Determinants of Reactive Agility Performance in Table Tennis Players

Henrieta Horníková

Faculty of Physical Education and Sport, Comenius University in Bratislava, Slovakia

ABSTRACT

BACKGROUND: Table tennis is considered as a reaction sport, in which reaction speed is the key factor of sports performance. However, in addition to the quality of sensory (or cognitive) functions, it also requires a rapid motor response. Reactive agility is one of the most important qualities of table tennis performance. It comprises both sensory and motor components. Therefore, the aim of this study was to find the relationship between reactive agility performance and reaction speed (sensory part), sprint and change of direction speed, and muscle strength parameters (motor part) and thus to identify determinants of reactive agility in table tennis players. METHODS: Fifteen male competitive table tennis players (26.3 ± 4.0 years, 179.4 ± 6.0 cm, 77.2 ± 6.4 kg) performed the Reactive Agility Test (RAT), three reaction time tests (simple and choice reaction, reaction to four visual stimuli), sprint for 5 m, 505 Agility test, countermovement and drop jumps. RESULTS: Pearson correlation coefficient revealed a significant relationship between RAT performance and reaction time to four visual stimuli ($r = 0.801$, $p < 0.001$). Nonsignificant, but the medium correlation was found between RAT performance and choice reaction time ($r = 0.404$) and decision-making time, which was calculated as a difference between choice and simple reaction time ($r = 0.410$). These results showed that reactive agility is determined by the cognitive component (reflected by the reaction time) in table tennis players. CONCLUSION: It seems that fast reactions associated with hand movements are more important than explosive strength and speed abilities in table tennis performance. Therefore, the trainers should focus primarily on the development of reaction-speed abilities in their training program. Secondary, they should focus on more specific movements (e.g., lateral change of direction or speed of first steps) rather than linear sprint speed or changing of direction under angles higher than 90°. Additionally, it seems that explosive strength training has only supportive character in relationship to the sports performance.

Keywords: motor component, racquet sports, reaction time, sensory component

INTRODUCTION

Table tennis is one of the fastest sports games in the world and performance in this sport is the result of multiple factors. It requires precise and fast movements with the high level of coordination (Kondrić et al., 2013). The players often have to move to an appropriate position using various footwork according to the opponent´s strike (forward or backward step, side-step, cross step) (Fuchs et al., 2018; Malagoli-Lanzoni et al., 2014; Zhang et al., 2018). Therefore, the level of reactive agility is one of the limiting factors of table tennis sports performance, which includes sensory and motor components (Young et al., 2002), and currently also technical aspects (Young et al., 2015). Due to the small playing area and high velocity of ball, the higher demands on sensory component are needed in this sports game (Vacenovský, 2014). Sports with direct opponents challenge the brain and these activities require a higher-level of cognitive function to be successful (Walsh, 2014). Therefore, playing table tennis brings more benefits associated with improving visual reaction time (Vidja et al., 2012) and is considered as one of alternatives to keep a good level of agility performance at any age especially in late middle-aged subjects when it tends to decrease more markedly (Horníková et al., 2018). Player needs to anticipate the opponent´s intentions in severe time constraints, recognize meaningful cues in the context of the game, and to decide and initiate which action to take as a response (Abernethy, 1991). It means that only rapid processing of the stimulus in the brain is not sufficient, because it is usually associated with subsequent high-speed movements of the lower body with fast but short accelerations and breaking phases (Padulo et al., 2016). Vacenovský (2014) reported the importance of the motor component, too, and that mainly explosive strength, because the movement behind the table consists of many multidirectional short starts as a response to visual stimuli – the ball. In addition to explosive strength, the motor component also includes sprint speed (linear and with directional changes) leg muscle strength (muscle power, reactive strength) and core strength (Young et al., 2002; Young et al., 2015). Nevertheless, many studies investigated only hand reaction time in table tennis players (Bhabhor et al., 2013; Cam et al., 2014; Deepa & Sirdesai, N. 2016). The motor response was thus minimized mostly only to the movement of finger. In these types of tests, table tennis players dominated compared to the healthy controls, but they achieved also shorter reaction times than players of other sports. Some authors were aware of the importance of both sensory and motor components, and they used specific reactive agility tests (Utama et al., 2021; Vacenovský et al., 2015). It seems that stop´n´go running tests are more suitable for table tennis players compared to non-stop running agility tests because they can better reflect the structure of effort in this sport.

