Analysis of reaction time and lateral displacements in national level table tennis players: are they predictive of sport performance?

Table tennis is a sport in which players perform technical actions at high speed. In this regard, response time (TTR), reaction time (RT) and movement time (MT) are key factors that can contribute to successful performance of table tennis players. The purposes of this study were to determine the magnitude of intra-subject and inter-subject variability in TTR based on player's lateral dominance, to establish possible differences between sex, age group and ranking position for TTR, RT and MT, and to relate these results with table tennis performance by analysing the achieved position in the national ranking. A total of 116 Spanish national level players (71 males and 45 females) carried out the Take-Off Reaction Test in a table tennis court simulating real sport conditions. There were no intra-sex differences for the total sample when lateral dominance was checked. On the other hand, male players showed lower MT than females whereas female players showed significantly lower RT values than males. Moreover, and taken into account the correlation analysis, we can conclude that both lower RT and MT can be considered as key variables of performance in table tennis.

Keywords: table tennis, reaction time, time of motion, ranking, athletic performance

Introduction

Table tennis is played on a small-sized rectangular table divided into two equal halves by a net. Shots take place in rapid succession and continuously alternate with intermittent rest periods (Watanabe et al., 1992). Coordinated execution of technical gestures at maximum speed together with a brief and swift travelling steps to constantly change direction are common characteristics of this sport (Pradas, González-Jurado, Molina, & Castellar, 2013). The ball travels at high speeds during rallies, sometimes reaching speeds of over 160 km·h^{-1} (Major & Lang, 2004). All these features imply the corresponding levels of response time and movement to enable such demands.

Analysing motor neuronal transmission speed is important to measure technical adaptation and athletic performance in athletes (Pawlak & Kaczmarek, 2010). In fact, the neuronal signal transmission speed is a useful variable in discriminating athletes who practice sports disciplines in which muscular power is more relevant from those which practice sports in which resistance is the main performance factor (Kamen, Taylor & Beehler, 1984).

Under this context, racquet sports show very specific characteristics with respect to reaction speed and adequate inhibitory control, both associated with athletic performance (Van de Water, Huijgen, Faber & Elferink-Gemser, 2017). The relation between eye movement and time lapsed for a body segment movement to occur (either upper or lower limbs) has been studied due to its importance in establishing the quality of motor response and the travelling speed of the ball during play (Lenoir et al., 2000; Hung, Spalding, Maria & Hatfield, 2004; Piras, Raffi, Lanzoni, Persiani & Squatrito, 2015; Piras, Lanzoni, Raffi, Persiani & Squatrito, 2016).

Total time of response (TTR) is an important variable in assessing athletic performance (Leseur, 1989; Nougier, Stein & Azemar, 1990). TTR includes reaction time (RT) and movement time (MT). RT starts with the onset of stimuli and ends with the onset of motor response. It is a predictive variable in athletic performance since implies the study of the cerebral cortex and its capacity to react to various stimuli for a specific sports event (Gao et al., 2015; Hülsdünker, Strüder & Mierau, 2016; Hülsdünker, Strüder & Mierau, 2017). RT is often considered as a measure of processing speed and reflects the efficiency of responses in data processing tasks (Van de Water, 2017). MT starts with the onset of motor response and ends with the execution of a specific technical gesture (end of the motor response).

In the same way, speed of reaction and capacity to anticipate have both been studied in elite table tennis players in comparison to other amateur levels considering them as performance variables in reaction time tests in response to various visual cues (Hughes, Bhundell & Waken, 1993; Land, 2016), in their reaction time and motor response when hitting the ball while aiming at different areas on the table (Padulo et al., 2016), or determining the influence of play fatigue in motor control and response velocity (Aune, Ingvaldsen & Ettema, 2008). Other racquet sports have likewise been analysed in which specific and general reaction times have been measured (Van de Water et al., 2017).

However, despite various studies probing the importance of variables TTR, RT and MT, none of them has found any of the variables to be related to the achieved athletic performance. In this sense, our study aims to determine intra- and inter-subject variability for TTR, RT and MT according to athlete dominance (dominant side vs. non-dominant side); to establish possible differences between sexes and age groups for TTR, RT and MT and to relate obtained results with ranking positions as a variable to measure achieved athletic performance.

Materials and methods

Sample

A total of 116 Spanish national level players (71 males and 45 females mean ± sd, age: 12.7 ± 4.3 years; height: 1.53 ± 0.13 m; body mass: 46.2 ± 13.7 kg; BMI: 19.2 ± 2.9 kg·m^{-2}) were distributed into five categories attending to their age: senior (n=8), under-18 (n=13), under-15 (n=22), under-13 (n=38) and under-11 (n=35). Players were also distributed according to their performance level into five national ranking categories: top-10 (n=63), top-20 (n=28), top-30 (n=11), top-40 (n=7) and over top-40 (n=7).

