Health, Sports & Rehabilitation Medicine
Vol. 25, no. 3, July-September 2024, 126–131

ORIGINAL STUDIES

Reaction time in female football players: an analysis of lower limb response speed to auditory and visual stimuli across positional roles

Elena-Andreea Trandafirescu[1], Mihai Ilie[2], Vladimir Potop[1,2,3]
[1] *Doctoral School of Sport Science and Physical Education, National University of Science and Technology Politehnica Bucharest, University Center Pitești, Romania*
[2] *Department of Physical Education and Sport, National University of Science and Technology Politehnica Bucharest, University Center Pitești, Romania*
[3] *State University of Physical Education and Sport, Chișinău, Republic of Moldova*

Abstract

Background. In women's soccer, performance may be influenced by factors such as auditory and visual abilities, which can be crucial for decision-making, ball tracking, and responding to opponents' movements on the field.

Aims. This study aimed to explore the response speed to acoustic and visual stimuli among female soccer players across various playing roles.

Methods. The research involved 49 female soccer players, including goalkeepers, defenders, strikers, and midfielders, with a mean age of 13.73 years. The Reaction Test from the OptoJump Next system was used to assess participants' reaction times.

Results. The data analysis reveals that female soccer players exhibit a generally more rapid response to visual stimuli in comparison to acoustic stimuli. Furthermore, reaction times are marginally superior when utilizing the right foot as opposed to the left foot. Additionally, the analysis underscores that playing position exerts a significant influence on reaction times, whereas stimulus type and leg preference do not. Notably, the effect of playing position on reaction times is consistently observed across various stimulus types.

Conclusions. The study reveals that female soccer players, with a mean age of 13.73 years, show differences in their visual performance and acoustic reaction time, with a faster visual reaction in the right foot. These findings could inform decision-making within football organizations, potentially aiding in the development of targeted player profiles for women's soccer.

Keywords: Women's Soccer, Female Football, Response Time, Visual Stimuli, Auditory Stimuli, Lower Limb

Introduction

In 2024, women football players appear more focused on achieving immediate success, showing a stronger determination to reach their goals. They are also increasingly willing to engage in research to gain insights that can help them advance on the field and it is important that training strategies also evolve to reflect the increased demands. Reaction time is a crucial element of athletic performance and is integral to the success of soccer players. It involves the capacity to swiftly and accurately respond to various stimuli, which can profoundly influence game outcomes. Reaction time serves as a key mechanism for psychologists to examine perception-action processes, contributing to the growing body of research on perception-action dynamics in sports performance (Carmichael, 2023).

Visual reactions involve how quickly and accurately a person responds to visual stimuli, such as changes in light, movement, or color. These reactions are influenced by the speed at which the brain processes visual information and triggers a motor response. Acoustic reactions pertain to the brain's response to auditory stimuli, such as sounds or spoken words. This process includes detecting sounds through the auditory system and generating an appropriate response. Acoustic reaction times are generally faster than visual reaction times due to the more direct neural pathways involved in auditory processing. Both types of reactions are studied in the context of cognitive and perceptual processes, motor response, attention, and neurological health. A review of the literature on the

Received: 2024, August 20; *Accepted for publication:* 2024, August 28
Address for correspondence: National University of Science and Technology Politehnica Bucharest, Pitesti University Center, Aleea Scolii Normale No. 7 (former Gheorghe Doja no. 41), Pitesti, Romania
E-mail: vladimir_potop@yahoo.com
Corresponding author: Vladimir Potop; vladimir_potop@yahoo.com
https://doi.org/10.26659/pm3.2024.25.3.126

perceptual processes involved in executing complex movements reveals a predominant focus on the visual domain, with relatively few studies examining the auditory domain (Agostini et al., 2020).

In soccer, where rapid decision-making and movements can decisively affect the result, a thorough understanding and optimization of reaction time may offer a significant competitive advantage. Reaction time can be categorized into three key components: perception Time or the duration to detect and interpret a stimulus, decision time or the period to decide on a response, and motor time or the time needed to execute the response (Magill 1998, quoted by Senel & Eroglu, 2006). The integration of congruent visual and auditory information (bimodal integration) leads to more accurate decision-making in sports compared to relying solely on visual or auditory information (Klatt & Smeeton, 2020).