This study is based on the model of Young et al. (2002) and its latest modification (Young et al., 2015), in which reactive agility comprises of two main components – cognitive (as a sensory) and physical (as a motor). Several studies investigated the relationship between reactive agility and parameters of motor abilities (Horička et al., 2014; Lockie et al., 2014; Sattler et al., 2015). However, there is a lack of information about the sensory part of this ability and their contribution to reactive agility in different types of sports. Therefore, the aim of this study is to investigate the relationship between reactive agility performance and parameters of reaction speed, sprint and change of direction speed, and leg muscle strength in table tennis players.

The modified version of the reactive agility test was used in this study. It consists of 20 movement reactions in the four directions arranged in a semicircle according to the visual stimulus appearing on the light semaphore. The movement type and distance (stop´n´go test with including speed of first one or two steps) was adapted as closely as possible to the specific conditions of table tennis. Therefore, the contribution of both sensory and motor components to reactive agility test performance may be expected.

METHODS

Participants

Total of 15 male table tennis players participated in this study (26.3 ± 4.0 years, 179.4 ± 6.0 cm, 77.2 ± 6.4 kg). The mean duration of sport specialization was 13 ± 4.0 years and they have trained in average 4.7 times per week with one match. Inclusion criteria were as follows: to be an active player (regularly play matches), to have at least 3 trainings per week (+ match), required level of performance (1st – 3rd league in Slovakia). Players who were injured in the last three months were excluded from this study. All participants were informed of the procedures, the main purpose of this study and signed an informed consent. The procedures were in accordance with the ethical standards for human experimentation as stated in Helsinki Declaration.

Data Collection

All participants performed a standard warm-up routine (light jogging, dynamic stretching exercises and then attended a familiarization session where testing conditions were explained, and one trial set was shown. At first, reaction time tests were performed using FiTRO Reaction Check (FiTRONIC, Bratislava, Slovakia) and Witty SEM (Microgate, Bolzano, Italy). Then countermovement and drop jumps were performed using OptoGait (Microgate, Bolzano, Italy) and reactive agility test, sprint for 5 m and 505 Agility test were measured by Witty SEM system from Microgate again. All tests were performed in a table tennis hall with a Taraflex vinyl sports floor.

Simple and Choice Reaction Time Test

Fitro Reaction Check consists of one or two switches connected by means of an interface to a computer. The software measures the time between appearing the stimulus and the response of participant by pushing the switch. The participants must respond to a visual stimulus (green circle) as fast as possible in a simple reaction test. In the choice reaction time test, they had to respond as fast as possible in accordance to a visual stimulus appearing on a computer screen – push the right switch when the green circle appeared and the left switch when the red cross appeared. Two trials of 20 responses were performed in each test with one-minute break between them. The better mean reaction time of two trials was selected for the analysis. Decision-making time was calculated as a difference between choice and simple reaction time.

Reaction Test to Four Visual Stimuli

The Witty SEM consisting of four light photocells which were placed in-line on the table with a distance 10 cm between them. They include a motor sensor, so it was not necessary to touch them directly. The task was to response as fast as possible with dominant hand (starting in the middle of semaphores) to photocell which lit up green. The others remained unenlightened. The participants were required to move back with their hand to the middle of these semaphores, so they had to complete the same movement distance. The test consisted of 20 reactions (four in each light photocell) which were generated immediately after each response. The result was the better total time of the test from two trials.

Countermovement jump (CMJ)

The participant starts from standing position with hands placed on the hips. They performed knee flexion (at a 90° angle) followed immediately by extension of legs as high as possible. They were asked to land in a fully extension without hip, knee, or ankle flexion. The higher of two jumps were selected for further analysis.

Drop Jump (DJ)

Drop jump was used to measure the reactive strength. The participants started from a 30 cm height box with hands on their hips, and their task was to step with their preferred leg and rebound as high as possible with both legs with a minimum contact time. They were required to avoid more pronounced knee bending and kicking during the jump. The result of this test was the reactive strength index (RSI) calculated as a ratio of the height of jump and ground contact time. The highest index from the two trials was taken for further analysis.