Testing procedure

Subjects carried out the Take-Off Reaction Test (Newtest® - Finland). From table tennis base position (on contact mat) subjects reacted to the red light (left or right) which an electronic device randomly emitted. Next, subjects left the contact mat and performed a lateral run (maximal sprint performance) until left or right photocells (placed 5 m from the mat). Subjects completed 12 attempts (6 to the left and 6 to the right) and the best result was registered. All attempts were carried out consecutively. At the end of each attempt subjects returned to the mat starting the next one when table tennis base position was adopted (Figure 1).

Figure 1: Take-Off Reaction Test (Newtest® - Finland)

Parameters measured were: a) reaction time (RT): elapsed time between lights on (right or left) and the moment in which subjects took–off from the mat (s); b) movement time (MT): elapsed time (s) between taking–off from mat and moment in which subjects broke photocell barriers (lateral displacement over 5 m); c) total time of response (TTR): elapsed time between lights on (right or left) and moment in which subjects broke photocells barrier (s). It is important to indicate that we considered anticipation when players reached a reaction capacity of <150 ms. Moreover, and in order to prevent any possible incidence from upper limbs on automatic timing, photocells were situated at the subject hips' height.

Statistical analysis

For the statistical analysis, IBM's SPSS 24 software was used. Descriptive statistics mean and standard deviation were calculated. A confidence interval of the mean values was obtained at 95% to estimate measurement reliability. Two inferential statistic analyses were performed. For intragroup comparisons, ANOVA with repeated measures between dominant and non-dominant response-time were calculated. A multivariate general linear model was applied to analyse differences between groups (sex and category). Differences in comparisons by pairs (pairwise comparisons) were analysed by Bonferroni correction. Likewise, in order to determine the magnitude of the differences between groups, the effect size was measured through partial Eta squared (η^2_p). Lastly, Pearson's correlation coefficients were assessed between RT, MT, and TTR and ranking position.

Results

After analysing relative values for variables TTR, RT and MT in order to determine possible variability between players' dominant and non-dominant side, no significant differences were found when comparing lateral dominance with sex and age groups. Values obtained for the full sample were 2.23±0.22 s and 2.23±0.19 s for dominant (DS) and non-dominant side (NDS) in TTR respectively. Male players obtained 2.15±0.20 s and 2.17±0.16 s, and women 2.36±0.18 s and 2.33±0.20 s in TTR for DS and NDS respectively. All other times obtained are shown in Table 1.

Table 1: Intra-sex differences in TTR, RT and MT as a function of lateral dominance.

Furthermore, differences in TTR, RT and MT as a function of lateral dominance by age groups has shown significant differences in TTR for female seniors (p=0.04;

η^2_p=0.03) with 2.19±0.10 s and 2.03±0.39 s for DS and NDS respectively, in RT for male U11s with values of 0.75±0.15 s and 0.69±0.09 s for DS and NDS (p=0.01; η^2_p=0.05) and in MT for female seniors (1.72±0.14 s and 1.53±0.15; p=0.03 and η^2_p=0.04). Table 2 shows all other registered results by sex and age groups.

Table 2: Intra-sex differences in TTR, RT and MT according to lateral dominance by categories.

Tables 3 and 4 show established comparisons for TTR, RT and TM for each category; moreover, these results are shown with the resulting value for the difference between females and males. Males achieved significantly better results for TTR in all categories except seniors (0.166±0.081 s, p=.04, η^2_p=0.03 in Under-18; 0.170±0.060 s, p=.005, η^2_p=0.07 in Under-15; 0.204±.045 s, p=.000, η^2_p=0.16 in Under-13 and 0.166±.047 s, p=.001, η^2_p=0.10 in Under-11). Similarly, males have also been faster in RT in all categories except Under-11. However, females achieved a significantly better result for RT with a difference between averages of -0.231±0.74 s (p=.002 and η^2_p=0.08). For all other comparisons, no statistically significant differences were found.

Table 3. Inter-sex comparison of TTR, RT and MT for senior, U18 and U15 categories based on average differences between males and females.

Table 4. Inter-sex comparison of TTR, RT and MT for U13 and U11 categories based on average differences between males and females.

Correlations between achieved performance for TTR, RT and MT and ranking position by age group and sex have shown to be statistically significant in RT for male Under-18 (r = -.689), male Under-11 (0.482), and female Under-11 (r = -.547). Table 5 shows all other correlated values.

Table 5. Correlations (Pearson's r) between TTR, RT, MT, and national ranking position by age group and sex.

Discussion

In many sports disciplines, the capacity to react swiftly to various visual cues is a key factor in achieving athletic success. In fact, research on perception skill and travelling speed is essential in identifying sports talent (Hughes et al., 1993; Williams, Davids & Williams, 1999). In the field of racquet sports, and more specifically in table tennis, this variable is of great importance due to the reduced dimensions in which the game is played and the high speeds at which it is played, making it one of the fastest sports there are (Toriola, Toriola & Igbokwe, 2004).

The purpose of this study is to determine any possible relations between the capacity to perform well in a reaction speed test (with DS and NDS) and the performance in elite table tennis players belonging to different age groups based on their ranking position.

