physical demands (2006).

Regarding construct validity, the findings revealed better performance in Badcamp for expert players as compared to non-expert players. This means that the performance in Badcamp was able to discriminate level of performance in badminton players groups, proving construct validity. Previous studies had presented advantages of high-level athletes over lower-level athletes of netball (Farrow, Young & Bruce, 2005), rugby (Gabbett, Kelly & Sheppard, 2008; Gabbet & Benton, 2009) and Australian football (Veale, Pearce & Carlson 2009) in open skill agility tests. These studies have used the same paradigm that consists in challenging the participant to run 2 m forward and change the direction quickly one time according to a movement of the experimenter or a video presented. This kind of test involves complex and expansive devices (i.e. high speed cameras, advanced multi-media equipment, movement sensors, and so on) and cannot be used in the field and courts. Also, badminton requires more complex change of directions in a single rally, the actions are faster, (i.e., one shot may reach 300 km/h). Therefore, it would be very demanding to create a multi-media device and an experimental protocol that simulate specific actions in badminton and that at the same time is able to control agility time. The authors of these aforementioned studies criticize simpler paradigms created to test open skill agility using bulbs, lights or other kind of visual stimulus. For then, generic stimuli are not able to distinguish performance level in athletes, they argue that advanced players are able to capture paths of the opponent movements and so anticipate their actions. Indeed, some of studies have showed that expert badminton players are able to know where the shuttle will land before the contact of shuttlecock with the racket of the opponent because they are able to extract visual information from body and racket of the opponent (Abrnethy & Russel, 1987; Hagemann & Strauss, 2006; Jin et al., 2010). However, in these experiments using videos, even the expert players made a considerable number of mistakes. For example, Jin et al, (2010) challenged badminton players of the Chinese League to predict the landing position of the shuttlecock during a stroke action having as possibilities the right and left side of the court. The group of Chinese players was more accurate then control group, but his index of success was always below 60% in the moments before or at the moment of impact of the racket with the shuttlecock. Considering that they had only two possibilities (i.e. 50% chance of success) and that in the badminton match the number of possible shuttlecock landing places and its trajectory is much greater, there are still doubts if the players always use anticipation during their actions. Previous studies showed that expert badminton players had shorter reaction time in experiments with presentations of generic stimulus (Loureiro Jr. & Freitas, 2012; Wang, Yan & Zhang, 2008; Cheng, Whang & Liang 2006). Players try to make their moves unpredictable to the opponents' eyes "hiding" their hits until the moment of impact of the racket with the shuttlecock, or performing trick-shots. During a rally it is possible notice a lot of reactions situations like when a player receives a high ball in the back court and perform a defensive hit with the shuttlecock below the height of the net. Accordingly, one might conclude that the perceptuomotor demand in a badminton match requires anticipation and reactive capacities. Therefore, the Badcamp could be considered a complete agility test because successful performance in it depends on the ability to perceive the correct stimulus and to displace the body as fast as possible, accelerating and decelerating it rightly.

Concerning test-retest reliability, the results showed a strong relationship between the Badcamp's performance in the test and in the retest (ρ=0.92) and no difference in performance in these two distinct moments, proving the reliability of Badcamp. One might conclude therefore, that badminton players have a very consistent performance in this test and that there was not learning or practice effect of the task on retest. An study with netball players (Farrow, Young & Bruce, 2005) assessed open skill agility using a test where videos were presented to change the individuals' running direction to the right or to the left showed a weaker relationship between test and retest when compared to our study ($r = 0.83$) and showed that the performance during retest was better than the performance during the test, indicating learning effect of the task. In this case the authors recommended a minimum interval of 8 weeks separating test occasions to avoid this learning effect.

Finally, regarding the specificity of this test, the results indicated that while in the Badcamp test badminton players presented the best performance when compared to athletes from other sports, i.e., collective sports players, tennis players, and track and field athletes in Shuttle run the performance among different sport modalities was similar. Badcamp test was designed to simulate actions of a badminton match, which involve specific movements and high level of uncertainty regarding the trajectory of the shuttlecock. The path from start position to the targets positions corresponds approximately the distance from the standing position assumed by players to wait the shots of the opponents to the court extremities where players hit the shuttlecock. These displacements require some kind of movements like short and fast front strides, lateral strides, back strides and lunges that are practiced in almost every practice section. So, after years of specific training this displacement techniques must be learned and automatized. Therefore, the familiarity with specific displacement technique should represent additional advantage not only upon the performance of movements, but also in its planning. Other factor that could have contributed to the better performance of badminton players in Badcamp is the compatibility and correspondence of the signals presented on the panel with the places on court when players are used to move. Kida, Oda & Matsumura (2005) have compared expert baseball players with non-experts baseball players, expert tennis players and non-experts tennis players in a reactive Go-No go task using a keyboard and a computer screen. In this task, four aligned squares were showed in the screen and the participants should no react when the 1st or 4th square (i.e. extremities) changed color and react when the change was in the 2nd and 3rd squares (i.e. middle ones). The results showed that expert baseball players presented shorter reaction time when compared to non-experts players, even the task be composed of generic signals. Furthermore, the relationship between this Go-No go task and simple reaction time task was very high ($r = 0.99$) to the experts baseball players, much higher than the other group. They justified that, even though the form of the signals was generic, its positioning was compatible and correspondent with the rule of strike zone in a baseball game. Similarly with the task, when the ball is thrown to a central position the hitter should strike the ball and, when the ball is thrown to extremities the hitter should not strike. Therefore, the large experience of the expert players contributed to shorten Go-No go reaction time and became as familiar as a simple reaction time task.

