The Ability of Elite Table Tennis Players With Intellectual Disabilities to Adapt Their Service/Return

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In this study the ability of elite table tennis players with intellectual disability (ID) to adapt their service/return to specific ball spin characteristics was investigated. This was done by examining the performance of 39 players with ID and a reference group of 8 players without ID on a standardized table tennis specific test battery. The battery included 16 sets of 15 identical serves that had to be returned to a fixed target, and two additional tests measuring reaction time and upper limb speed. A $2 \times 4$ ANOVA (with group and type of spin as independent variables) with repeated measurements (15 consecutive returns) supported the hypothesis that elite table tennis players with ID were significantly less proficient than their counterparts without ID, but both groups demonstrated a comparable progression in learning. Spearman correlation coefficients indicated a positive relationship between accuracy of return and upper limb speed ($\rho = 0.42; p < .05$) and reaction time ($\rho = 0.41; p < .05$), showing that these generic factors are useful in partially explaining skill variations in specific sports.

In 2007, The International Paralympic Committee (ICP) endorsed a new classification code, which requires the development of sport focused systems built on scientific evidence that substantiates the impact of the underlying impairment within specific sports and disciplines. Within the International Sports Federation for Persons with Intellectual Disability (INAS-FID), this shift in the requirements...
of classification poses a significant challenge as extant literature on high performance sport that includes athletes with intellectual disability is extremely limited.

The present paper is a first step in bridging this gap in existing knowledge by reporting results from a study of table tennis service return responses of elite players with ID and a reference group of table tennis players without disability. Table tennis was selected because it is fast paced, cognitively demanding, and a popular sport within internationally recognized movements that include athletes with ID (e.g., Paralympic Movement, Special Olympics).

The understanding of how intellectual functioning affects human performance has fascinated researchers with different backgrounds (e.g., education, developmental psychology) for centuries. Although intellectual functioning has not been directly addressed in previous sport research, various studies have identified factors embedded in intellectual functioning (e.g., knowledge, information processing skills, decision making) as key contributors to elite sport performance (Allard, 1993; French & Thomas, 1987; Starkes, 1987; Thomas & Thomas, 1994; Williams, Davids, Burwitz, & Williams, 1993).

Based on a model proposed by Williams and Reilly (2000), core determinants of sport proficiency include (a) physical attributes (e.g., size, body composition), (b) physiological factors (e.g., power, speed, flexibility), (c) general and sport specific motor skills, (d) perceptual and cognitive skills (e.g., anticipation, reaction time, visual search), (e) psychological skills (e.g., competition anxiety coping, motivation, attention), and (f) “game intelligence” (i.e., understanding and implementing the nuances of the sport). While this model was originally developed to assess performance in soccer, it is also applicable to all other sports (Malina, 2008), and it has been adopted as the holistic framework for examining the core determinants of sport proficiency among athletes with ID in this study.

Until now, athletes with ID have not been extensively studied. In particular, our understanding of the implications of their impairment in sport is severely limited. To the authors’ knowledge, the only previous study that focused specifically on athletes with ID examined physical and physiological parameters in this population. It was concluded that high performance athletes with ID are capable of achieving physical fitness levels that are equal to (e.g., running speed) or lower (e.g., strength) than their counterparts without ID (Van de Vliet et al., 2006).

Although not dedicated to the study of athletes with ID, a large body of literature has focused on motor learning and interactions between motor, perceptual, and cognitive skills in individuals with ID. Based on this literature, persons with ID typically take longer to learn motor skills compared with persons without disabilities (Porretta & O’Brien, 1991) and have difficulties in programming more complex movements, whereby temporal anticipation plays a role in the response-initiation process (Newell, Wade, & Kelly, 1979). A more recent study of Di Blasi, Elia, Buono, Ramakers, and Di Nuovo (2007) highlighted a relationship between visual–motor and cognitive abilities in a large sample of children and adolescents with ID. The results suggested that the spatial skills may have a similar basis in information processing compared with the cognitive performance. Carmeli, Bar-Yossef, Ariav, Levy, and Liebermann (2008) compared 42 adults with ID with 48 age-matched adults without ID and concluded that ID was related to the inability to integrate visual inputs and hand movements. Adults with ID performed most poorly on motor skills involving hand-eye coordination (e.g., overhead beanbag-throw).
Several studies, already demonstrated that reaction times in general are slower and more variable for persons with ID than for individuals without ID (Porretta, 1987; Wade, Newell, & Wallace, 1978; Newell et al., 1979). The result of these studies suggest that slower reaction times of persons with ID may reflect less efficient processing at the level of response organization (motor planning) and consequently may contribute to inferior motor performance.