The intra-sex analysis of TTR, RT and MT based on lateral dominance (DS vs. NDS) has shown no statistical difference in the total sample. Data show analysed players are capable of reacting (RT) and travelling (MT) quickly both to DS and NDS. Results in this sense are logical for, in table tennis, players may hit be ball randomly towards either side of the table, creating a great degree of uncertainty in the opponent who does not know this information in advance. These results are similar to those found in other studies in which swift movements and quick decisions taken in split seconds are essential in table tennis success (Toriola, Toriola & Igbokwe, 2004).

With respect to intra-sex comparison for TTR, RT and MT based on lateral dominance by age groups, significant differences have been found between Ds and NDS exclusively in TTR for female seniors (p= .04), and in RT for male Under-11s (p= .01), despite showing a very low effect size. These results could indicate how table tennis is developing differently between male and female players with the former showing a faster game with shorter rallies, especially seniors who have a well-defined game (Zagatto, Morel & Gobatto, 2010; Tamaki, Yoshida & Yamada, 2017). Obtained results are in accordance with those found in the general sample, which suggest players adapt to the game's needs. Although table tennis players show shorter TTR than non-athletes, (Padulo et al., 2016), there is no confirmation that intra-sex comparison is enough to show differences. These results agree with those by Padulo et al. (2016), who found no differences in RT and MT between well-trained table tennis players and other average level ones.

In inter-sex comparison, TTR, RT and MT for each age group based on differences for male-female average values, significant differences were observed in TTR for Under-18 (p= .04), Under-15 (p= .005), Under-13 (p= .000) and Under-11 (p=0.001). These results confirm previous results and come to emphasize existing differences in the game of male and female players with males showing a faster and more explosive game with shorter bouts of effort whereas females show a slower and more conservative game with longer rallies (Zagatto, Morel & Gobatto, 2010; Tamaki, Yoshida & Yamada, 2017). Nevertheless, since we found no differences in RT (taking RT as time elapsed from the onset of a visual stimulus to the movement of feet on the mat) for any of these age groups (except in Under-18) yet we found differences in MT in all categories (except in Under-11), a neurophysiological approach might explain this difference. RT is based primarily on a neurological component whereas MT does so on a muscular component. The former is less trainable whereas the latter depends more on the fibre type and shows a larger degree of improvement through training processes (Gollnick et al., 1973). However, selective reaction time should be considered as an essential skill in order to achieve a high degree of motor organization (Jaworski & Zak, 2015), and should therefore also be equally stimulated.

Correlation results show the influence that the observed performance for RT and MT has on how well the player is ranked. The better the RT is, the higher the player is ranked with significant differences in males Under-18 and Under-11 and in females Under-11. On the other hand, MT showed significant correlation with ranking in senior males. These data show the importance of these variables and agree with those found for other racquet sports such as badminton (Yuan, Fan, Chin & So, 1995; Wang, Yan & Zhang, 2008), which demonstrated how important eye-movement coordination and RT are in athletic performance.

The study is somehow limited due to sample size considerations for some of the analysed age groups, a feature hard to deal with when working with elite players. Additionally, the only movements considered in this study were the lower limb ones, ignoring those performed by upper limbs.

We can conclude that both lower RT and MT seem to be key variables of performance in table tennis.

References

Aune, T. K., Ingvaldsen, R. P., & Ettema, G. J. C. (2008). Effect of physical fatigue on motor control at different skill levels. *Perceptual and motor skills, 106*(2), 371-386.

Gao, Y., Chen, L., Yang, S. N., Wang, H., Yao, J., Dai, Q., & Chang, S. (2015). Contributions of Visuo-oculomotor Abilities to Interceptive Skills in Sports. Optometry & *Vision Science, 92*(6), 679-689. doi: 10.1097/OPX.0000000000000599

Gollnick, P. D., Armstrong, R. B., Saltin, B., Saubert, C., Sembrowich, W. L., & Shepherd, R. E. (1973). Effect of training on enzyme activity and fiber composition of human skeletal muscle. *Journal of Applied Physiology, 34*(1), 107-111.

Hughes, P. K., Bhundell, N. L., & Waken, J. M. (1993). Visual and psychomotor performance of elite, intermediate and novice table tennis competitors. *Clinical and Experimental Optometry, 76*(2), 51-60. doi: 10.1111/j.1444-0938.1993.tb05090.x

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2016). Neural Correlates of Expert Visuomotor Performance in Badminton Players. *Medicine and science in sports and exercise, 48*(11), 2125. doi: 10.1249/MSS.0000000000001010

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2017). Visual Motion Processing Subserves Faster Visuomotor Reaction in Badminton Players. *Medicine and science in sports and exercise*. doi: 10.1249/MSS.0000000000001198

Hung, T. M., Spalding, T. W., Maria, D. L. S., & Hatfield, B. D. (2004). Assessment of reactive motor performance with event-related brain potentials: attention processes in elite table tennis players. *Journal of Sport and Exercise Psychology, 26*(2), 317-337. doi: http://dx.doi.org/10.1123/jsep.26.2.317

