THE RELATIONSHIP BETWEEN REACTION TIME AND GAMING TIME IN E-SPORTS PLAYERS

Aybuke Ersin[1], Halime Ceren Tezeren[2], Nihan Ozunlu Pekyavas[2], Burak Asal[2], Anıl Atabey[2], Ardacan Diri[2], and İsmail Gonen[2]

[1]Istanbul Atlas University, Faculty of Health Science, Department of Physiotherapy and Rehabilitation, Istanbul, Turkey
[2]Baskent University, Faculty of Health Science, Department of Physiotherapy and Rehabilitation, Ankara, Turkey

Original scientific paper
DOI 10.26582/k.54.1.4

Abstract:

E-sports can be defined as an electronic sports form and is growing at a rapid pace worldwide. E-sport requires high-speed reactions during all games. The purpose of this study was to evaluate auditory, visual and aim reaction times in different duration of game playing in e-sport players. Fifty-three participants were assigned into two groups according to their playing time which was either more or less than 14 hours per week. The participants were tested for auditory reaction time with online website at playback.fm, visual and aim reaction time on website of humanbenchmark.com. There were statistically significant differences in visual ($p<.001$) and aim ($p<.001$) reaction time between the groups, whereas in auditory reaction time no significant difference was found ($p=.397$). The visual and aim reaction times were higher in the gamers who play more than 14 hours in e-sport. Our study showed that visual and aim reaction time was more affected from game playing time than auditory reaction time in e-sport gamers. Playing e-sport may have positive effects on visual and aim reaction time in young population.

Key words: *eSports, visual reaction time, aim reaction time, auditory reaction time*

Introduction

The growing number of players and spectators increase the popularity of recreational activities in e-sports (Sainz, Collado-Mateo, & Coso, 2020). In 2020, the community of e-sport continued to grow with an audience of 495 million and estimated income of $1.1 billion (Bickmann, et al., 2021). With this growth, the number of games and different genres are increasing such as multiplayer online battle arena (MOBA), first-person shooter (FPS), fighting games or sports games (Bányai, Griffiths, Király, & Demetrovics, 2019). These e-sports genres require from players high-speed reactions to different visual and auditory stimuli for victory (Bickmann, et al,. 2021; Jonasson & Thiborg, 2010). Gamers spend at least 12-14 hours on e-sports related games per day (Kocadağ, 2020). The video game publisher, who produces League of Legends, has several hundred professional gamers on salary. The gamers practice up to 14 hours per day in order to be competitive at the elite level (Jenny, Manning, Keiper, & Olrich, 2016).

E-sports requires accuracy. The milliseconds can determine whether to win or lose. Specialized skills such as hand-eye coordination, muscle memory, and fast reaction time increase chances of reaching success in video games which are fast paced and require these skills (Stewart, Martinez, Perdew, Green, & Moore, 2020; Urbaniak, Wątróbski, & Sałabun, 2020). Reaction time is referred to as the time interval between the presentation of a stimulus and initiation of a voluntary response (Vishteh, Mirzajani, Jafarzadehpour, & Darvishpour, 2019). It demonstrates the level of neuromuscular coordination with different auditory or/and visual afferent stimuli and it is so related with human physical skill (Bickmann, et al,. 2021). Evaluation of the reaction time shows the unity and action capabilities of the central nervous system (Vishteh, et al,. 2019). Fast reaction time can be a decisive factor in e-sports, as it is important for quick decision-making. Perceptual and attentional skills are also important for performance in sports-related tasks. Therefore, numerous studies show that the athletes

have significantly shorter reaction times than non-athletes (Bickmann, et al,. 2021). In the past decades much of the focus was on visual components of the athlete's experience but an increasing emphasis placed on the role of sound had also been seen in informing and enhancing gameplay (Brandmeyer, Swedlow, Hertensteiner, & Crum, 2021).

In this study, we investigated e-sports players' auditory, visual and aim targeting reaction times. We hypothesized that reaction time of players who played video games for more than 14 hours would be better than that of players who played video games for less than 14 hours.

Methods

The study protocol was approved by the Ethics Committee of University and written consent was collected from all participants. The clinical trial number of the study is NCT04944849.