Reactive Agility Test (RAT)

It was used the modified version of stop´n´go reactive agility test from Sekulic et al. (2014). Four light photocells were placed in a semi-circular arrangement at a distance of 2 m from the starting point. The task was to respond to a visual stimulus (green light) as fast as possible, wave at this photocell and run back to the starting point. The test consisted of one trial with 20 reactions (5 reactions in each direction). Before this trial, they had one test trial of five stimuli. The result was the total time of the test.

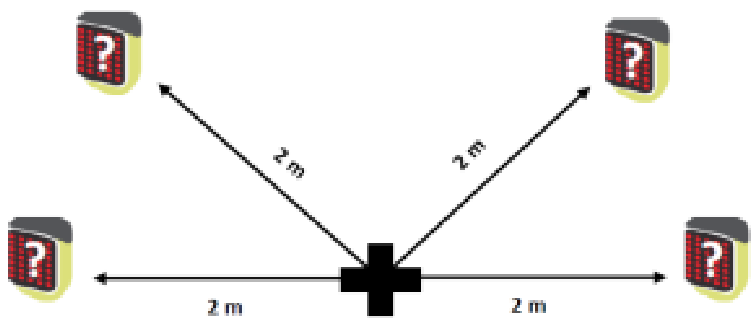

Figure 1. Modified Reactive agility test for table tennis players.

5 m Sprint Test

This test assessed the acceleration sprint for a short distance. The task was run as fast as possible 5 m from starting gate to the second gate positioned at a distance of 5 m. Participants started 30 cm behind the starting line to prevent early triggering of the starting gate. Gates were set at a width of 1.5 m and a height of 1.20 m. Two trials were carried out with one-minute rest, the result was a shorter time of them.

505 Agility Test

This test measured the change of direction speed. It includes a 15 m linear sprint, one-directional change at a 180° angle and another sprint for 5 m to the finish gate. The test result included a time only of 5 m sprint before and after changing of direction. They were asked to place their left or right foot on the line of this turn, depending on the trial (one to the left and one to the right side). They had two trials with 2-minutes of rest between them, the better one was taken for further analysis.

Statistical Analysis

The data were computed in the statistical program SPSS for Windows (version 22.0, SPSS, Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were calculated for all results. The Shapiro-Wilk test was used to determine whether the data were normally distributed. The standardized measure of the dispersion of probability distribution was check via coefficient of variation (CV). The higher values in coefficient of variation in decision-making time and drop jump arose as result of the calculation from two different measured parameters. Pearson correlation coefficient was used to find the relationship between the reactive agility performance and parameters of other variables (reaction speed, sprint speed and explosive strength). The size of correlation coefficient (r) was interpreted by Hendl (2004): 0.10 – 0.30 – small effect; 0.31 – 0.70 – medium effect; 0.71 – 1 – large effect. Additionally, the coefficient of determination (R2) was used to estimate the contribution of measured variables to reactive agility. The level for statistical significance was set at $p < 0.05$.

RESULTS

Results of the tests achieved by table tennis players and coefficient of variation are shown in Table 1.

Table 1. Descriptive statistics of table tennis players performance

Test	Mean ± SD	CV
Simple Reaction Time [ms]	295.6 ± 9.0	3 %
Choice Reaction Time [ms]	407.5 ± 30.1	7.4 %
Decision-making Time (CRT-SRT) [ms]	111.9 ± 25.4	22.7 %
Reaction Time to Four Visual Stimuli [s]	9.5 ± 0.8	8.4 %
Reactive Agility Test [s]	39.6 ± 2.1	5.3 %
5 m Sprint Test [s]	1.1 ± 0.1	9.1 %
505 Agility Test [s]	2.4 ± 0.1	4.2 %
Countermovement Jump [cm]	36.9 ± 4.8	13 %
Drop Jump (RSI)	1.2 ± 0.3	25 %

Note. SD = standard deviation, CV = coefficient of variation.

The RAT performance significantly correlated with the reaction time to four visual stimuli ($r = 0.801$, $p < 0.001$). Nonsignificant, but medium effect size was detected with choice reaction time ($r = 0.404$) and decision-making time ($r = 0.410$). The coefficient of determination was R2 = 0.642, which means that reaction speed explained the reactive agility performance by 64.2 % in table tennis players. Reaction test to four visual stimuli included choice reaction, which confirmed significant relationship with choice reaction time test and decision-making time ($r = 0.612$, $p = 0.015$ and $r = 0.588$, $p = 0.021$, respectively). The relationship between RAT performance and speed and muscle strength parameters was not significant with only a small effect size (Table 2).