The evidence increasingly supports that high-skilled performers have a clear advantage over their low-skilled counterparts in utilizing kinematic information to interpret deceptive intent (Jackson et al., 2018). Also, the literature suggests that age significantly impacts the perceptual-cognitive abilities of skilled soccer players, and that these abilities vary by playing position. In practice, visual and auditory stimuli should be directly tied to soccer-specific actions like dribbling, passing, and running (Schumacheret al., 2018; Abdurrahman, 2017). Coaches and practitioners should consider this informations and adjust training sessions to address the specific needs of women soccer players (Datson & Okholm, 2022). This article contributes to the broader effort of profiling female football players based on their positional roles, serving as a key piece in understanding position-specific characteristics.

Hypothesis

Null hypothesis

There is no significant difference in reaction times based on the playing position of female soccer players. There is no significant difference in reaction times between different types of stimuli (acoustic vs. visual) or legs (left vs. right). There is no significant interaction between playing position and the type of stimulus (acoustic or visual) in relation to reaction times.

Alternative hypothesis

There is a significant difference in reaction times based on the playing position of female soccer players. There are significant differences in reaction times between different types of stimuli (acoustic vs. visual) and between left and right legs. There is a significant interaction between playing position and the type of stimulus (acoustic or visual) in relation to reaction times.

Material and methods

Research protocol

The OptoJump Next system used to measure reaction time is the property of the Human Performance Research Center, Department of Physical Education and Sports, National University of Science and Technology Politehnica Bucharest, University Center of Pitești, Romania (1); (2).

a) Period and place of the research

The research was conducted between April 30 and May 6, 2024, at Human Performance Research Center of the Department of Physical Education and Sports within the National University of Science and Technology Politehnica Bucharest, University Center of Pitești, Romania

b) Subjects and groups

A group of 49 female football players (N=49) participated in this study (mean age = 13.73 years, mean height = 160.43cm, foot sole mean length = 24.19 cm, mean weight = 51.39 kg, and mean BMI = 19.85 kg/m²). The participants were drawn from the women's football teams of ACS Champions Football Club FC Argeș in Argeș County, Romania. Parental consent was secured prior to initiating the research, in line with the Declaration of Helsinki. Additionally, approval was obtained from the coaches and club management before the study commenced. The research was approved by the Ethics Committee of the Doctoral School of Physical Education and Sport Science (ID: 16 /22.07.2024), National University of Science and Technology Politehnica Bucharest, University Center Pitești, Pitești, 110254 Romania.

c) Applied tests

Testing was conducted in a controlled environment at approximately the same time each day to minimize potential performance discrepancies. The OptoJump system was employed to assess and collect data on participants' reaction times. In this regard, the Reaction Time (RT) Test was used for the left (L) and right (R) foot, recording the reaction time (TReac.) in seconds. This test measures the time interval between an optical or acoustic impulse and the participant's movement. The communication bars were placed on the floor, with each player positioning one leg between the OptoJump sensor bars while keeping the other leg outside. Participants were exposed to two types of stimuli to measure their reaction times: visual and acoustic. For the visual stimulus, a red circle on the PC screen turned green after a random interval, prompting the athlete to raise their leg as soon as the color change occurred. For the acoustic stimulus, a sound was emitted by the PC's internal soundboard after a random interval, requiring the athlete to react promptly. Each stimulus type had 2 repetitions per leg.

d) Statistical processing

The collected data were tabulated, and the shortest reaction time, in seconds (s), from the two recorded trials was kept to be analyzed. Statistical analyses - including Descriptive Statistics, Levene Test, ANOVA, Bonferroni Post-hoc Test, and Cronbach's Alpha - were computed using DATAtab statistics software. Statistical significance was set at $p < 0.05$.

Results

The descriptive statistics provided a detailed breakdown of the mean scores, categorized by player position (Table I).