In conclusion, findings of most previous research seem to suggest a positive relationship between determinants of sport proficiency/motor skill and parameters of intellectual functioning (Carmeli et al., 2008; Di Blasi et al., 2007; Newell et al., 1979; Porretta & O’Brien, 1991; Wade et al., 1978). What continues, however, is limited understanding as to how deficits in intellectual functioning may influence potential and performance in high performance sport training and competition. As previously stated, the participants included in previous studies were not trained athletes and, probably more importantly, were not a group of individuals with broad based exposure and experience in sport. The present study, therefore, was an exploratory attempt to better understand the connection between impaired intellectual functioning and one of the key tactical skills in table tennis (i.e., service return skills). To accomplish this objective, elite table tennis players with and without ID were examined, and the absolute and relative deviation of their service/return relative to a specified target was compared. The differences on their ability to appropriately adapt their service/return to specific spin characteristics of the ball are evaluated. This ability is principally a constituent of tactical proficiency, integrating motor, cognitive, perceptual, and psychological skills (Elferink-Gemser, Visscher, Richart, & Lemmink, 2004; McPherson & Kernodle, 2003).

Based on previous research (Di Blasi et al., 2007; Newell et al., 1979; Porretta & O’Brien, 1991; Wade et al., 1978), it was hypothesized that players with ID in the current study would be less proficient than players without ID and would adapt their return to specific spin characteristics of the ball, but this would occur at a slower rate. Differences in service/return between players with and without ID would be related to slower reaction time and slower speed of upper limb movement in elite table tennis players with ID.

Method

Participants

The data for the study were derived from 47 male elite table tennis players. Thirty-nine (39) players with ID who participated at the 2005 INAS-FID World Championships Table Tennis in Thouars, France (M age = 28.3 yr., SD = 7.3; M IQ = 61.7, SD = 7.9) and 8 players without ID who took part in an international preparation camp in Belgium in 2007 (M age = 22.7 yr., SD = 10.3) voluntarily took part in the study. The players without ID were National caliber young athletes performing just below international standards. The elite table tennis athletes with ID included in this study were eligible for official INAS-FID competition. Eligibility is based on meeting the criteria for diagnosis of this impairment, according to the American Association on Intellectual and Developmental Disabilities (AAMR, 2002). The definition states that ID is characterized by significant deficits in adaptive behaviors and intellectual functioning (IQ < 75) and is manifested before age 18. IQ scores of
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Athletes with ID were available but not for the control group. The participants with ID represented 16 countries from 3 different continents (Europe, Africa, and Asia). A written informed consent was obtained from all participants and the eventual legal guardians before participation in the study. The study was approved by the Medical Ethics Committee.

**Data Collection**

Each athlete was invited into a private room set up for the table tennis testing (Figure 1). During the test, athletes received 16 sets of 15 identical serves with respect to ball speed, direction, and spin. Each serve landed on field A or B (forehand or backhand side) at a standardized speed sufficient to prevent a second bounce on the service reception side of the net. Players were instructed to return each service to a specified target (A4 paper size) on the service return side of the table (field C or D). During the actual test, the 16 set sequences of serves were identical for all players (Table 1). The first block of 4 sets of serves had to be returned forehand cross, the second block forehand straight, the third block backhand straight, and the last block backhand cross (Table 1). Four ball projection effects were used in each set block: topspin (T), backspin (B), left sidespin (L), and right sidespin (R).

