Reaction time and special fitness of tennis players aged 10-12 years

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Tomasz Waldziński

Faculty of Health Sciences, University of Lomza, Lomza, Poland

Received: 09 June 2023; **Accepted:** 16 October 2023; **Published online:** 30 October 2023

AoBID: 15946

Abstract

Background & Study Aim: Reaction time is the time elapsed from the stimulus (nerve impulse) to the initiation of movement. This ability involves performing a deliberate motor action in the shortest possible time, utilizing the entire body or a specific part of it. Excellent speed and short reaction time are among the most essential elements of modern tennis. A lightning-fast start towards the ball, quick decision-making during returns or volleys (especially in doubles matches) can contribute to high performance in tennis. Recent match analyses of the world's top tennis players have shown that speed is the motor skill that distinguishes the exceptional among the best players. The aim of the study was to knowledge of the relationship between reaction time and special fitness of tennis players aged 10-12 years old.

Material & Methods: The study involved 45 tennis players training in clubs in the Podlaskie Voivodeship, Poland. The participants were divided into age categories, and the tennis players varied in their level of sport advancement. Two tests were used to assess reaction time: Blink.Pro Infinity (reaction time test); International Tennis Number (special fitness of tennis players test).

Results: Positive average and high correlation coefficients between reaction time test (Blink) and special fitness of tennis players test (ITN) scores increased with the age of the tennis players tested: 10-year-olds r = 0.358 (average correlation) and positive correlations 11-year-olds r = 0.521, $p<0.05$ and 12-year-olds r = 0.599, $p<0.02$.

Conclusions: The results of the study provide evidence that the training of juvenile tennis players influences not only the increase of their special fitness, but also the speed (effectiveness) of their motor response to stimuli simulated in laboratory conditions. The increasing interdependence of the indices of both variables (special fitness and reaction time to external stimuli) with age indicates that stimulating the natural process of biological growth of the organism at this stage of ontogenesis with specific tennis exercises has a positive effect on this component of coordination ability (motor reaction time), which is related to human motor safety in the general sense (health and survival).

Keywords: Blink.Pro Infinity • innovative agonology • International Tennis Number • motor safety • motor skill

Conflict of interest: Author has declared that no competing interest exists

Ethical approval: The study was approved by the local Ethics Committee

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: Departmental sources

Author's address: Tomasz Waldziński, Faculty of Health Sciences, University of Lomza, 14 Akademicka St., 18-400 Lomza, Poland; e-mail: twaldzinski@al.edu.pl

Power area for double points – execution instructions: 'Now start at centre of the baseline and measure 16 feet (4.87m) towards the back fence. Make a small mark on the court just as you did with the other lines. Now measure 15 Feet (4.57m) from the doubles side line towards the back fence at each side and make a small mark on the court. When you have all three markers you will be able to place the provided line across the court to create the Power Area for Double Points (...)' [14, p. 6].

SFI – abbreviation of the name of the phenomenon 'susceptibility to the body injuries during the fall' [39, 33].

Innovative agonology – is an applied science dedicated to promotion, prevention and therapy related to all dimensions of health and regarding the optimization of activities that increase the ability to survive from micro to macro scales [40, p. 274].

INNOAGON – acronym 'innovative agonology' [41].

Core training – the goal of core training is definitely not to develop muscle hypertrophy but to improve functional predispositions of physical activity. This particularly involves improving intermuscular coordination or synchronization of participating muscles [42].

Athlete – *noun* **1.** someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races; **2.** a competitor in track or field events [43].

Player – *noun* someone taking part in a sport or game [43].

Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [43].

Motor safety – is consciousness of the person undertaking to solve a motor task or consciousness the subject who has the right to encourage and even enforce from this person that would perform the motor activity, who is able to do it without the risk of the loss of life, injuries or other adverse health effects [44].