Strikers exhibit identical reaction times (0.92 s) for both legs in acoustic tests, indicating a balanced and consistent auditory reaction capability. However, their reaction times suggest there may be room for improvement, as they do not show the fastest responses in this category compared to other positions. In visual tests, Strikers also display equal performance (0.50 s) between their left and right legs. While their visual reaction times are not the fastest, they are consistent, suggesting a stable visual response but also indicating potential for improvement.

Midfielders show slightly better acoustic reaction times with their left leg (0.90 s) compared to their right leg (0.92 s). This small difference indicates a minor asymmetry but overall suggests relatively fast auditory responses, especially with the left leg. In visual tests, Midfielders display a notable difference between legs, with the right leg reacting significantly faster (0.50 s) than the left (0.66 s). This suggests a potential dominance of the right leg in visual processing, which could be attributed to specific training or a natural predisposition**.**

Defenders exhibit identical reaction times for both legs (0.96 s) in acoustic tests, similar to Strikers. However, their reaction times are slightly longer, suggesting that while their auditory reactions are consistent, they are slower compared to other positions, particularly Goalkeepers and Midfielders. In visual tests, Defenders perform almost equally with both legs, with the left leg being marginally faster (0.47 s). Their visual reaction times are competitive, though not the fastest, indicating reliable but not superior visual processing speed.

Goalkeepers demonstrate the best acoustic reaction times among all positions, with the left leg (0.83 s) slightly outperforming the right (0.84 s). This suggests that Goalkeepers may possess highly developed auditory processing skills, likely due to the demands of their role, which require rapid responses to auditory cues. In visual tests, Goalkeepers also excel, particularly with their left leg (0.41 s), showing the fastest reaction time overall. The significant difference between legs indicates strong left-leg dominance in visual processing, which could be crucial for their performance, as quick visual reactions are essential for effectively stopping shots aimed at their goal.

Table II shows the results of Levene's test for equality of variances. The test is used to assess whether two or more groups have equal variances. A test statistic (F) of 1.97 was obtained, with degrees of freedom 15 and 180. A p-value threshold of 0.05 was used to determine statistical significance.

Table II

Levene Test of variance equality.

Test	F	df1	df2	p
Levene's Test (Mean)	1.97	15	180	.02

The p-value of .02, which is less than the conventional alpha level of 0.05, suggests that there was statistically significant evidence to reject the null hypothesis of equal variances. This means that the variances of the groups are likely different. After Levene Test was conducted, a two-way ANOVA was performed (Table III).

Playing Position: The p-value was .73, indicating no significant difference in reaction times based on the playing position. The null hypothesis regarding playing position is supported, as there is no significant effect of playing position on reaction times.

Stimulus Type and Leg: The p-value was less than .001, showing a significant difference in reaction times between different types of stimuli (acoustic vs. visual) and between left and right legs. This supports the alternative hypothesis that there are significant differences related to stimulus type and leg.

Interaction: The p-value was .815, indicating no significant interaction between playing position and the type of stimulus (acoustic or visual) with regard to reaction times. The null hypothesis regarding the interaction effect is supported, as there is no significant combined effect of playing position and stimulus type on reaction times.

The ANOVA outcome support the null hypothesis for playing position and the interaction between playing position and stimulus type, showing no significant effects. However, the ANOVA results support the alternative hypothesis regarding differences in reaction times based on stimulus type and leg, indicating that reaction times vary significantly with the type of stimulus and between left and right legs.

Table I

OptoJump Reaction Test Descriptive Statistics.