Jaworski, J., & Żak, M. (2015). The structure of morpho-functional conditions determining the level of sports performance of young badminton players. *Journal of human kinetics, 47*(1), 215-223. doi: https://doi.org/10.1515/hukin-2015-0077

Kamen, G., Taylor, P., & Beehler, P. J. (1984). Ulnar and posterior tibial nerve conduction velocity in athletes. *International journal of sports medicine, 5*(01), 26-30. doi: 10.1055/s-2008-1025876

Land, W. M. (2016). Action Effects and Task Knowledge: The Influence of Anticipatory Priming on the Identification of Task-Related Stimuli in Experts. *PloS One, 11*(6), e0156928. doi: https://doi.org/10.1371/journal.pone.0156928

Lenoir, M., Crevits, L., Goethals, M., Duyck, P., Wildenbeest, J., & Musch, E. (2000). Saccadic eye movements and finger reaction times of table tennis players of different levels. *Neuro-ophthalmology, 24*(2), 335-338. doi: http://dx.doi.org/10.1076/noph.24.2.335.7153

Leseur, H. (1989). Étude des réactions visuo-motrices chez des escrimeurs de haut niveau au cours dune étape dentraînement. *Science et motricité, 8*, 47-52.

Major, Z., & Lang, R. W. (2004). Characterization of table tennis racket sandwich rubbers. En: A. Lees, J.-F. Kahn, y I. W. Maynard (Eds.), *Science and Racket Sports III* (pp. 146-151). Oxon: Routledge.

Nougier, V., Stein, J. F., & Azemar, G. (1990). Covert orienting of attention and motor preparation processes as a factor of success in fencing. *Journal of Human Movement Studies, 19*(6), 251-272.

Padulo, J., Pizzolato, F., Tosi, R. S., Migliaccio, G. M., Attene, G., Curcio, R., & Moura, Z. A. (2016). Task complexity reveals expertise of table tennis players. *The Journal of sports medicine and physical fitness, 56*(1-2), 149-156.

Pawlak, M., & Kaczmarek, D. (2010). Field hockey players have different values of ulnar and tibial motor nerve conduction velocity than soccer and tennis players. *Archives italiennes de biologie, 148*(4), 377-388. doi: 10.4449/aib.v148i4.1208.

Piras, A., Lanzoni, I. M., Raffi, M., Persiani, M., & Squatrito, S. (2016). The within-task criterion to determine successful and unsuccessful table tennis players. *International journal of Sports Science & Coaching, 11*(4), 523-531.

Piras, A., Raffi, M., Lanzoni, I. M., Persiani, M., & Squatrito, S. (2015). Microsaccades and Prediction of a Motor Act Outcome in a Dynamic Sport SituationMicrosaccades in Table Tennis. *Investigative ophthalmology & visual science, 56*(8), 4520-4530. doi:10.1167/iovs.15-16880

Pradas, F., González-Jurado, J. A., Molina, E., & Castellar, C. (2013). Características antropométricas, composición corporal y somatotipo de jugadores de tenis de mesa de alto nivel. *International Journal of Morphology, 31*(4), 1355-1364. doi: http://dx.doi.org/10.4067/S0717-95022013000400033

Tamaki, S., Yoshida, K., & Yamada, K. (2017). A Shot Number Based Approach to Performance Analysis in Table Tennis. *Journal of Human Kinetics, 55*(1), 7-18. doi: 10.1515/hukin-2017-0002

Toriola, A. L., Toriola, O. M., & Igbokwe, N. U. (2004). Validity of specific motor skills in predicting table-tennis performance in novice players. *Perceptual and motor skills, 98*(2), 584-586. doi: 10.2466/pms.98.2.584-586

Van de Water, T., Huijgen, B., Faber, I., & Elferink-Gemser, M. (2017). Assessing Cognitive Performance in Badminton Players: A Reproducibility and Validity Study. *Journal of Human Kinetics, 55*(1), 149-159. doi: https://doi.org/10.1515/hukin-2017-0014

Wang, S. M., Yan, C., & Zhang, J. C. (2008). A research on evaluation target reaction ability correctly for badminton players in the process of appraising perceptual-motor skill. *Journal of Beijing Sport University, 31*(6), 779-781.

Watanabe, M., Yano, H., Nagata, M., Kitahara, T., Oka, S., Shu, J. Z., … Mori, T. (1992). Evaluation of table tennis practice by blood lactate concentration. *International Journal of Table Tennis Sciences, 1*, 38.

Williams, A. M., Davids, K., & Williams, J. G. P. (1999). *Visual perception and action in sport*. Taylor & Francis.

Yuan, Y. W., Xu, F., Chin, M. K., & So, R. C. H. (1995). Hand-eye co-ordination and visual reaction time in elite badminton players and gymnasts. *New Zealand Journal of Sports Medicine, 23*, 19-19.

Zagatto, A. M., Morel, E. A., & Gobatto, C. A. (2010). Physiological responses and characteristics of table tennis matches determined in official tournaments. *The Journal of Strength & Conditioning Research, 24*(4), 942-949.