INTRODUCTION

Tennis is one of the most popular sports in the world. It is characterised by both complexity and simplicity of tactical solutions. It requires players to be extremely precise in carrying out the outlined tasks, taking into account their psycho-physical predispositions. It is a 'sport of life' (from childhood to old age), with significant social and health benefits. A sport that provides positive emotions (the pleasure of physical activity in a unique atmosphere, the joy of each successful stroke, both for children, amateurs and professionals, etc.). Tennis allows one to test one's technical, tactical, motor and mental abilities in every sequence of the game [1]. The dynamic progress of this sport has to do with improving methods of directing the training process. The variety of plays and the accuracy of the fragments of the game are increasing, and this requires maintaining a focus of attention for long periods of time (despite), which make up the formations and the need to adapt appropriate tactics. Over the last ten years, one sees a significant increase in the speed and power of ball strikes during play by both experienced and novice tennis players. This is the result of improved technical and tactical skills and all-round physical preparation of the tennis players. The course of match action is definitely gaining pace and dynamics, as an offensive, style of play is preferred. Modern competitive tennis is characterised by the ability to play a game-ending stroke from any position on the court. Thus, an adequate level of physical preparation of the players, documented by various manifestations of fitness and coordination abilities, is fundamental. It is the speed, reaction time and technical skills that distinguish the outstanding of the best tennis players [2-8].

Coordinative abilities are related to the functioning of the entire human organism and all its systems. They are the resultant of the interaction of many processes interacting in a variety of mutual multilevel interactions. At the core of these abilities are physical processes particularly based on the properties of the nervous system [9]. Co-ordinating abilities determine the organism's ability to perform precise and accurate movements under constantly changing external conditions (changes in planes, axes and directions of ball strikes, etc.). They represent integrated psychomotor properties predominantly determined by the functions of the central nervous system. The substrate of these abilities is the information coming mainly from the analysers (receptors) and the way information is received, transmitted, stored and processed [10].

According to Raczek et al. [11], the basic co-ordinating abilities that determine a person's motor performance include: the ability of kinesthetic differentiation, spatio-temporal orientation, balance, rhythmisation of movements, rapid motor response, coupling of movements, motor adaptation and high frequency of movements.

Reaction time is defined as the interval between the onset of a signal and the onset of a response to the signal occurring. Many factors determine the length of an athlete's reaction time, but external stimuli have the most direct influence. With regard to motor control, researchers assume that information processing consists of three stages. The first concerns stimulus identification in response to sensory stimuli. After this stage, information is processed to select a response and then transferred to elicit a response until an action (output) occurs. Stimulus sources, such as a flying ball or court lighting, can affect the timing of information processing by the player. The "cost" of time associated with each of these three stages determines the length of the reaction time. For example, hitting a volley from under the net requires a quick reaction, taking into account information related to the speed of the incoming ball and the distance from the opponent (which is less than when the opponents bounce the ball from deep in the court). A sufficiently quick reaction of the tennis player is then crucial, as it allows him/her to think about the correct execution of the appropriate move and the intention of the stroke. In addition, we can distinguish two important components of this manifestation of coordination motor skills. These are the time associated with changes in muscle tension before the onset of the muscular contraction generating the occurrence of the movement, and the motor reaction time.

Researchers considering the electromyograph signal point out that premotor reaction time is related to the process between the occurrence of the signal(s) and the first detected changes in the EMG. Motor reaction time, on the other hand, is the time between the initial increase in muscle activity and the initiation of actual movement. Among the extrinsic factors affecting reaction time, the main ones to consider are the speed of the incoming ball, the distance from the opponent and the intensity of the lighting (related to the decrease in visual acuity and optic nerve fibres; the cut-off point is around 200 lux below which the quality of visual ability decreased by 20%). Among the intrinsic factors, it is primarily synaptic activity [12].

The aim of the study was to knowledge of the relationship between reaction time and special fitness of tennis players aged 10-12 years old.

MATERIAL AND METHODS

Participants

The study included 45 tennis players aged 10-12 years training in clubs in the Podlaskie Voivodeship. Athletes were divided by age categories: 10 years (n = 16); 11 years (n = 15), 12 years (n = 15). The groups of tennis players differed in their level of sporting sophistication. Juvenile tennis players achieving success both at the level of district and provincial competition and at the level of national competition were studied.

Study design

All participants were optimally warmed up before starting the tests.