Stimulus type Time reaction [s] / LEG	Player position	%	Mean	Std. Deviation	Variance	95% Confidence interval for mean
ACOUSTIC [s] LEFT LEG	Defender	42.86%	0.96	0.15	0.02	0.89 - 1.03
	Midfielder	36.73%	0.9	0.14	0.02	0.83 - 0.96
	Striker	14.29%	0.92	0.21	0.05	0.73 - 1.12
	Goalkeeper	6.12%	0.83	0.02	0	0.77 - 0.88
ACOUSTIC [s] RIGHT LEG	Defender	42.86%	0.96	0.15	0.02	0.89 - 1.03
	Midfielder	36.73%	0.92	0.14	0.02	0.85 - 0.99
	Striker	14.29%	0.92	0.13	0.02	0.8 - 1.04
	Goalkeeper	6.12%	0.84	0.03	0	0.77 - 0.91
VISUAL [s] LEFT LEG	Defender	42.86%	0.47	0.05	0	0.45 - 0.49
	Midfielder	36.73%	0.66	0.86	0.74	0.23 - 1.08
	Striker	14.29%	0.5	0.09	0.01	0.42 - 0.59
	Goalkeeper	6.12%	0.41	0.03	0	0.33 - 0.49
VISUAL [s] RIGHT LEG	Defender	42.86%	0.48	0.07	0.01	0.45 - 0.52
	Midfielder	36.73%	0.5	0.07	0	0.46 - 0.53
	Striker	14.29%	0.5	0.05	0	0.46 - 0.55
	Goalkeeper	6.12%	0.5	0.08	0.01	0.29 - 0.71

Table III
Two-Way ANOVA.

Factors	Type III Sum of Squares	df	Mean Square	F	p	η^2_p
Player position	0.11	3	0.04	0.43	.73	0.01
ACOUSTIC [s] LEFT LEG, ACOUSTIC [s] RIGHT LEG, VISUAL [s] LEFT LEG, VISUAL [s] RIGHT LEG	8.35	3	2.78	33.8	<.001	0.36
Player position x ACOUSTIC [s] LEFT LEG, ACOUSTIC [s] RIGHT LEG, VISUAL [s] LEFT LEG, VISUAL [s] RIGHT LEG	0.43	9	0.05	0.58	.815	0.03

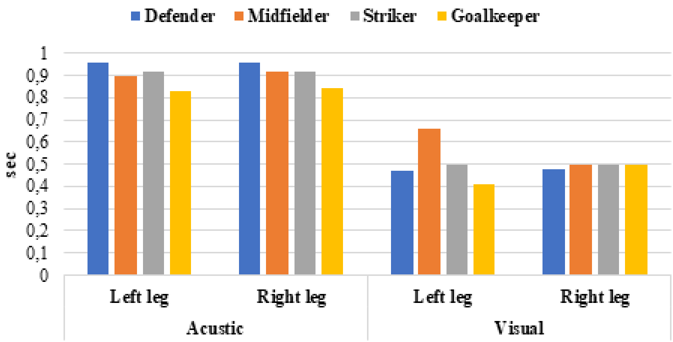

Fig. 1 – OptoJump Reaction Test by Player Position (lower limb acoustic and visual reaction test).

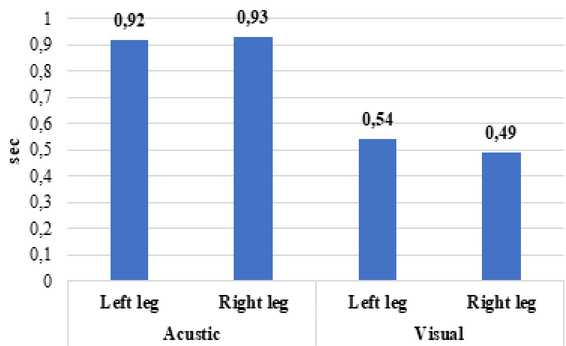

Fig. 2 – Average Reaction Time by Stimulus Type.

Table IV shows the results of Bonferroni post-hoc tests comparing different positional roles (Striker, Midfielder, Defender, Goalkeeper).

Table IV
Bonferroni Post-hoc-Tests - Positional role.