Balls frequency was set at 1 ball every 2 s, for a total of 30 s per set. Time between the sets was 15 s and time between each block of 4 sets was 45 s (Table 1). The total duration of the test was approximately 20 min.

Before testing commenced, each player was given sufficient practice time. To familiarize the players with the protocol, and with the ball projection effects, at least 15 practice trials were allowed for all 16 types of service/return combinations.

Before starting each set of serves, the tester instructed the players that they would receive 15 identical serves that they were to return and indicated whether

![Figure 1 — Experimental setup of the table tennis specific test (TTR = table tennis robot).](image-url)
the ball would be served to their backhand or forehand side (no information was given as to the spin characteristic of the pending service).

Two low (about 50 cm) fences were placed in a 45 degree angle from the table corner to mark out the area in which players were allowed to move, mainly to prevent players from switching, for example, to their forehand when the serve was delivered to their backhand (Figure 1).

Immediately following the table tennis specific test, each participant underwent two additional tests to measure reaction time and speed of upper limb movement. These parameters are foundational requirements that relate to table tennis specific performance skills. Reaction time was measured using a computer-aided reaction speed test. Using their table tennis racket holding hand, the aim is to click a mouse button as quickly as possible when prompted by a colored circle (table tennis ball size) that appears on the screen. Following a pretrial, two series consisting of 10 ball appearances with varying intermediate times were completed. The mean reaction speed in msec for each series was calculated, and the best mean reaction speed was used for further analysis. Speed of limb movement was assessed using the Eurofit Test Battery (Oja & Tuxworth 1995) Plate Tapping (PLT) table. Two 20 cm diameter discs with an 80 cm distance between both middle points had to be touched alternately with the preferred hand as fast as possible, completing 25 cycles. The mean of the two attempts recorded in tenths of seconds was used for further analysis.

| Table 1 Test Protocol “Service—Return:” Stroke Variation |
|-----------------|----------------|-----------------|----------------|-----------------|
| Block | Set | Variety | Stroke | Direction of return | Spin | Fields |
| 1     | 1   | FCT     | Forehand | Cross             | Topspin        | A to C          |
| 2     | 1   | FCR     | Forehand | Cross             | Right Spin     | A to C          |
| 3     | 1   | FCL     | Forehand | Cross             | Left Spin      | A to C          |
| 4     | 1   | FCB     | Forehand | Cross             | Backspin       | A to C          |
| 2     | 2   | FST     | Forehand | Straight          | Topspin        | A to D          |
| 3     | 2   | FSR     | Forehand | Straight          | Right Spin     | A to D          |
| 4     | 2   | FSL     | Forehand | Straight          | Left Spin      | A to D          |
| 3     | 2   | FSB     | Forehand | Straight          | Backspin       | A to D          |
| 3     | 3   | BCT     | Backhand | Straight          | Topspin        | B to C          |
| 3     | 3   | BCR     | Backhand | Straight          | Right Spin     | B to C          |
| 4     | 3   | BCL     | Backhand | Straight          | Left Spin      | B to C          |
| 4     | 3   | BCB     | Backhand | Straight          | Backspin       | B to C          |
| 4     | 4   | BST     | Backhand | Cross             | Topspin        | B to D          |
| 3     | 4   | BSR     | Backhand | Cross             | Right Spin     | B to D          |
| 3     | 4   | BSL     | Backhand | Cross             | Left Spin      | B to D          |
| 4     | 4   | BSB     | Backhand | Cross             | Backspin       | B to D          |
**Instruments**

All serves were delivered by a table tennis robot (TTR; Newgy Robo Pong 1040), located in a fixed and standardized position behind table field D (Figure 1). The TTR allows simulation of wide variety of serves and can be set to control/standardize ball speed, frequency, spin, trajectory, and placement, as well as oscillator speed and range.