Reaction time test

The device used was *Blink.Pro Infinity* (abbreviated as Blink) which comprehensively assesses reaction speed linked to eye-hand coordination, spatial orientation, psychomotor speed, perceptual speed and accuracy, attentional capacity, decision-making under time pressure and exhaustion resistance [13].

The test consists of reacting as quickly as possible to sensors lighting up in a random order. The test subject was at a distance of 1 metre from the device at the start of the test. The test, during which the number of sensors touched was counted, lasted 30 seconds. Each test subject performed five trials, with the one with the highest result being considered as the final result. Thirteen sensors were used in the study, one of which (located highest) was excluded from the trial due to the body height of the tennis players.

Special fitness of tennis players test

ITN – *International Tennis Number* [14]

The ITN is recognised as a tool for the accurate assessment of tennis skills also among younger tennis players. The reliability coefficient of the test is 0.982 for players aged 12 years and younger, while its validity is demonstrated by the wide range of ball strokes to be assessed. The ITN is therefore a reliable (practical) tool for assessing the special skills of juvenile tennis players [15].

The test is used to determine the level of tennis skills of individual players worldwide (special fitness). It consists of a scoring assessment of the basic tennis strokes – forehand, backhand, volley and serve – as well as an evaluation of speed and agility abilities on court. The test assesses the accuracy, depth and power of the strokes. Points for accuracy and depth of individual strokes are awarded based on where the ball lands in the court. A player scores power points when his ball makes a second buck between the end line and the bonus line – see glossary '**power area for double points'** – (1 point) or when his ball makes a second buck behind the bonus line (points multiplied by 2). During the stroke assessment tests, the regularity of tennis strokes is also additionally scored (1 point for each stroke that is not erroneous). Players can score a maximum of 430 points.

Before starting each part, the players performed 4 trial strokes. If the ball landed on the line a higher score was always accepted. Scores were recorded in the protocol immediately after each stroke. The balls were played to the player according to the guidelines.

The assessment of tennis strokes consists of four parts (tasks):

1. Evaluation of the depth of strokes from deep in the court: the tennis player, positioned from deep in the court, performs 10 strokes from forehand and backhand (alternately); the depth and power of the strokes are evaluated (an athlete may receive a maximum of 90 points for this task);

2. Evaluation of the accuracy of the strokes from deep in the court: the tennis player, positioned from deep in the court, performs 12 strokes from forehand and backhand (alternately); the first 6 strokes are played along the line, the next 6 along the loft; the accuracy and power of the strokes are evaluated (an athlete may receive a maximum of 84 points for this task);

3. Evaluation of the depth and power of the backhand stroke: the tennis player, positioned in front of the net, performs 8 backhand strokes (alternately forehand and backhand); the depth and power of the strokes are evaluated (an athlete may obtain a maximum of 72 points for this task);

4. Evaluation of service strokes: the athlete performs 12 service strokes; the accuracy and power of the strokes are evaluated (the athlete can receive a maximum of 108 points for this task). The second part of this task is the evaluation of speed and agility skills. The test consists in the fastest possible collection on the racket of 5 balls arranged in a specific way in the 'service court' (a term belonging to the language of tennis specialists); the time of the test in seconds is recorded (an athlete may obtain a maximum of 76 points in this part of the test).

Statistical analysis

Results were analysed, using the statistical package STATISTICA version 7.0 from StatSoft. The estimation of the results is based on the following indicators: mean (M); minimum (Min); Maximum (Max); standard deviation (SD); skewness; kurtosis. The significance test F for the difference of two variances preceded the measurement of the difference in means. The t-test of significance for the difference of two means was used in the case of different variances and equal sample sizes (between 11-year-old and 12-year-old tennis players). Significance test C (Cochron & Cox [16]) in the case of different variances and different numbers (between 11 – and 12-year-old tennis players in relation to ten-year-olds). Pearson's linear correlation r coefficient between the main empirical variables was calculated. Statistical inference was performed with an assumed significance level of $p<0.05$.

RESULTS

It was observed that the mean value of reaction time test (Blink) scores increases with the calendar age of the tennis players. A similar pattern

Table 1. Results of coordination and special fitness tests of juvenile tennis players (n = 46).