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Figure 1: Take-Off Reaction Test (Newtest® - Finland)

Parameters measured were: a) reaction time (RT): elapsed time between lights on (right or left) and the moment in which subjects took–off from the mat (s); b) movement time (MT): elapsed time (s) between taking–off from mat and moment in which subjects broke photocell barriers (lateral displacement over 5 m); c) total time of response (TTR): elapsed time between lights on (right or left) and moment in which subjects broke photocells barrier (s). It is important to indicate that we considered anticipation when players reached a reaction capacity of <150 ms. Moreover, and in order to prevent any possible incidence from upper limbs on automatic timing, photocells were situated at the subject hips' height.

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Table 1: Intra-sex differences in TTR, RT and MT as a function of lateral dominance.

Furthermore, differences in TTR, RT and MT as a function of lateral dominance by age groups has shown significant differences in TTR for female seniors (p=0.04;

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Tables 3 and 4 show established comparisons for TTR, RT and TM for each category; moreover, these results are shown with the resulting value for the difference between females and males. Males achieved significantly better results for TTR in all categories except seniors (0.166±0.081 s, p=.04, η^2_p=0.03 in Under-18; 0.170±0.060 s, p=.005, η^2_p=0.07 in Under-15; 0.204±.045 s, p=.000, η^2_p=0.16 in Under-13 and 0.166±.047 s, p=.001, η^2_p=0.10 in Under-11). Similarly, males have also been faster in RT in all categories except Under-11. However, females achieved a significantly better result for RT with a difference between averages of -0.231±0.74 s (p=.002 and η^2_p=0.08). For all other comparisons, no statistically significant differences were found.

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Correlations between achieved performance for TTR, RT and MT and ranking position by age group and sex have shown to be statistically significant in RT for male Under-18 (r = -.689), male Under-11 (0.482), and female Under-11 (r = -.547). Table 5 shows all other correlated values.

Table 5. Correlations (Pearson's r) between TTR, RT, MT, and national ranking position by age group and sex.

Discussion

In many sports disciplines, the capacity to react swiftly to various visual cues is a key factor in achieving athletic success. In fact, research on perception skill and travelling speed is essential in identifying sports talent (Hughes et al., 1993; Williams, Davids & Williams, 1999). In the field of racquet sports, and more specifically in table tennis, this variable is of great importance due to the reduced dimensions in which the game is played and the high speeds at which it is played, making it one of the fastest sports there are (Toriola, Toriola & Igbokwe, 2004).

The purpose of this study is to determine any possible relations between the capacity to perform well in a reaction speed test (with DS and NDS) and the performance in elite table tennis players belonging to different age groups based on their ranking position.

The intra-sex analysis of TTR, RT and MT based on lateral dominance (DS vs. NDS) has shown no statistical difference in the total sample. Data show analysed players are capable of reacting (RT) and travelling (MT) quickly both to DS and NDS. Results in this sense are logical for, in table tennis, players may hit be ball randomly towards either side of the table, creating a great degree of uncertainty in the opponent who does not know this information in advance. These results are similar to those found in other studies in which swift movements and quick decisions taken in split seconds are essential in table tennis success (Toriola, Toriola & Igbokwe, 2004).

With respect to intra-sex comparison for TTR, RT and MT based on lateral dominance by age groups, significant differences have been found between Ds and NDS exclusively in TTR for female seniors ($p= .04$), and in RT for male Under-11s ($p= .01$), despite showing a very low effect size. These results could indicate how table tennis is developing differently between male and female players with the former showing a faster game with shorter rallies, especially seniors who have a well-defined game (Zagatto, Morel & Gobatto, 2010; Tamaki, Yoshida & Yamada, 2017). Obtained results are in accordance with those found in the general sample, which suggest players adapt to the game's needs. Although table tennis players show shorter TTR than non-athletes, (Padulo et al., 2016), there is no confirmation that intra-sex comparison is enough to show differences. These results agree with those by Padulo et al. (2016), who found no differences in RT and MT between well-trained table tennis players and other average level ones.

In inter-sex comparison, TTR, RT and MT for each age group based on differences for male-female average values, significant differences were observed in TTR for Under-18 ($p= .04$), Under-15 ($p= .005$), Under-13 ($p= .000$) and Under-11 ($p=0.001$). These results confirm previous results and come to emphasize existing differences in the game of male and female players with males showing a faster and more explosive game with shorter bouts of effort whereas females show a slower and more conservative game with longer rallies (Zagatto, Morel & Gobatto, 2010; Tamaki, Yoshida & Yamada, 2017). Nevertheless, since we found no differences in RT (taking RT as time elapsed from the onset of a visual stimulus to the movement of feet on the mat) for any of these age groups (except in Under-18) yet we found differences in MT in all categories (except in Under-11), a neurophysiological approach might explain this difference. RT is based primarily on a neurological component whereas MT does so on a muscular component. The former is less trainable whereas the latter depends more on the fibre type and shows a larger degree of improvement through training processes (Gollnick et al., 1973). However, selective reaction time should be considered as an essential skill in order to achieve a high degree of motor organization (Jaworski & Zak, 2015), and should therefore also be equally stimulated.