Table 2. Pearson´s correlation matrix of relationships among all variables measured

TEST	SRT	CRT	DM	RFS	CMJ	DJ (RSI)	RAT	5 m sprint	505 Agility
SRT	–								
CRT	0.637*	–							
DM	0.402	0.962**	–						
RFS	0.392	0.612*	0.588*	–					
CMJ	-0.348	-0.657**	-0.657**	-0.286	–				
DJ (RSI)	0.422	-0.309	-0.517*	-0.022	0.268	–			
RAT	0.196	0.404	0.410	0.801**	-0.160	-0.335	–		
5 m sprint	0.102	0.146	0.137	0.010	-0.035	-0.04	-0.035	–	
505 Agility	-0.026	0.327	0.398	0.089	-0.290	-0.510	-0.058	0.380	–

Note. SRT = simple reaction time; CRT = choice reaction time; DM = decision-making time; RFS = reaction time to four visual stimuli; CMJ = countermovement jump; DJ = drop jump * = $p < 0.05$; ** = $p < 0.01$.

DISCUSSION

Reactive agility test performance significantly correlated with the reaction time to four visual stimuli. It may be ascribed to the structure of these tests, in which reaction to four visual stimuli was needed. It means that the sensory component was the same and they differed only in motor component. Reaction time test required shorthand movement, while RAT included the whole-body movement. On the other side, less similarity of conditions could affect nonsignificant, but medium effect size between time in RAT and choice reaction and decision-making time. These parameters were measured by another diagnostic system than RAT and they have differed for example in the type or size of stimuli and recording of participant´s response. Nevertheless, it can be concluded that perceptual and decision-making factors contribute to reactive agility performance of table tennis players by 64.2 %. These results are difficult to compare with the others because we did not find the similar studies focused on table tennis players. Many authors investigated reactive agility in relationship to speed and strength parameters mostly in team sports, but only a few of them were focused on sensory component (Henry et al., 2016; Scanlan et al., 2014; Spiteri et al., 2015; Šimonek et al., 2017).

Surprisingly, there were not found significant correlations between the time in the reactive agility test and any parameters of sprint speed and muscle strength in table tennis players. Based on the study of Young et al. (2015) and Young et al. (2002) we assumed, that RAT performance will be determined by both, sensory (perceptual and decision-making factors) and motor components (mainly by reactive strength). In an older deterministic model of reactive agility from the year 2002, the change of direction speed represented the motor component. In the newer one (Young et al., 2015), it was replaced by the physical factors which include leg muscle qualities (strength, power, reactive strength), core strength, and straight speed. This knowledge was confirmed by several authors in their studies. For example, it was revealed significant relationships between the time in the Y-shaped agility test under reactive conditions and 10 m sprint time in active males and basketball players (Lockie et al., 2014; Oliver & Meyers, 2009). Furthermore, the time in RAT (Five-Time Shuttle Run to Gates test) highly correlated with the change of direction speed test in a study of Popowczak et al. (2021). In our study, no significant relationship between the time in RAT and sprint time for 5 m was found. One possible reason could be that our RAT required only the speed of the first one or two steps. Probably, the distance of 5 m is less specific for table tennis players. A similar explanation may be also attributed to the nonsignificant relationship between RAT performance and time in the 505 Agility test. Their structure differed, especially in the running distance and angle of directional change. Whereas our RAT was force-oriented (type of stop´n´go test) rather than velocity-oriented, we assumed the significant relationship mainly with the parameter of reactive strength – RSI, which is important especially in explosive starts and change of directions (Bourgeois et al., 2017; Jeffries et al., 2015). This assumption was not confirmed, probably due to lower values of RSI in our group of table tennis and/or their inability to transfer this power to more specific conditions.

These findings indicate that the sensory component is the main determinant of reactive agility in table tennis players. However, this ability undeniably consists of the motor component as well, its relationship showed to be nonsignificant to reactive agility. It may be attributed to the low similarity in structure between sprint and change of direction speed tests and the main reactive agility test. Likely, the shorter running distance and changes in direction under lower angles could be more specific for these players in testing and training. Another possible reason should be the small transfer of speed and strength abilities to reactive agility itself or more specific conditions of table tennis.