Player position		Mean Difference	SE	t	p
Striker	Midfielder	-0.03	0.064	-0.44	1
Striker	Defender	0	0.063	-0.06	1
Striker	Goalkeeper	0.07	0.099	0.71	1
Midfielder	Defender	0.02	0.046	0.52	1
Midfielder	Goalkeeper	0.1	0.089	1.11	1
Defender	Goalkeeper	0.07	0.089	0.84	1

In this analysis, all p-values were 1, meaning that after applying the Bonferroni correction, none of the pairwise comparisons between the positional roles (Striker, Midfielder, Defender, Goalkeeper) are statistically significant. This suggests that there were no meaningful differences between these groups in the measured variable. The mean differences were consistently small and close to zero, reinforcing the notion that the positional roles do not vary substantially from one another. Additionally, the t-values, which ranged from -0.44 to 1.11, were quite small, indicating that the differences observed were minimal relative to the variability in the data. This further confirms the lack of significant differences between the positional roles.

A bar chart (Fig. 1) was created to visual represent the results of acoustic and visual reaction time tests for the lower limbs of football players, categorized by their positions on the field: Strikers, Midfielders, Defenders, and Goalkeepers. Since shorter reaction times indicate better performance, these results provide insight into the strengths and weaknesses of each position.

The Cronbach's Alpha for our set of data was 0.68. Generally, an Alpha above 0.7 is considered acceptable, above 0.8 is good, and above 0.9 is excellent. Therefore, a value of 0.68 indicated that the items were somewhat consistent in measuring the same underlying concept but not to an ideal extent.

Discussion

In soccer, where every second matters, players' visual and acoustic reactions are continuously pushed to their limits. The practical significance of understanding these reactions lies in their real-world impact: by optimizing both visual and auditory response times, players can enhance their performance and make more effective decisions on the field.

Although the Bonferroni post-hoc tests did not reveal statistically significant differences, the descriptive statistics suggest meaningful patterns in reaction times across positions. The data suggests that *Goalkeepers* exhibit the fastest reaction times overall, particularly in both acoustic and visual tests, indicating their critical role in quickly responding to stimuli. *Midfielders* also perform well, especially with their right leg in visual tests, though they show a slight lag in acoustic reaction times. *Strikers* and *Defenders* have consistent reaction times across both legs, but their times are slower compared to those of *Goalkeepers* and *Midfielders*, indicating potential areas for improvement in their sensory response capabilities. The differences between left and right leg reaction times are most pronounced in *Midfielders* and *Goalkeepers*.

When analyzing the differences between left and right leg reaction time score across player positions, it becomes evident that the *right leg* is the dominant leg. This is suggested by the slightly faster reaction times for the right leg in both acoustic and visual. In a practical way, most players exhibit relatively balanced bilateral responses, with minor asymmetries that might be position-specific. *Strikers* and *Defenders* have highly symmetrical reaction times, showing no difference between their left and right legs in both acoustic and visual tests. This suggests well-balanced reaction capabilities. *Midfielders* and *Goalkeepers* exhibit slight but potentially meaningful differences, particularly in visual tests, where *Midfielders'* right leg and *Goalkeepers'* left leg perform better. These asymmetries may reflect either specialized training or natural lateral dominance that enhances performance in one leg over the other. The data suggest that while most players exhibit balanced reaction times, specific positions could develop slight lateral differences due to the demands of their roles. Additionally, the results indicate that reaction times might be lower when standing on the non-dominant foot (Flôres et al., 2023).

Also, in our findings there seem to be notable differences between the acoustic and visual reaction times (Fig. 2) for both the right and left legs. Specifically, the mean visual reaction times for the left leg (Mean = 0.54 s) and the right leg (Mean = 0.49 s) were lower than the mean acoustic reaction times for the left leg (Mean = 0.92 s) and the right leg (Mean = 0.93 s).

The practical implication of these findings suggests that the female soccer players who participated in this study respond more quickly to visual stimuli than to acoustic stimuli, regardless of which leg is used. This finding appears to contradict much of the previous research, which suggests that auditory reaction times are generally faster than visual reaction times, likely due to the more direct neural pathways involved in auditory processing (Arafat et al., 2022; Rahman & Shahidul Islam, 2021; Sors et al., 20 17; Jain et al., 2015; Ghuntla et al. , 2014), and align with other research indicating that while traditional coaching often relies on verbal commands and auditory stimuli, visual stimuli, such as gestures and signals, may enhance awareness and improve performance in soccer players (Verleger, 1997 quoted by Song et al., 2019; Solanki et al,, 2012; Pesce et al., 2007, quoted by Spierer et al., 2011; Şenel & Eroğlu, 2006). Some authors suggest that auditory reaction time may hold less significance in soccer, as the sport primarily relies on visual cues (Ruschel et al., 2011).