Correlation results show the influence that the observed performance for RT and MT has on how well the player is ranked. The better the RT is, the higher the player is ranked with significant differences in males Under-18 and Under-11 and in females Under-11. On the other hand, MT showed significant correlation with ranking in senior males. These data show the importance of these variables and agree with those found for other racquet sports such as badminton (Yuan, Fan, Chin & So, 1995; Wang, Yan & Zhang, 2008), which demonstrated how important eye-movement coordination and RT are in athletic performance.

The study is somehow limited due to sample size considerations for some of the analysed age groups, a feature hard to deal with when working with elite players. Additionally, the only movements considered in this study were the lower limb ones, ignoring those performed by upper limbs.

We can conclude that both lower RT and MT seem to be key variables of performance in table tennis.

References

Aune, T. K., Ingvaldsen, R. P., & Ettema, G. J. C. (2008). Effect of physical fatigue on motor control at different skill levels. *Perceptual and motor skills, 106*(2), 371-386.

Gao, Y., Chen, L., Yang, S. N., Wang, H., Yao, J., Dai, Q., & Chang, S. (2015). Contributions of Visuo-oculomotor Abilities to Interceptive Skills in Sports. Optometry & *Vision Science, 92*(6), 679-689. doi: 10.1097/OPX.0000000000000599

Gollnick, P. D., Armstrong, R. B., Saltin, B., Saubert, C., Sembrowich, W. L., & Shepherd, R. E. (1973). Effect of training on enzyme activity and fiber composition of human skeletal muscle. *Journal of Applied Physiology, 34*(1), 107-111.

Hughes, P. K., Bhundell, N. L., & Waken, J. M. (1993). Visual and psychomotor performance of elite, intermediate and novice table tennis competitors. *Clinical and Experimental Optometry, 76*(2), 51-60. doi: 10.1111/j.1444-0938.1993.tb05090.x

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2016). Neural Correlates of Expert Visuomotor Performance in Badminton Players. *Medicine and science in sports and exercise, 48*(11), 2125. doi: 10.1249/MSS.0000000000001010

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2017). Visual Motion Processing Subserves Faster Visuomotor Reaction in Badminton Players. *Medicine and science in sports and exercise*. doi: 10.1249/MSS.0000000000001198

Hung, T. M., Spalding, T. W., Maria, D. L. S., & Hatfield, B. D. (2004). Assessment of reactive motor performance with event-related brain potentials: attention processes in elite table tennis players. *Journal of Sport and Exercise Psychology, 26*(2), 317-337. doi: http://dx.doi.org/10.1123/jsep.26.2.317

Jaworski, J., & Żak, M. (2015). The structure of morpho-functional conditions determining the level of sports performance of young badminton players. *Journal of human kinetics, 47*(1), 215-223. doi: https://doi.org/10.1515/hukin-2015-0077

Kamen, G., Taylor, P., & Beehler, P. J. (1984). Ulnar and posterior tibial nerve conduction velocity in athletes. *International journal of sports medicine, 5*(01), 26-30. doi: 10.1055/s-2008-1025876

Land, W. M. (2016). Action Effects and Task Knowledge: The Influence of Anticipatory Priming on the Identification of Task-Related Stimuli in Experts. *PloS One, 11*(6), e0156928. doi: https://doi.org/10.1371/journal.pone.0156928

Lenoir, M., Crevits, L., Goethals, M., Duyck, P., Wildenbeest, J., & Musch, E. (2000). Saccadic eye movements and finger reaction times of table tennis players of different levels. *Neuro-ophthalmology, 24*(2), 335-338. doi: http://dx.doi.org/10.1076/noph.24.2.335.7153

Leseur, H. (1989). Étude des réactions visuo-motrices chez des escrimeurs de haut niveau au cours dune étape dentraînement. *Science et motricité, 8*, 47-52.

Major, Z., & Lang, R. W. (2004). Characterization of table tennis racket sandwich rubbers. En: A. Lees, J.-F. Kahn, y I. W. Maynard (Eds.), *Science and Racket Sports III* (pp. 146-151). Oxon: Routledge.

Nougier, V., Stein, J. F., & Azemar, G. (1990). Covert orienting of attention and motor preparation processes as a factor of success in fencing. *Journal of Human Movement Studies, 19*(6), 251-272.

Padulo, J., Pizzolato, F., Tosi, R. S., Migliaccio, G. M., Attene, G., Curcio, R., & Moura, Z. A. (2016). Task complexity reveals expertise of table tennis players. *The Journal of sports medicine and physical fitness, 56*(1-2), 149-156.

Pawlak, M., & Kaczmarek, D. (2010). Field hockey players have different values of ulnar and tibial motor nerve conduction velocity than soccer and tennis players. *Archives italiennes de biologie, 148*(4), 377-388. doi: 10.4449/aib.v148i4.1208.