The relatively high variations in players´ level of sports performance can be considered as the main limitation of this study. For future research, it would be interesting to investigate the difference in determinants of reactive agility between recreational, semi-professional and professional table tennis players and to compare their demands on both sensory and motor component.

CONCLUSION

In this study, there was a significant relationship between the time in reactive agility testing and reaction time to four visual stimuli. The performance in RAT was determined by the reaction speed by 64.2 % in table tennis players. Although a significant relationship with other parameters of reaction speed was not observed, medium effect size indicates that also choice reaction time and decision-making time may determine the reactive agility performance, but probably in the second-order factors.

These findings indicate that the sensory component contributes to reactive agility performance rather than the motor component in table tennis players. Although the importance of sprint speed and explosiveness in this sports game is undeniable, they are not directly responsible for the level of sports performance in table tennis. Nevertheless, it is important to focus also on the motor component in the training because reaction to ball is mostly if not always connected with the fast movement of lower extremities. It can be assumed that table tennis players who achieved great values of reaction time should focus just on the development of movement speed through explosive strength and sprint speed training.

ACKNOWLEDGEMENTS

This research was funded by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (No. 1/0089/20).

REFERENCES

Abernethy, B. (1991). Visual search strategies and decision-making in sport. *International Journal of Sports Psychology*, 22(3-4), 189–210.

Bandi, U., Tomolyius, Fauzi, & Widodo, H. (2021). Modification of reactive agility test measuring instrument for table tennis performance: Aiken´s validity and retest reliability. *Turkish Journal of Computer and Mathematics* Education, 12(14), 3214–3220.

Bhabhor, M. K., Vidja, K., Bhanderi, P., Dodhia, S., Kathrotia, R., & Joshi, V. (2013). A comparative study of visual reaction time in table tennis players and healthy controls. In: *Indian Journal of Physiology and Pharmacology*, 57(4), 439–442.

Bourgeois, F. A., McGuigan, M. R., Gill, N. D., & Gamble, P. (2017). Physical characteristics and performance in change of direction tasks: A brief review and training considerations. *Journal of Australian Strength and Conditioning,* 25, 104–117.

Cam, S., Kilit, B., Arslan, E., & Suveren, S. (2014). The comparison of reaction time of male tennis players, table tennis players and the ones who don´t exercise at all in 10 to 12 age group. In: *Journal of Physical Education and Sport Science*, 8(2), 195–201.

Deepa, Hs, Sirdesai, N. (2016). A comparative study of auditory & visual reaction time in table tennis players and age matched healthy controls. In: *Indian Journal of Clinical Anatomy and Physiology*, 3(4), 408–411.

Fuchs, M., Liu, R., Malagoli-Lanzoni, I., Munivrana, G., Straub, G., Tamaki, S., Yoshida, K., Zhang, H., & Lames, M. (2018). Table tennis match analysis: a review. In: *Journal of Sports Sciences*, 36(23), 2653–2662.

Hendl, J. (2004). Přehled statistických metod zpracování dat: Analýza a metaanalýza dat. Praha: Portál. ISBN 80-7178-820-1.

Henry, G., Dawson, B., Lay, B., & Young, W. B. (2016). Relationships between reactive agility movement time and unilateral vertical, horizontal and lateral jumps. In: *Journal of Strength and Conditioning Research*, 30(9), 2514–2521.

Horička, P., Hianik, J., & Šimonek, J. (2014). The relationship between speed factors and agility in sport games. In: *Journal of Human Sport and Exercise*, 9(1), 49–58.

Horníková, H., Doležajová, L., & Zemková, E. (2018). Playing table tennis contribute to better agility performance in middle-aged and older subjects. *Acta Gymnica*, 48(1), 15–20.

Jeffriess, M. D., Schultz, A. B., McGann, T. S., Callaghan, S. J., & Lockie, R. G. (2015). Effects of preventative ankle taping on planned change-of-direction and reactive agility performance and ankle muscle activity in basketballers. *Journal of Sports Sciences in Medicine*, 14, 864–876.