Age (years)	Statistical indicators	Blink (number of affected sensors)	ITN (points)
10 (n = 16)	M	**56.565**/**/**	**121.298**/***/**
	SD	5.942	19.236
	Min	48	98
	Max	63	190
	skewness	–0.127	0.59
	kurtosis	0.76	0.29
11 (n = 15)	M	**63.282**^**	**153.497**^^**
	SD	4.189	15.962
	Min	53	111
	Max	65	193
	skewness	0.366	–0.624
	kurtosis	–0.923	–1.33
12 (n = 15)	M	**66.47/**/^**	**174.247/***/^^**
	SD	2.747	13.642
	Min	57	138
	Max	70	214
	skewness	0.82	0.68
	kurtosis	0.34	–0.43

Differences between 10-year-olds and 11-year-olds and /10-year-olds and 12-year-olds/ for the C test: **$p<0.01$; differences between 11-year-olds and 12-year-olds for the t-test: ^$p<0.05$, ^^$p<0.01$.

was found with regard to the results of the special fitness of tennis players (ITN). The differences in the mean values of the results of both tests between each age group are statistically significant (Table 1).

Positive average and high correlation coefficients between reaction time test (Blink) and special fitness of tennis players test (ITN) scores increased with the age of the tennis players tested: 10-year-olds r = 0.358 (average correlation) and positive correlations 11-year-olds r = 0.521, $p<0.05$ and 12-year-olds r = 0.599, $p<0.02$.

DISCUSSION

Information on coordination and conditioning motor skills (general fitness) and special fitness (which, among other things, in tennis is a specific combination of various abilities) is important from the beginning of the participation of exercising individuals in the training process. It is a fundamental element in optimising training, taking into account individual predispositions and gradually expanding movement skills. The next step is the prediction of individual training stages and effects [17-21].

In the process of competitive training of tennis players, as in other disciplines, many tools for diagnosing general and special fitness are available. It is not revealing to say that trainers, guided by methodological knowledge and practical experience, are looking for such a set of tests that take into account the age and sporting sophistication of the practitioners and reflect (to some extent) the diversity of playing situations on the court. The non-cyclic, dynamic movements observed during tournament matches and the frequent changę of their direction are very difficult to reproduce in any one specific test. The control of the dynamics of change and the effectiveness of this type of motor skills, although a very difficult task, should be a key element of adequate tests of special fitness with a coordination skills component. [22, 19, 23, 24].

Recent match analyses of the best tennis players in the world have shown that speed is the motor ability that distinguishes the outstanding among the best tennis players [25]. A very important component of speed is reaction time. The results of a study by Tu et al. [12] showed that reaction times were shorter for faster balls compared to slower ones. This is probably due to the fact that this coordination ability is better stimulated and the intensity of the stimulus. The reaction time of strokes from deep in the court tends to be slightly shorter for forehand strokes, however, these differences are not statistically significant. However, this is individually determined and is related, for example, to the positioning of the legs (e.g. open, semi-open, closed position) or the individual hitting technique [26]. Some tennis players before certain strokes (return, air strokes played from under the net) perform a two-legged jump to improve and accelerate the reaction to the stimulus. In order to accelerate the movement in the intended direction, the centre of pressure when landing must be positioned on the side opposite the direction of the intended movement. It is estimated that, in order to perform a quick and sure side step, a tennis player should land a jump approximately 180 ms after the visual stimulus (which corresponds to the player's reaction time) [12].

With regard to younger tennis students, researchers from Beijing Sport University proved that training experience was related to reaction time. Children between the ages of 8 and 12 had the shorter reaction time the more experience they had and the more / more intensively they trained. Tennis training from an early age improves decision-making skills and reduces reaction time [27].