Piras, A., Lanzoni, I. M., Raffi, M., Persiani, M., & Squatrito, S. (2016). The within-task criterion to determine successful and unsuccessful table tennis players. *International journal of Sports Science & Coaching, 11*(4), 523-531.

Piras, A., Raffi, M., Lanzoni, I. M., Persiani, M., & Squatrito, S. (2015). Microsaccades and Prediction of a Motor Act Outcome in a Dynamic Sport SituationMicrosaccades in Table Tennis. *Investigative ophthalmology & visual science, 56*(8), 4520-4530. doi:10.1167/iovs.15-16880

Pradas, F., González-Jurado, J. A., Molina, E., & Castellar, C. (2013). Características antropométricas, composición corporal y somatotipo de jugadores de tenis de mesa de alto nivel. *International Journal of Morphology, 31*(4), 1355-1364. doi: http://dx.doi.org/10.4067/S0717-95022013000400033

Tamaki, S., Yoshida, K., & Yamada, K. (2017). A Shot Number Based Approach to Performance Analysis in Table Tennis. *Journal of Human Kinetics, 55*(1), 7-18. doi: 10.1515/hukin-2017-0002

Toriola, A. L., Toriola, O. M., & Igbokwe, N. U. (2004). Validity of specific motor skills in predicting table-tennis performance in novice players. *Perceptual and motor skills, 98*(2), 584-586. doi: 10.2466/pms.98.2.584-586

Van de Water, T., Huijgen, B., Faber, I., & Elferink-Gemser, M. (2017). Assessing Cognitive Performance in Badminton Players: A Reproducibility and Validity Study. *Journal of Human Kinetics, 55*(1), 149-159. doi: https://doi.org/10.1515/hukin-2017-0014

Wang, S. M., Yan, C., & Zhang, J. C. (2008). A research on evaluation target reaction ability correctly for badminton players in the process of appraising perceptual-motor skill. *Journal of Beijing Sport University, 31*(6), 779-781.

Watanabe, M., Yano, H., Nagata, M., Kitahara, T., Oka, S., Shu, J. Z., … Mori, T. (1992). Evaluation of table tennis practice by blood lactate concentration. *International Journal of Table Tennis Sciences, 1*, 38.

Williams, A. M., Davids, K., & Williams, J. G. P. (1999). *Visual perception and action in sport*. Taylor & Francis.

Yuan, Y. W., Xu, F., Chin, M. K., & So, R. C. H. (1995). Hand-eye co-ordination and visual reaction time in elite badminton players and gymnasts. *New Zealand Journal of Sports Medicine, 23*, 19-19.

Zagatto, A. M., Morel, E. A., & Gobatto, C. A. (2010). Physiological responses and characteristics of table tennis matches determined in official tournaments. *The Journal of Strength & Conditioning Research, 24*(4), 942-949.

Table

		TTR		p (η^2_p)	RT		p (η^2_p)	MT		p (η^2_p)
		Avg±SD	**IC95%**		**Avg±SD**	**IC95%**		**Avg±SD**	**IC95%**	
Males n=71	**DS**	2.15±0.20	2.05-2.15	.620	0.67±0.11	.637-.704	.530	1.48±0.20	1.37-1.48	.928
	NDS	2.17±0.16	2.07-2.15	(.002)	0.67±0.97	.646-.713	(.004)	1.50±0.18	1.57-1.67	(.000)
Females n=45	**DS**	2.36±0.18	2.23-2.45	.137	0.68±0.16	.588-.669	.800	1.68±0.18	1.60-1.73	.138
	NDS	2.33±0.20	2.20-2.30	(.021)	0.68±0.16	.593-.673	(.001)	1.64±0.14	1.57-1.67	(.021)
All sample n=116	**DS**	2.23±0.22	2.19-2.27	.450	0.67±0.13	0.65-0.70	.552	1.55±0.22	1.51-1.59	.276
	NDS	2.23±0.19	2.20-2.27	(.007)	0.67±0.12	0.65-0.70	(.003)	1.56±0.18	1.52-1.59	(.011)

SD: standard deviation; IC95%: confidence interval at 95 %; η^2: effect size; TTR: total time of response (s); RT: reaction time (s); MT: movement time (s); DS: dominant side; NDS: non-dominant side.