Conclusion

During a badminton match, the players are challenged to perform strokes moving their body in different directions due to opponent actions, thus agility is one of predominant capacities in badminton performance. The aim of this project was develop an agility test (i.e., device and experimental protocol) that is able to measure agility through an open task that requires specific badminton movements. The findings confirm concurrent and construct validity, reliability and specificity for this test that we called “Badcamp”. The easy device operation and no complex protocol make Badcamp an interesting and handy tool to coaches and athletic trainers to evaluate athletic condition of the players, training effectiveness, or detect possible success athletes for this sport.

References

Abernethy, B., & Russell, D. G. (1987). Expert-novice differences in an applied selective attention task. *Journal of Sport Psychology*, 9(4), 326-45.

Adam, C., Klissouras, V., Ravazzolo, M., Reson, R. & Tuxworth, W. (1988). *EUROFIT: Eurofit Test of Physical Fitness.* Rome, Council of Europe, Committee for the Development of Sport.

Besier, T. F., Lloyd, D. G., Ackland, T. R., & Cochrane, J. L. (2001). Anticipatory effects on knee joint loading during running and cutting manoeuvers. *Medicine and Science in Sports and Exercise*, 33(7), 1176-1181.

Cheng, Y., Whang, Y. & Liang, C. (2006) Reaction time and competitive ability of badminton players. Zhejiang Sport Sci, 28(2), 60-63.

Chelladurai, P. (1976). *Manifestations of agility. Canadian Association of Health, Physical Education, and Recreation*, 42, 36-41.

Farrow, D., Young, W., & Bruce, L. (2005). The development of a test of reactive agility for netball: a new methodology. *Journal of Science and Medicine in Sport*, 8(1), 52-60.

Gabbett, T., & Benton, D. (2009). Reactive agility of rugby league players. *Journal of Science and Medicine in Sport*, 12(1), 212-214.

Hughes, M. G., & Bopf, G. (2005). Relationships between performance in jump tests and speed tests in elite Badminton players. *Journal of Sports Sciences*, 23, 194-195.

Hagemann, N., & Memmert, D. (2006). Coaching anticipatory skill in badminton: laboratory versus field-based percepetual training. *Journal off-Iumczn Movement Studies*, 50, 381-398.

Jaitner, T., & Gawin, W. (2010). A mobile measure device for the analysis of highly dynamic movement techniques. *Procedia Engineering*, 2(2), 3005-3010.

Jin, H., Xu, G., Zhang, J. X., Ye, Z., Wang, S., Zhao, L. & Mo, L. (2010). Athletic training in badminton players modulates the early C1 component of visual evoked potentials: A preliminary investigation. *International Journal of Psychophysiology*, 78(3), 308-314.

Kida, N., Oda, S., & Matsumura, M. (2005). Intensive baseball practice improves the Go/Nogo reaction time, but not the simple reaction time. *Cognitive brain research*, 22(2), 257-264.

Loureiro Jr, L. D. F. B., & Freitas, P. B. D. (2012). Influência do nível de desempenho de jogadores de badminton em aspectos neuromotores durante uma tarefa de apontar um alvo; Influence of the performance level in badminton players in neuromotor aspects during a target-pointing task. *Rev. bras. med. esporte*, 18(3), 203-207.

Monte, A., & Monte, F. G. (2007). Testes de agilidade, velocidade de reação e velocidade para o tênis de campo. Rev. Bras. *Cineantropom. Desempenho Hum*, 9(4), 401-407.

Negrete, R., & Brophy, J. (2000). The relationship between isokinetic open and closed chain lower extremity strength and functional performance. *Journal of Sport Rehabilitation*, 9(1), 46-61.

Scanlan, A. T., Tucker, P. S., & Dalbo, V. J. (2014). A Comparison of Linear Speed, Closed-Skill Agility, and Open-Skill Agility Qualities Between Backcourt and Frontcourt Adult Semi-professional Male Basketball Players. *The Journal of Strength & Conditioning Research*, 28(5), 1319-1327.

Sheppard JM, Young, WB, Doyle, T.A. Sheppard, TA, Newton, RU. (2006) An evaluation of a new test of reactive agility, and its relationship to sprint speed and change of direction speed *Journal of Science and Medicine in Sport*, *9*(4), 342-349.

Sheppard JM, Young WB. (2006) Agility literature review: Classifications, training and testing. *Journal of sports sciences*, 24(9), 919-932.

Schmidt RA, Lee TD. (2005*) Motor control and learning: a behavioural emphasis.* Champaign, Human Kinetics.

Tsai, C. L., & Chang, S. S. (1998). Biomechanical analysis of differences in the badminton smash and jump smash between Taiwan elite and collegiate players. *In XVI International Symposium on Biomechanics in Sports* (Vol. 2, pp. 259-262).

Veale, J. P., Pearce, A. J., & Carlson, J. S. (2010). Reliability and validity of a reactive agility test for Australian football. *International journal of sports physiology and performance*, 5(2), 239-248.

Walklate, B. M., O'Brien, B. J., Paton, C. D. & Young, W. (2009). Supplementing regular training with short-duration sprint-agility training leads to a substantial increase in repeated sprint-agility performance with national level badminton players. *The Journal of Strength & Conditioning Research*, 23(5), 1477-1481.

Young, W. B., & Willey, B. (2010). Analysis of a reactive agility field test. *Journal of Science and Medicine in Sport*, 13(3), 376-378.

Young, W. B., James, R., & Montgomery, I. (2002). Is muscle power related to running speed with changes of direction*? Journal of Sports Medicine and Physical Fitness*, 43, 282-288.

Wang, S.， Yan, C. & Zhan, J. research on evaluation target of reaction ability correctly for badminton players in the process of appraising perceptual-motor skill. *Journal of Beijing University*. 31(6), 779-781.