These views are reflected in our study. It was found that the results of the tests assessing reaction speed (*simple reaction test and complex reaction test*), correlate with the results of the test assessing special fitness in all age groups studied. The criterion for the tennis player's special fitness in this case was the *International Tennis Number* score. Against the background of the available research results using this test, the juvenile tennis players participating in my study scored slightly higher. In a study by Olcucu and Vatansever [28], 8-10-year-old tennis players affiliated with the Turkish tennis federation obtained an average score of 82 points while in my study 10-year-olds obtained an average score of 140 points (and the minimum score was 98 points). Moreover, in a study by Jian and Iringan [29] involving 30 young tennis players aged 7-10 years, the ITN test results were slightly lower compared to my study (average score of 100 points). The authors of these studies also analysed the relationship between reaction time and ITN test scores. The results are consistent with my observations. The researchers showed that reaction time scores are strongly correlated with ITN scores. The researchers showed that reaction time scores were strongly correlated with ITN scores. As in my study, shorter reaction times were associated with higher tennis skill levels. Similar ITN test results were obtained by Arslan and Ergin [30] analysing the effects of 8-week core training (see glossary) on agility, strength and tennis skills. Tennis players aged 10-14 from the experimental group (participating in an 8-week core training combined with tennis training) scored an average of 140 points before the intervention was applied, while after the training programme their results oscillated around 173 points. In contrast, the control group (tennis players of the same age) participating only in traditional tennis training had an average score of 91 points before the experiment and 105 points after the 8-week period. The results of the tennis players included in my study averaged: 141 points 10-year-olds; 153 points 11-year-olds; 174 points 12-year-olds. The group of tennis players (aged 10-14 years) studied by Arslan and Ergin [30] also included slightly older athletes compared to my study.

As tennis is one of the games characterised by one of the highest coordinative complexity of movements, specific actions (special technique) during training and game play requirę high accuracy and speed of execution under variable court conditions [31, 32, 4] The above analysis of our own research indicates that the tests used can be used to assess current physical fitness and sporting effects and, in a sense, to evaluate the prospective capabilities of the practitioners.

In this thesis, I have not used the word 'development', in any of the contexts concerning the diagnosis and extension of the coordination abilities (special fitness) of adolescent tennis players. The ground-breaking findings of Kalina et al. [33] provide evidence that the paradigm of 'toddlerhood and pre-school motor development' should be replaced with 'the first period of positive and negative changes in human motor skills already at toddlerhood and pre-school age'. If the hypothesis that 'the discovery of an organic cause of the extreme degree of SFI already among toddlerhood and preschool children is at the same time the establishment of a highly probable common source of many neuro-degenerative diseases and disabilities' tennis, due to its coordination qualities, may in future play an important role in prevention and therapy. For the new applied science, 'innovative agonology' (acronym INNOAGON see glossary), 'development' is a key word and used only in positive connotations [34, 35]. It would be ludicrous to talk at the same time about 'development of special skills in tennis' and 'development of specific 'neurodegenerative diseases'. Not only in a logical sense, but above all in a humanistic (ethical) dimension, the sentence: 'the development of special fitness in tennis' has proven to be an effective means of therapy despite 'progressive neuro-degenerative diseases' [36, 37]. Treating tennis and any other sport exclusively from the perspective of supreme success, fame, material gain, but also tying scientific reports to such a perspective, contradicts the social mission of science [38].

CONCLUSIONS

The results of the study provide evidence that the training of juvenile tennis players influences not only the increase of their special fitness, but also the speed (effectiveness) of their motor response to stimuli simulated in laboratory conditions. The increasing interdependence of the indices of both variables (special fitness and reaction time to external stimuli) with age indicates that stimulating the natural process of biological growth of the organism at this stage of ontogenesis with specific tennis exercises has a positive effect on this component of coordination ability (motor reaction time), which is related to human motor safety in the general sense (health and survival).

REFERENCES

1. Pluim BM, Miller S, Dines D et al. Sport science and medicine in tennis. Br J Sports Med 2007; 41(11): 703-704
2. Kovacs MS. Tennis physiology: training the competitive athlete. Sports Med 2007; 37(3): 189-198
3. Królak A. Technika współczesnego tenisa. Warszawa: Estrella; 2012 [in Polish]
4. Żurek P. Somatyczne, kondycyjne i koordynacyjne uwarunkowania sprawności specjalnej tenisistów na etapie treningu ukierunkowanego. Poznań: Akademia Wychowania Fizycznego imienia Eugeniusza Piaseckiego; 2013 [in Polish]
5. Bane MK, Reid M, Morgan S. Has player development in men's tennis really changed? An historical rankings perspective. J Sports Sci 2014; 32(15): 1477-1484
6. Söğüt M. Gross motor coordination in junior tennis players. J Sports Sci 2016; 34(22): 2149-2152