Table

			TTR Avg±SD	p (η^2_p)	RT Avg±SD	p (η^2_p)	MT Avg±SD	p (η^2_p)
Males	**Senior n=4**	**DS**	1.99±0.15	.655	0.70±0.12	.565	1.29±0.18	.466
		NDS	1.96±0.15	(.002)	0.73±0.18	(.003)	1.23±0.31	(.005)
	Under-18 n=19	**DS**	1.94±0.63	.891	0.60±0.08	.068	1.33±0.07	.357
		NDS	1.95±0.10	(.000)	0.67±0.09	(.031)	1.28±0.08	(.008)
	Under-15 n=14	**DS**	2.10±0.85	.428	0.63±0.05	.791	1.47±0.11	.572
		NDS	2.14±0.82	(.006)	0.64±0.07	(.001)	1.49±0.10	(.003)
	Under-13 n=23	**DS**	2.18±0.24	.209	0.64±0.08	.840	1.53±0.25	.307
		NDS	2.22±0.14	(.015)	0.65±0.09	(.000)	1.57±0.15	(.010)
	Under-11 n=21	**DS**	2.27±0.17	.776	0.75±0.15	.012*	1.52±0.20	.089
		NDS	2.28±0.11	(.001)	0.69±0.09	(.059)	1.59±0.13	(.027)
			TTR Avg±SD	**p (η^2_p)**	**RT Avg±SD**	**p (η^2_p)**	**MT Avg±SD**	**p (η^2_p)**
Females	**Senior n=4**	**DS**	2.19±0.10	.041*	0.47±0.23	.603	1.72±0.14	.033*
		NDS	2.03±0.39	(.039)	0.49±0.25	(.003)	1.53±0.15	(.042)
	Under-18 n=4	**DS**	2.09±0.11	.483	0.54±0.06	.889	1.54±0.86	.476
		NDS	2.14±0.07	(.005)	0.53±0.06	(.000)	1.60±0.43	(.005)
	Under-15 n=8	**DS**	2.33±0.15	.209	0.63±0.09	.777	1.70±0.22	.330
		NDS	2.26±0.05	(.015)	0.62±0.05	(.001)	1.64±0.05	(.009)
	Under-13 n=15	**DS**	2.42±0.14	.449	0.68±0.12	.355	1.73±0.14	.227
		NDS	2.39±0.14	(.005)	0.70±0.15	(.008)	1.68±0.15	(.014)
	Under-11 n=14	**DS**	2.44±0.18	.950	0.81±0.13	.684	1.63±0.21	.774
		NDS	2.44±0.14	(.000)	0.80±0.14	(.002)	1.64±0.18	(.001)

SD: standard deviation; η^2_p: effect size. Senior: 18 y.o.a or over; U18: under 18 y.o.a; U15: under 15 y.o.a; U13: under 13 y.o.a; U11: under 11 y.o.a. TTR: total time of response. RT: reaction time. MT: movement time. DS: dominant side. NDS: non-dominant side. *p<.05.

Table

	TTR		p (η^2_p)	RT		p (η^2_p)	MT		p (η^2_p)
	DifAvg±SE	**$IC_{95\%}$**		**DifAvg±SE**	**$IC_{95\%}$**		**DifAvg±SE**	**$IC_{95\%}$**	
Senior n=8	.135±0.096	-0.54/3.25	.161 (.018)	-.231±0.74	-.379/-.084	.002** (.084)	.366±.103	.162/.571	.001*** (.106)
Under-18 n=13	.166±0.081	.005/.327	.044* (.038)	-.099±.063	-.225/.026	.119 (.023)	.265±.088	.091/.439	.003** (.079)
Under-15 n=22	.170±.060	.051/.289	.005** (.071)	-.017±0.47	-.110/.075	.710 (.001)	.187±0.65	.059/.316	.005** (.073)

SE: standard error; IC95%: confidence interval at 95 %; η^2_p: effect size; Senior: 18 y.o.a or over; U18: under 18 y.o.a; U15: under 15 y.o.a; * $p<0.05$; ** $p<0.01$; ***$p<0.001$

Table

	Under-13 (n=38)				**Under-11 (n=35)**			
	Dif Avf±SE	**$IC_{95\%}$**	**p**	**η^2_p**	**Dif Avf±SE**	**$IC_{95\%}$**	**p**	**η^2_p**
TTR	.204±.045	.115/.293	.000***	.163	.166±.047	.074/.259	.001***	.107
RT	.046±.035	-.024/.115	.193	.016	.083±.036	.011/.155	.024*	.047
MT	.158±.048	.062/.254	.001***	.091	.083±.050	-.017/.183	.101	.025

SE: standard error; IC95%: confidence interval at 95 %; η^2_p: effect size; U13: under 13 y.o.a; U11: under 11 y.o.a. * $p<0.05$; ***$p<0.001$

Table

	Ranking Males (n= 71)				
	Senior (n=4)	**U18-years (n= 9)**	**U15-years (n=14)**	**U13-years (n=23)**	**U11-years (n= 21)**
TTR	-.817	.538	.186	.216	.349
RT	.745	.689*	.125	.171	.482*
MT	.932*	-.131	.050	.123	-.036
	Ranking Females (n= 45)				
	Senior (n= 4)	**U18-years (n=4)**	**U15-years (n=8)**	**U13-years (n=15)**	**U11-years (n=14)**
TTR	.302	.446	.346	.436	.379
RT	.086	.405	-.247	.098	.547*
MT	.810	.396	.361	.341	-.057

Senior: 18 y.o.a or over; U18: under 18 y.o.a; U15: under 15 y.o.a; U13: under 13 y.o.a; U11: under 11 y.o.a; TTR: total time to response; RT: reaction time; MT: movement time; DS: dominant side. NDS: non-dominant side; * Significant correlation for p <.05

Figure