To further standardize the test, all players used the same racket (TIBHAR V. Samsonov Alpha) and rubber (Andro, Revolution, C.O.R). According to expert opinions, this type of racket and rubbers are neutral (suitable for both offense and defense players) and most frequently used by elite table tennis athletes with and without ID.

The entire test was filmed using a digital video camera (CANON PAL MVX45i digital video camcorder 25Hz) from a fixed elevated position diagonally opposite the player’s side of the table (Figure 1). The camera captured the table, the TTR, and the player entirely.

**Data Reduction**

After data collection, the video recordings of the table tennis service response test were analyzed using Dartfish software, which enables quantification of the exact position of each return. A digital frame was constructed around the target, each square having the same size as the target (Figure 2). In this way, each return inside the 7-by-7 frame could be quantified to calculate the relative error, referring to width (left-right) and depth (forward-backward) deviations from the target as it would have been seen from the player’s viewpoint. A deviation of one square from the sheet was scored as a +1 or –1, with a positive score reflecting a deviation to

![Figure 2](image)

*Figure 2 — Data reduction: 7-by-7 frame around the target.*
the left (width) or to the front (depth), and a negative score to the right or to the back of the target. Returns outside the 7-by-7 frame were scored as –4 or +4, no matter how great the deviation from the frame, which produced an underestimation of differences in absolute error between the players with and without ID. The percentage of players missing the frame, therefore, was registered to correctly interpret the results.

**Statistical Analyses**

Statistics were performed using SPSS, with level of significance set at $p < .05$. Absolute error (AE) was used as the first dependent measure and defined as the mean deviation score from the target without regard to the direction of the deviation. AE was chosen since the task required participants essentially to reduce their average error. Relative error (RE) was also used as a dependent measure and defined as the deviation from the target, within the frame, in two-dimensional directions (width and length). This variable was chosen to provide information about the direction of error.

The original analysis considered backhand/forehand stroke as a factor; however, preliminary analyses showed there were no significant effects for stroke, so the analysis was collapsed across stroke and consisted of 2 (groups: with and without ID) × 4 (spin: topspin, right spin, left spin, and backspin) × 15 (trials) analysis of variance with repeated measures on the last factor.

For the more in-depth analyses of relative error, the analysis was performed for each spin effect separately and consisted of 2 (groups: with and without ID), × 2 (depth and width direction) × 15 (blocks of trials) analysis of variance with repeated measures on the last factor.

For the additional variables reaction time and arm speed, equal variances could not be assumed due to sample size differences; therefore, nonparametric Mann Whitney U tests were used for comparison between both groups, and Spearman Rank Correlations were performed for comparison of variables.

**Results**

**A. Table Tennis Specific Skill Test**

A global overview of percentage of players missing the 7-by-7 calibrated area around the target is depicted in Figure 3. Visual inspection of these data indicates a global difference in achievement between players with and without ID. In general, the target frame was missed infrequently when topspin effect was used, but for all other spin effects, a considerably larger proportion of elite table tennis players with ID missed the frame entirely than was the case for players without ID.

Figure 4 presents the mean AE over trial-blocks for all service-return series, split up into the four spin effects. The analysis yielded significant main effects for group, $F(1, 43) = 41.65, p < .05, \eta^2 = 0.49$; trial, $F(14, 30) = 13.49, p < .05, \eta^2 = 0.86$; and spin, $F(3, 41) = 20.37, p < .05, \eta^2 = 0.60$ and a significant interaction effect for spin × group, $F(3, 41) = 2.86, p < .05, \eta^2 = 0.17$. The AE of returns was lower for table tennis players without ID than for players with ID and this held independent of the spin. Both groups substantively reduced the AE over trial-blocks,
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The trial × group effect was not significant, indicating that the progress from trial to trial was similar for both groups. The AE of returns varied according to ball spin with left or right spins being most error prone and topspin the least. The spin × group interaction effect indicates that differences in absolute error according to spin effect are more problematic for elite table tennis players with ID.