In summary, playing position significantly influences reaction times, but the type of stimulus and the leg used do not show significant differences in their effect on reaction times, and there's no significant interaction between playing position and stimulus type. While the results suggest a current advantage in visual cue processing, optimizing both sensory modalities could be important for enhancing overall performance. Improved auditory reaction times might be particularly beneficial in situations where visual information is limited or delayed, such as in crowded situations or during rapid changes in play. The findings offer practical insights that coaches and players can use to improve specific reaction skills based on positional role.

It is important to acknowledge the potential limitations of the study. The small sample size limits the generalizability of the statistical results to a broader population. Additionally, it is important to highlight that the sample sizes for strikers and goalkeepers were significantly smaller than those for defenders and midfielders. Moreover, the limitations of the software employed in this study, as identified by its creators, should be acknowledged. Future research should consider increasing the number of repetitions per test, expanding the sample for each position, and including a more diverse age range of participants to provide more robust conclusions. The findings in this report can serve as a new puzzle piece for decision-making institutions in football in creating targeted profiles of female football players.

Conclusions

1. The null hypothesis is rejected regarding the effect of playing position on reaction times: This means that there's sufficient evidence to suggest that playing position does affect reaction times. In other words, players in different positions have different reaction times, which supports the alternative hypothesis that playing position has an impact.
2. The null hypothesis regarding differences between stimuli types (acoustic vs. visual) or legs (left vs. right)

cannot be rejected. This implies that the evidence provided doesn't show a significant difference in reaction times based on the type of stimulus (acoustic versus visual) or the leg used (left versus right). The data doesn't provide strong enough evidence to conclude that these factors have a meaningful effect on reaction times.

3. The null hypothesis regarding the interaction between playing position and the type of stimulus is accepted. This suggests that there is no significant interaction between playing position and the type of stimulus. In practical terms, it means that the effect of playing position on reaction times is consistent regardless of whether the stimulus is acoustic or visual; there's no combined effect of playing position and stimulus type that affects reaction times differently.

4. Female soccer players involved in this study generally respond more rapidly to visual stimuli than to auditory stimuli.

5. Reaction times are slightly faster when using the right foot compared to the left foot.

Conflict of interests

The authors declare no conflict of interest.

Acknowledgement

This paper is part of the doctoral thesis of the first author, completed at the Doctoral School of Physical Education and Sports Sciences at the National University of Science and Technology Politehnica Bucharest, University Centre Pitești. We extend our gratitude to ACS Champions Football Club FC Argeș Romania and to the women soccer players who participated in this research.

References

Abdurrahman A, Orhan Kuzu, Emel Çetin. Analysis Of Attention, Eye-Hand Coordination And Reaction Time Of Young Soccer Players. Eur Proceed. Soc Behav Sci. Int Conf Sport Educ Psychol, 2017. DOI: https://doi.org/10.15405/epsbs.2017.06.2.

Agostini T, Sors F, Mingolo S, Baldassi G, Murgia M. Perception and Action in Complex Movements: The Emerging Relevance of Auditory Information. Gestalt Theory. 2020;42(3):243-252). DOI:10.2478/gth-2020-0021.

Arafat Y, Abedin J, Rickta J, Johora Mukta F, Islam R. Comparison of reaction time ability for different forms of stimuli among various athletes. Saudi J Sports Med. 2022;22(3):113. Medknow. DOI: https://doi.org/10.4103/sjsm.sjsm_19_22.

Carmichael AL. The Athlete Advantage: The impact of sport participation on auditory and visual reaction times. Honors Thesis. Pub. Butler University, Indianapolis. 2023,1-47. Available at: https://digitalcommons.butler.edu/ugtheses/669.