Kondrić, M., Zagatto, A. M., & Sekulic, D. (2013). The physiological demands of table tennis: a review. In: *Journal of Sports Science and Medicine*, 12(3), 362–370.

Lockie, R. G., Jeffriess, M. D., McGann, T. S., Callaghan, S. J., & Schultz, A. B. (2014). Planned and reactive agility performance in semiprofessional and amateur basketball players. *International Journal of Sports Physiology and Performance*, 9, 766–771.

Malagoli-Lanzoni, I., Di Michele, R., & Merni, F. (2014). A notational analysis of shot characteristics in top.level table tennis players. In: *European Journal of Sport Science*, 14(4), 309–317.

Oliver, J. L., & Meyers, R. W. (2009). Reliability and generality of measures of acceleration, planned agility, and reactive agility. *International Journal of Sports Physiology and Performance*, 4, 345–354.

Padulo, J., Di Giminiani, R., Dello Iacono, A., Zagatto, A. M., Migliaccio, G. M., Grgantov, Z., & Ardigò, L. P. (2016). Lower arm muscle activation during indirect-localized vibration: The influence of skill levels when applying different acceleration loads. *Frontiers in Physiology*, 7, 242.

Popowczak, M., Cichy, I., Rokita, A., & Domaradzki, J. (2021). The relationship between reactive agility and change of direction speed in professional female basketball and handball players. *Frontiers in Psychology,* 12, 708771. doi: 10.3389/fpsyg.2021.708771

Sattler, T., Sekulić, D., Spasić, M., Perić, M., Krolo, A., Uljević, O., & Kondrić, M. (2015). Analysis of the association between motor and anthropometric variables with change of direction speed and reactive agility performance. *Journal of Human Kinetic,* 47, 137–145.

Scanlan, A., Huphries, B., Tucker, P. S., & Dalbo, V. (2014). The influence of physical and cognitive factors on reactive agility performance in men basketball players. *Journal of Sports Science,* 32, 367–374.

Sekulic, D., Krolo, A., Spasic, M., Uljevic, O., & Peric, M. (2014). The development of a new stop'n'go reactive-agility test. *Journal of Strength and Conditioning Research,* 28, 3306–3312.

Spiteri, T., Newton, R. U., Binetti, M., Hart, N. H., Sheppard, J. M., & Nimphius, S. (2015). Mechanical determinants of faster change of direction and agility performance in female basketball athletes. In: *Journal of Strength and Conditioning Research*, 29(8), 2205–2214.

Šimonek, J., Horička, P., & Hianik, J. (2017). The differences in acceleration, maximal speed and agility between soccer, basketball, volleyball and handball players. *Journal of Human Sport and Exercise*, 12, 73–82.

Utama, B., Tomoliyus, Fauzi, Widodo, H. (2021). Modification of reactive agility test measuring instrument for table tennis performance: Aiken´s validity and retest reliability test. In: *Turkish Journal of Computer and Mathematics Education*, 12(14), 3214–3220.

Vacenovský, P. (2014). Struktura sportovního výkonu u stolního tenisu. In P. Korvas, & L. Bedřich (Eds.), Struktura sportovního výkonu: učební texty pro studenty FSpS (118–120). Brno: Masarykova univerzita.

Vacenovský, P., Vencúrik, T., & Sebera, M. (2015). The reactive agility of table tennis players before and after sport-specific warm-up. *Studia Sportiva*, 9(1), 31–44. https://doi.org/10.5817/StS2015-1-5

Vidja, K., Shital, D., Mahesh, B., Proti, B., Jatin, C., & Hitesh, J. (2012). Long term playing of table tennis improve the visual reaction time. *International Journal of Scientific Research*, 1(6), 155–156.

Walsh V. (2014). Is sport the brain's biggest challenge? *Current Biology*, 24(18), 859–860. https://doi.org/10.1016/j.cub.2014.08.003

Young, W.B., Dawson, B., & Henry, G. (2015). Agility and change-of-direction speed are independent skills: Implications for agility in invasion sports. *International Journal of Sports Sciences and Coaching*, 10, 159–169.

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* 2002, 42, 282–288.

Zhang, H., Zhou, Z., & Yang, Q. (2018). Match analyses of table tennis in China: A systematic review. *Journal of Sports Sciences*, 36(3), 2663–2674.

Corresponding Author:

henrieta.hornikova@uniba.sk