Participants

A total of 53 male participants, 28 of whom played video games for more than 14 hours per week (Group 1) and 25 of whom played for less than 14 hours per week (Group 2) were included in the study. All of the participants were male, aged ranging from 19 to 27 years. The inclusion criteria were as follows: individuals between the age 18 and 30 years who played at least 6 hours or more of e-sports per week for at least previous six months. The exclusion criteria were as follows: 1) any neurologic, visual, or auditory disorder; 2) having had upper extremity surgery; and 3) taking medications known to having stimulant effects.

The sociodemographic characteristics of participants like body height, body weight, dominant side, habits of smoking, alcohol taking, antidepressant or stimulant use, any vision and hearing problems, duration of a weekly sporting activity, duration of game playing, genre of video game, daily and weekly video game playing time, their participation in the video game-related tournament were interrogated. All the participants performed visual, auditory and aim reaction tests at respective online website. The tests were done in the same online platform on which the participants played the game (mobile phone, laptop, computer or PlayStation, etc.). The participants were instructed about the tests via online meeting before the assessment.

Outcome measures

Reaction time test

In this study, the Reaction Time Test was used to evaluate visual reaction time on the Human Benchmark website (https://humanbenchmark.com/tests/reactiontime). When the subject was ready, the test was started and the participant tried to press the button as soon as the green light came up on the screen (Bickmann, et al., 2021). The test was executed five times and the mean reaction time was calculated in milliseconds (ms).

Aim trainer test

The aim reaction time assesses reaction time and hand-eye coordination. In this study, the Aim Trainer Test on the Human Benchmark website (https://humanbenchmark.com/tests/aim) was used to evaluate aim targeting. When the test started, the subject tried to click on the 30 targets on the screen as quickly and accurately as he/she could. At the end of the test, the average time per target was displayed in ms (Bickmann, et al,. 2021).

Auditory reaction time

Auditory reaction time was evaluated with the test on playback.fm (https://playback.fm/audio-reaction-time). The subjects were asked to click the 'spacebar' key every time they heard a sound. After five executions, the data were taken from the output page and the mean reaction time was calculated. The average of these collected data was used in the statistical calculation.

Statistical analysis

The power analysis indicated that 25 participants for each group were needed with 80% power and 5% type 1 error. Mean and standard deviations were calculated for numerical data, with confidence intervals of 95% ($p<.05$). The data were analyzed using statistical software (SPSS version 18, SPSS Inc. Chicago, Illinois). The normality of data distribution in both groups in terms of descriptive statistics was analyzed using the Levene's test. The Wilcoxon test was used for a pairwise comparison of measurements and Mann-Whitney U test was used for non-parametric group comparisons.

Results

Fifty-three participants were divided in two groups: Group 1, playing digital game 14 hours and more per week (n=28) and Group 2, playing digital game less than 14 hours a week (n=25).

Data from all 53 subjects were used for the analysis. Subjects' average age was 22.8±1.77 years, average body height 180.9±6.70 centimeters (cm), average body weight 82.32±14.76 kilograms (kg) and all but one participant was right-handed. Subjects' gaming experience average was 9.96±5.07 years. There was no significant difference between the groups in terms of antidepressant or stimulant use and vision or hearing disturbance except smoking (all $p>0.05$). The groups' demographic information is shown in Table 1.

Most of the participants were playing more than one genre of games such as MOBA, FPS and sports games. Forty-four participants were playing MOBA

Table 1. Demographic information

	Group 1 (n=28)	Group 2 (n=25)	
	Mean±SD	Mean±SD	p
Age (years)	22.5±1.97	23.16±1.49	0.765
Height (cm)	181.96±7.56	179.72±5.51	0.654
Weight (kg)	84.14±15.47	80.28±13.95	0.365
Gaming experience (years)	12.32±4.88	7.32±3.90	0.053

*Significant at the p=.05 level, SD=standard deviation

Table 2. Number of gamers according to playing games genres

LOL	WARCRAFT	STARCRAFT	DOTA 2	CS: GO	PUBG	VALORANT	CALL OF DUTY	TOM CLANCY'S RAINBOW SIX: SIEGE	FIFA	NBA	PES
36	5	1	2	16	12	9	9	6	15	8	14

Note. LoL – League of Legends, CS:GO – Counter-Strike: Global Offensive, PUBG – PlayerUnknown's Battlegrounds, PES – Pro Evolution Soccer.