Datson N, Okholm KOK. Performance considerations in women's football. Targeted Topic 25 - Sports Science in Football. Aspetar-Sports Med J. 2022;11:36-41. Available at: https://journal.aspetar.com/en/archive/volume-11-targeted-topic-sports-science-in-football/performance-considerations-in-womens-football.

Flôres FS, Lourenço J, Phan L, Jacobs S, Willig RM, Marconcin PEP, Casanova N, Soares D, Clemente FM, Silva AF. Evaluation of Reaction Time during the One-Leg Balance Activity in Young Soccer Players: A Pilot Study. Children. 2023;10(4):743. doi: 10.3390/children10040743.

Ghuntla T, Mehta H, Gokhale P, Shah C. A comparison and importance of auditory and visual reaction time in basketball players. Saudi J Sports Med. 2014;14(1):35-38. doi: 10.4103/1319-6308.131616

Jackson R C, Barton H, Ashford K J, Abernet B. Stepovers and Signal Detection: Response Sensitivity and Bias in the Differentiation of Genuine and Deceptive Football Actions. Front Psychol. 2018;9:2043. doi: 10.3389/fpsyg.2018.02043.

Jain A, Bansal R, Kumar A, Singh K. A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. In International Journal of Applied and Basic Medical Research 2015;5(2):124-127. Int J Appl Basic Med Res. doi: 10.4103/2229-516X.157168.

Klatt S, Smeeton N J. Visual and Auditory Information During Decision Making in Sport. J Sport Exer Psychol. 2020;42(1):15-25. Human Kinetics. DOI: https://doi.org/10.1123/jsep.2019-0107.

Rahman H, & Shahidul Islam. Investigation of Audio-Visual Simple Reaction Time of University Athletes and Non-Athletes. J Adv Sports Phys Educ 2021;4(3):24-29. DOI:10.36348/jaspe.2021.v04i03.002.

Ruschel C, Haupenthal A, Hubert M, Fontana HB, Pereira SM, Roesler H. Tempo de reação simples de jogadores de futebol de diferentes categorias e posições. Motricidade, 2011;7(4):73-82. DOI:10.6063/motricidade.7(4).90.

Schumacher N, Schmidt M, Wellmann K, Braumann K-M. General perceptual-cognitive abilities: Age and position in soccer. PLOS ONE 2018;13(8):e0202627). Public Library of Science (PLoS). doi: 10.1371/journal.pone.0202627.

Şenel Ö, Eroğlu H. Correlation between reaction time and speed in elite soccer players. J Exer Sci Fitness. 2006;4(2):126-130.

Solanki J, Joshi N, Shah C, Mehta HB, Gokhle PA. A Study of Correlation between Auditory and Visual Reaction Time in Healthy Adults. Int J Med Pub Health. 2012;2(2):36-38). DOI:10.5530/ijmedph.2.2.8.

Song YH, Ha S-M. Yook JS, Ha M-S. Interactive Improvements of Visual and Auditory Function for Enhancing Performance in Youth Soccer Players. Int J Environ Res Public Health. 2019;16(24):4909. doi: 10.3390/ijerph16244909.

Sors F, Murgia M, Santoro I, Prpic V, Galmonte A, Agostini T. The contribution of early auditory and visual information to the discrimination of shot power in ball sports. Psychol Sport Exerc. 2017;31:44-51. DOI:10.1016/j.psychsport.2017.04.005.

Spierer DK, Petersen RA, Duffy K. Response Time to Stimuli in Division I Soccer Players. J Strength Cond Res. 2011;25(4):1134-41. doi: 10.1519/JSC.0b013e3181d09e4c.

Websites

(1) Microgate. OptoJump Next - Reaction test. 2024. Retrieved from: https://training.microgate.it/en/products/optojump-next/test-typologies/reaction-test. Accessed on: May 2024.

(2) Microgate, Bolzano, Italy. 2024. Retrieved from: https://www.researchgate.net/figure/The-Gyko-inertial-sensor-system-Microgate-Bolzano-Italy-presented-beside-a-2-Euro_fig2_309955689. Accessed on: May 2024.