7. Kolman NS, Kramer T, Elferink-Gemser MT et al. Technical and tactical skills related to performance levels in tennis: A systematic review. J Sports Sci 2019; 37(1): 108-121

8. Tubez F, Schwartz C, Croisier JL et al. Evolution of the trophy position along the tennis serve player's development. Sports Biomech 2021: 20(4): 431-443

9. Osiński W. Antropomotoryka. Poznań: Akademia Wychowania Fizycznego imienia Eugeniusza Piaseckiego; 2003 [in Polish]

10. Fugiel J, Czajka K, Posłuszny P et al. Motoryczność człowieka: podstawowe zagadnienia z antropomotoryki. Wrocław: MedPharm Polska; 2017 [in Polish]

11. Raczek J, Mynarski W, Ljach W. Kształtownie i diagnozowanie koordynacyjnych zdolności motorycznych: podręcznik dla nauczycieli, trenerów i studentów. Katowice: Wydawnictwo Akademii Wychowania Fizycznego; 2003 [in Polish]

12. Tu J-H, Lin Y-F, Chin S-C. The influence of ball velocity and court illumination on reaction time for tennis volley. J Sports Sci Med 2010; 9(1): 56-61

13. https://www.blink.pro/en/infinity (accessed 2023 Feb 03)

14. International Tennis Federation. International Tennis Number — Testing Procedure 2004 [accessed 2023 Feb 03]. Available from: URL:https://sonc.net/wp-content/uploads/2018/08/ITN-Assesment-Guide-levels-4-and-5.pdf

15. Ngatman N, Guntur G, Broto DP. Test of Validity, Reliability and Relevance of The "ITN 10.3 ITF Test" on The Level of Basic Technical Ability in Forehand and Backhand Groundstrokes For Tennis Players Aged 12 Years and Under. In: Prasetyo Y, Siswantoyo, Nopembri S, Arovah NI, Gaus N, Elumalai G, Choeibuakaew W, editors. Proceedings of the 6th Yogyakarta International Seminar on Health, Physical Education, and Sports Science (YISHPESS 2023); 2023 Sep 16; Yogyakarta, Indonesia. Advances in Health Sciences Research, Vol. 73. Dordrecht: Atlantis Press; 2013: 48-58

16. Cochran WG, Cox GM. Experimental Designs. 2nd ed. New York: John Wiley & Sons; 1992

17. Ljach W, Mynarski W, Raczek J. Biopsychiczne predyspozycje koordynacyjnych zdolności motorycznych – przegląd badań w piśmiennictwie rosyjskojęzycznym. Antropomotoryka 1995; 12-13: 83-106 [in Polish]

18. Płatonow WN. General theory of training athletes in Olympic sports. Kyiv: Olympic literature; 1997 [in Russian]

19. Sozański H. Podstawy teorii treningu sportowego. Warszawa: Centralny Ośrodek Sportu; 1999 [in Polish]

20. Kochanowicz K, Zaporożanow W. Podstawowe wskaźniki oceny poziomu specjalnego przygotowania gimnastyczek w wieku 10-17 lat. In: Kuder A, Perkowski K, Śledziewski D, editors. Proces doskonalenia treningu i walki sportowej. Vol 1. Warszawa: Akademia Wychowania Fizycznego; 2004: 146-149 [in Polish]

21. Kochanowicz K, Waldziński T. Sprawność specjalna tenisistów w wieku 8-10 lat w Uczniowskim Klubie Sportowym „Return" Łomża. Rocz Nauk AWFiS Gda 2011: 52-69 [in Polish]

22. Arnot RB, Gaines CL. Sport selection. New York: Viking Press; 1984

23. Królak A. Praca nóg, szybkość, balans i precyzja. Tenis 2005; 3(81): 53-54 [in Polish]

24. Kochanowicz K. Podstawy kierowania procesem szkolenia sportowego w gimnastyce. Gdańsk: Akademia Wychowania Fizycznego i Sportu; 2006 [in Polish]