Table 3. Reaction time scores of the groups

	Group 1 (n=28)			Group 2 (n=25)			p
	Min	Max	Mean±SD	Min	Max	Mean±SD	
Visual reaction time (msn)	168.0	296.0	227.13±33.15	223.66	456.33	278.67±45.44	**<.001***
Auditory reaction time (msn)	172.0	550.0	258.73±33.15	169.0	359.40	255.76±40.53	397
Aim reaction time (msn)	308.33	571.33	440.61±64.93	365.0	865.33	578.83±123.98	**<.001***

*Significant at the p=.05 level., min = minimum, max = maximum, SD = standard deviation

games, 53 participants were playing FPS games, and 37 participants were playing sports games (Table 2). All of them were playing games on a computer, tablet or mobile phone.

Visual, auditory and aim reaction time comparison values between the groups are shown in Table 3. There were statistically significant differences in visual (p<.001) and aim (p<.001) reaction times between the groups. No differences were revealed between the groups in auditory reaction time (p=.397). Visual and aim reaction time values in Group 1 were significantly lower than in Group 2.

Discussion and conclusions

The aim of our study was to investigate whether the reaction times of digital game players who played digital games for more than 14 hours were better than those in gamers who do not play digital games more than 14 hours in a week. As a result of our study, we found that players who play more than 14 hours a week had better visual and aim reaction times, but there was no difference in auditory reaction time.

Considering today's technology, playing digital games is perceived as a very popular activity among

children and young people. Staying inactive for a long time in bad postures while playing digital games causes various damages to the posture of individuals, their cardiovascular systems and musculoskeletal systems. Also joint pain, headache, sleep problems, and vision problems are reported to be seen in e-sport players (Benchebra, Alexandre, Dubernet, Fatséas, & Auriacombe, 2019). Latest literature shows that contrary to this effects, e-sports players, who are considered to be physically inactive by sitting, spend approximately 40% more energy than sitting, even at the amateur level (Kocak, 2021).

In a study by Bickmann et al. (2021) it has been found that there is no difference between professional players and individuals doing professional physical sports in terms of visual and auditory reaction times. In terms of athletes, giving a quick reaction to a stimulus is seen as an important factor especially for the prevention of injuries and sports success. For this reason, it is an important finding that the reaction times of e-sports players are as good as those of professional athletes in their study. According to the results of our study, the visual and aim targeting reaction times of individuals playing digital games for more than 14 hours a week were found to be better (difference is 51.54 ms for visual reaction time and 138.22 ms for aim reaction time). We think that this is due to excessive exposure to visual effects and images while playing digital games. Considering that there is a very seriously long-playing time of 14 hours or more per week, we think that it is an expected result – so much exposure to visual feedback inevitably increases the visual reaction time. In one of the studies (Koposov, et al,. 2020), it was stated that there was a difference in visual reaction time between professional e-sports players and amateur e-sports players; professional e-sports players were reported to be better in visual reaction time. In the study, unlike in our study, amateur e-sports players were specified as digital players with a total playing time of 700 hours, while professional e-sports players were stated as individuals who played professionally in a team (Koposov, et al,. 2020). In addition, a study stated that those who played digital games for 14-33 hours over a few months had better reaction time (Lager & Bremberg, 2005).

According to the results of our study, auditory reaction time was not found to be better in those playing digital games for long hours. Exposure to auditory feedback during digital gaming may not be as frequent as exposure to visual feedback. The environment and the equipment the individual plays the games with are also important factors here. Also, the latest research by Conroy, Toth, and Campbell (2022) showed that the equipment was also important since the target acquisition response times improved when using a computer mouse lighter than 100g (Conroy, Toth, & Campbell, 2022). In addition, the individual may voluntarily turn off auditory feedback. Therefore, auditory reaction time may not be as improved as much as visual reaction time. In addition, the type of game played has a significant effect on the reaction time. FPS game players are found to have faster reaction times than the MOBA game players (Deleuze, Christiaens, Nuyens, & Billieux, 2017; Santos, Alloza, & Escribano, 2018; Sousa, et al,. 2020).