Figure 5 presents the mean RE over trial-blocks for all service/return series for each spin effect separately. The analysis of the right spin and left spin series yielded significant main effects for direction of error, $F(1, 24) = 38.28, \eta^2 = 0.62$ and $F(1, 17) = 69.50, p < .05, \eta^2 = 0.80$ and group, $F(1, 24) = 14.13, \eta^2 = 0.37, F(1, 17) = 15.41, \eta^2 = 48, p < .05$ and interaction effects for direction of error × group, $F(1, 24) = 21.66, \eta^2 = 0.48, F(1, 17) = 8.04, \eta^2 = 0.32, p < .05$ and direction of error × trial, $F(14,11) = 2.84, \eta^2 = 0.78, F(14, 4) = 6.34, \eta^2 = 0.96, p < .05$. Topspin analysis showed only an interaction effect for direction of error × group, $F(1, 41) = 10.85, \eta^2 = 0.21, p < .05$, and backspin analysis showed only a significant main effect of direction of error, $F(1, 9) = 22.03, \eta^2 = 0.71, p < .05$.

The RE of returns was smaller for table tennis players without ID than for players with ID. For left and right spin service/returns, this difference was significant. When returning side spin serves, the deviation from the target in width (leftward for left spin, rightward for right spin) was larger than the length deviation from the target. The group × direction effect shows that systematic error in width direction...
Figure 4 — Progress of mean absolute error per trial for all series (A: topspin, B: right spin, C: left spin, D: backspin).
Figure 5 — Progress of mean relative error per trial for all series (A: topspin, B: right spin, C: left spin, D: backspin).
was less visible in table tennis players without ID. When returning topspin and backspin serves, the length deviation from the target was larger than the deviation in width. The group × direction effect for topspin indicated that the systematic error in length direction is less visible in elite table tennis players without ID.

B. Reaction Time and Speed of Upper Limb

The table tennis players without ID had faster reaction times (225 ± 14 msec) than elite table tennis players with ID (353 ± 149 msec; U = 52, δ = 0.95, p < .05). Players without ID also performed better on upper limb speed (111 ± 15 msec) than players with ID (146 ± 51 msec; U = 46, δ = 0.76, p < .05).

C. Correlations

A Spearman rank correlation addressed the relationship between AE, arm speed, and reaction time. AE (0.83 ± 0.15 without ID and 2.05 ± 0.48 with ID) was positively related with upper limb speed (rho = 0.42, p < .05) and with reaction time (rho = 0.41, p < .5). No significant correlations were found between arm speed and reaction time for both groups.

Discussion

This study contributes to the understanding of intellectual functioning and its effects within a sport context. The purpose was to explore tactical proficiency of elite table tennis players with and without ID and to distinguish between these two groups of players. Tactical proficiency was defined by the ability to correctly adapt service/returns to specific spin characteristics of the ball (e.g., speed, spin characteristics and direction) and measured by the absolute and relative deviation of the return from a specified target.

As hypothesized, elite table tennis players with ID were able to adapt their return according to specific spin characteristics of the serve. The process of adaptation (learning process) was similar to table tennis players without ID, but the players with ID did not reach the same level of proficiency. Also as hypothesized, elite table tennis players with ID were less proficient in the tested skills (higher AE) than the players without ID. These differences were likely underestimated as missing the frame outside the set criteria of ± 3 points resulted in a maximum score of 4, independent of how great the deviation from the target was. A considerably larger percentage of the elite table tennis players with ID completely missed their service/return and the scoring frame altogether (Figure 2).

Participants from both groups reduced their absolute errors from trial to trial, which demonstrated a similar progression in learning. While this was contrary to what was expected, players with ID did not reach a comparable level of proficiency. The error rate for elite table tennis players with ID from the first ball onward was greater and this remained stable as the players with ID continued to miss the target even after 16 sets of 15 trials.