25. Ziemann E. Fizjologiczna kontrola efektów treningu tenisisty. Sport Wyczynowy 2008; 7/9: 95-104 [in Polish]

26. Starosta W. Globalna i lokalna koordynacja ruchowa w wychowaniu fizycznym i w sporcie. Warszawa: Międzynarodowe Stowarzyszenie Motoryki Sportowej; 2006 [in Polish]

27. Uzu R, Shinya M, Oda S. A split-step shortens the time to perform a choice reaction step-and-reach movement in a simulated tennis task. J Sports Sci 2009; 27(12): 1233-1240

28. Olcucu B, Vatansever S. Correlation Between Physical Fitness and International Tennis Number (ITN) Levels Among Children Tennis Players. Anthropologist 2015; 21(1-2): 137-142

29. Jian H, Iringan EM. Predictive validity of reaction time and attention distribution ability on children's tennis skills development. Glow (St. Paul University Philippines) 2024; 3: 90-106

30. Arslan E, Ergin E. The Effect of Core Training on Agility, Strength Performance and Tennis Skills on 10-14 Year Old Tennis Players. Mediterr J Sport Sci 2022; 5(4): 834-843

31. König D, Huonker M, Schmid A et al. Cardiovascular, metabolic, and hormonal parameters in professional tennis players. Med Sci Sports Exerc 2001; 33(4): 654-658

32. Perkins RH, Davis D. Musculoskeletal injuries in tennis. Phys Med Rehabil Clin N Am 2006; 17(3): 609-631

33. Kalina RM, Dłubacz N, Zachwieja J et al. Innovative method of diagnosing the susceptibility to the body injuries during the fall of children from 2 to 6 years. Arch Budo Sci Martial Art Extreme Sport 2022; 18: 211-228

34. Kalina RM. Language and methods of innovative agonology as a guide in interdisciplinary research on interpersonal relationships and people with the environment – from micro to macro scale. Arch Budo 2020; 16: 271-280

35. Kalina RM, Bagińska J. Language of Innovative Agonology: A Guide in Combining Micro and Macro Scales of Preventive, Therapeutic and Defensive Actions. Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023); 2023 Jul 20-24; San Francisco, USA. Healthcare and Medical Devices 2023; 79: 307-315

36. Kalina RM. Complementary Medicine – An Example of the Application of the Basic Research Method of Innovative Agonology. Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023); 2023 Jul 20-24; San Francisco, USA. Healthcare and Medical Devices 2023; 79: 316-324

37. Waszkiewicz E. Multidimensional Educational Models Recommended by Innovative Agonology – Examples of Physical Education and Music Education. Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023); 2023 Jul 20-24; San Francisco, USA. Healthcare and Medical Devices 2023; 79: 290-298

38. Kalina RM. Methodology of complementary research as the basis for integrating science in fulfilling its social mission in the future. Arch Budo 2023; 19: 77-82

39. Gąsienica Walczak B, Kalina RM. Validation of the new version of "the susceptibility test to the body injuries during the fall" (STBIDF-M). Arch Budo 2021; 17: 371-400

40. Kalina RM. Innovative Agonology – Its Definition, Detailed Theories, General Rule of Struggle, and Laws. Proceedings of the 14th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE 2023); 2023 Jul 20-24; San Francisco, USA. Healthcare and Medical Devices 2023; 79: 272-279

41. Kalina RM, Kruszewski A. INNOAGON is an acronym for 'innovative agonology', but is not synonymous with 'science of martial arts'. Arch Budo 2023; 19: 193-204

42. Bushman B, editor. American College of Sports Medicine. Complete Guide to Fitness & Health. 2nd ed. Champaign: Human Kinetics; 2017

43. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

44. Kalina RM, Barczyński BJ. EKO-AGRO-FITNESS© original author's continuous program of health-oriented and ecological education in the family, among friends or individually implemented – the premises and assumptions. Arch Budo 2010; 6(4): 178-184

Cite this article as: Waldziński T. Reaction time and special fitness of tennis players aged 10-12 years. Arch Budo Sci Martial Art Extreme Sport 2023; 19: 179-185