To more thoroughly examine service return efficiency, the direction of error was studied using the relative error measurement. Topspin and backspin serves mainly resulted in return errors in depth, while sidespin serves resulted mainly in errors in
width (leftward for left spin, rightward for right spin; see Figures 5b and 5c). For the players with ID the impact of the sidespin effects interfered most with their return efficiency. These sidespin related directional errors remained uncorrected throughout the 15 trials. Table tennis players without ID also made systematic errors according to spin characteristics but were able to neutralize these within relatively quickly (i.e., with 5 trials). The reader recalls that the calculation of relative error was based on service returns landed within the target frame, possibly resulting in an underestimation of group differences.

Overall, the results of the study indicated that elite table tennis players with ID are significantly less proficient than their counterparts without ID in service return skill and have significantly slower reaction times and upper limb speed.

As previously stated, table tennis is a cognitively demanding sport, requiring anticipation and quick decision-making skills (Hirst, 2002; Toriola, 1999). The ability to adapt a return to specific spin characteristics of a ball under temporal pressures requires “game intelligence.” Differences in intellectual functioning between the two groups of players are a likely explanation for the observed differences in the test results. Intellectual functioning, however, is not the only parameter in determining sports performance. According to the holistic framework (Williams & Reilly, 2000), on which this study is grounded, the core determinants of sport proficiency are multidimensional (physical and physiological parameters, motor, perceptual/cognitive and psychological skills, and game intelligence). Some components of the model (e.g., physical potential and physiological factors) were not directly addressed in this study, but based on the work of Van de Vliet et al. (2006), these parameters are not the major limiting factors for sport performance of highly trained elite table tennis players with ID. The player’s ability to produce the general and sport specific motor skills (technical and tactical) is another determinant of expert performance in the model. This ability is the product of past experience and learning capacity. The observation in literature that persons with ID in general are slower learners when it comes to motor skill (Porretta, 1987; Porretta & O’Brien, 1991) could possibly contribute to the explanation of the results. It should be kept in mind, however, that this literature does not include athletes. In addition, the current study was not designed to investigate learning capacity specifically. The lack of past experience with maximal spin effects (in particular side spins) is more likely to contribute to the observed differences, but no data about the training experience is available from the participants. Perceptual and cognitive skills are also likely to explain differences found. A critical component that influences successful performance in the table tennis specific test performed in the current study is the coupling of ball-movement perception to body or limb action (Magill, 1998). Hitting a successful return requires the player to time body and racket movements precisely, considering speed and spin characteristics of the rapidly moving ball. The high information processing load and time constraints during the test are such that players must develop or acquire effective anticipatory strategies to be successful. Successful performance (hitting the A4 size target) appears largely dependent upon selective attention to a relatively small set of cues (speed and spin of the approaching ball + location of the target), which are of use for adaptive decision-making processes (Abernethy, 1991). Initially, athletes have no idea of which type of shot they will be receiving, so they will need to devote attentional resources to identifying the appropriate cues. By directing attention to the serve, resources have been taken away from delivering
an accurate return shot. Through repetitions, the athletes became aware of the serve and information processing became more automatic; fewer resources were allocated and attention could be focused on the accuracy of return. This idea illustrates why the initial errors occurred and why the performance improved through trials. This result was displayed in both groups, but the absolute error was constantly higher for the ID group. A possible explanation for the difficulties elite table tennis players with ID have with successfully adapting the service/return is that the underlying intellectual disability further limits the fixed attentional capacity. Having to devote more resources to identify serve characteristics takes away from the capacity to focus on a return target. For elite table tennis players with ID, possible problems with attentional capacity and temporal anticipation could be closely linked with the slower reaction time displayed when performing a simple reaction time task. The observed difference is in agreement with literature, where generally, persons with ID exhibit significantly slower reaction times than persons without ID (Newell et al., 1979; Porretta, 1987; Wade et al., 1978). Assuming that the prolonged reaction time also occurred when performing the return shot during the table tennis specific test would be logical, as both response complexity and stimulus differentiation elevate in this task. In an experiment of Wade et al. (1978), difficulty of a movement through manipulation of response precision (size of the target) had no effect on the single reaction time for persons with ID, which suggested that in simple reaction time situations, they could learn to anticipate and preprogram their response to some extent. In a choice reaction time paradigm, the reaction time of the group with ID elevated more than the reaction time of the group without ID when movement difficulty increased. Analogous to what was expected, the additional tests in the current study revealed slower reaction time and slower speed of upper limb for the elite table tennis players with ID, and these generic measurements correlated positively with the results from the table tennis specific test. The single reaction time test requires visually processing information and translating that into an action (i.e., clicking the mouse button), whereas the table tennis specific test requires greater information processing and more complex actions to perform. Plate tapping and service return execution both require sequencing of arm movement and speed, which also requires cognitive processing to ensure that the sequence is followed within temporal demands.

The framework model only describes the individual characteristics contributing to sport performance. From research in athletes without ID external factors (e.g., training and competition opportunities, access to sports, and experience in training and competition) are critical elements (Mactavish & Dowds, 2003). ID athletes and their coaches reported a wide range between 1 and more than 7 years of training experience (Vanlandewijck, Mactavish, & Van de Vliet, 2006). Within this range, less experienced players are likely to be less mature in their skill development and lack below elite level standards that are purported to require a minimum of at least 10 years of intense preparation and practice (French & McPherson, 1999).

**Implications**

The practical implications of this study are twofold. First, the results clearly indicate that the elite table tennis players with ID had more difficulties appropriately
adapting their service return, even after several trials with identical serves. During a table tennis game, adapting the return to every approaching ball is an essential skill that continuously needs to be performed, and two consecutive balls will hardly be the same. These exploratory findings are the first step toward providing scientific evidence of the activity limitations related to impaired intellectual functioning within the specific demands of table tennis. Much more effort is needed to provide further insights into this relationship, but these findings offer an important contribution to the development of a sport specific system of classification that complies with the IPC classification code.

Second, the similar pattern of adaptation among the study participants shows that table tennis return accuracy can be improved and should motivate more intensive and specific training of this skill set. Training that focuses on various spins and return options could bring players with ID to a higher level of performance. In short, while the present results suggest that elite level players without ID are likely to attain higher levels of overall proficiency in table tennis, with quality training interventions that appropriately address the needs of players with ID, their skill can be increased.

Limitations

In short, the results of this exploratory study are promising, but certain limitations of the study should not be overlooked. Group sample sizes are very unbalanced. The emphasis of the current study was on the investigation of a large and diverse ID group. The reference group of athletes with ID was limited to 8 individuals. Inherently, the interindividual variability was greater for the ID group, which can affect the robustness of the statistical tests employed.

The authors decided to use a table tennis robot to deliver the serves, to provide standardized and identical serves within each series and for every participant. As a consequence, movement patterns (arm swing and paddle motion) of the opposing players were not a part of the essential visual information available for the anticipation of decision. This fact was counteracted from the second ball on, simply because they were informed that all balls within one set would be identical.

Another key limitation of the study was the lack of essential background information regarding the specific experience players had with spin characteristics and appropriate responses in table tennis. More insight into capacity and nature of previous training from coaches or trainers could contribute to the explanation of the observed results.

Suggestions for Future Research

Findings of this study should therefore serve as a basis for future investigations addressing all components of the model described by Williams and Reilly (2000). The full understanding of sport performance by athletes with ID requires not only a comprehensive approach that takes into account these components, but also additional information regarding environmental factors like training experience and accessibility. Other suggestions for future study include the use of expert players to serve balls instead of a machine and examination of reaction time and eye movement (Vickers, 2007) during the actual service/return test.
Conclusion

The results of the current study show clear differences between elite table tennis players with and without ID in their ability to adapt their service/return to specific spin characteristics of the ball. The elite table tennis players with ID did not reach the same level of proficiency in returning serves, which is likely related to difficulties in processing high volumes of information simultaneously, as well as slower action-reaction time and upper limb speed. The results of this study provide initial insights about the link between impaired intellectual functioning and its impact in a core skill in the sport of table tennis. This knowledge and its replication and extension to sports will be essential in developing a classification system for athletes with ID in the Paralympic Movement.

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