One of the limitations of our study is that a group that never played digital games was not included in the study. However, considering lifestyle of contemporary youth, it is thought that the number of individuals who never play games will be very few. For this reason, as stated in literature, individuals who play games for 14 hours or more per week and less than 14 hours per week as digital players are included.

In conclusion, this study showed that visual and aim reaction time are more effected from game playing time than the auditory reaction time of digital gamer players. Playing digital games may have positive effects on visual and aim reaction time in young population. According to the study, it was thought that digital games could be used in situations where visual and target reaction time need to be improved (athletes, neurological patients, etc.).

References

Akenhead, R., Harley, J.A., & Tweddle, S.P. (2016). Examining the external training load of an English Premier League football team with special reference to acceleration. *Journal of Strength and Conditioning Research*, *30*(9), 2424-2432. doi: 10.1519/JSC.0000000000001343

Anderson, L., Orme, P., Di Michele, R., Close, G.L., Morgans, R., Drust, B., & Morton, J.P. (2016). Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: Implications for carbohydrate periodisation. *Journal of Sports Sciences*, *34*(13), 1250-1259. doi: 10.1080/02640414.2015.1106574

Aquino, R.L.Q.T., Cruz Goncalves, L.G., Palucci Vieira, L.H., Oliveira, L.P., Alves, G.F., Pereira Santiago, P.R., & Puggina, E.F. (2016). Periodization training focused on technical-tactical ability in young soccer players positively affects biochemical markers and game performance. *Journal of Strength and Conditioning Research*, *30*(10), 2723-2732. doi: 10.1519/JSC.0000000000001381

Bangsbo, J., Iaia, F.M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test. *Sports Medicine*, 38(1), 37-51. doi: 10.2165/00007256-200838010-00004

Bangsbo, J., Nørregaard, L., & Thorsoe, F. (1991). Activity profile of competition soccer. *Canadian Journal of Sport Sciences=Journal Canadien des Sciences du Sport*, *16*(2), 110-116.

Brink, M.S., Frencken, W.G., Jordet, G., & Lemmink, K.A. (2014). Coaches' and players' perceptions of training dose: Not a perfect match. *International Journal of Sports Physiology and Performance*, *9*(3), 497-502. doi: 10.1123/IJSPP.2013-0009.

Brink, M.S., & Lemmink, K.A. (2018). Performance analysis in elite football: All in the game? *Science and Medicine in Football*, *2*(4), 253-254. doi: 10.1080/24733938.2018.1532659.

Campos-Vazquez, M.A., Mendez-Villanueva, A., Gonzalez-Jurado, J.A., León-Prados, J.A., Santalla, A., & Suarez-Arrones, L. (2015). Relationships between rating-of-perceived-exertion and heart-rate-derived internal training load in professional soccer players: A comparison of on-field integrated training sessions. *International Journal of Sports Physiology and Performance*, *10*(5), 587-592. doi: 10.1123/ijspp.2014-0294

Carling, C., Bradley, P., McCall, A., & Dupont, G. (2016). Match-to-match variability in high-speed running activity in a professional soccer team. *Journal of Sports Sciences*, *34*(24), 2215-2223. doi: 10.1080/02640414.2016.1176228.

Casamichana, D., Castellano, J., Calleja-Gonzalez, J., San Román, J., & Castagna, C. (2013). Relationship between indicators of training load in soccer players. *Journal of Strength and Conditioning Research*, *27*(2), 369-374. doi: 10.1519/JSC.0b013e3182548af1

Clemente, F.M., Clark, C., Castillo, D., Sarmento, H., Nikolaidis, P.T., Rosemann, T., & Knechtle, B. (2019a). Variations of training load, monotony, and strain and dose-response relationships with maximal aerobic speed, maximal oxygen uptake, and isokinetic strength in professional soccer players. *PLoS One*, *14*(12), e0225522. doi: 10.1371/journal.pone.0225522

Clemente, F.M., Owen, A., Serra-Olivares, J., Nikolaidis, P.T., van der Linden, C.M., & Mendes, B. (2019). Characterization of the weekly external load profile of professional soccer teams from Portugal and the Netherlands. *Journal of Human Kinetics*, *66*, 155. doi: 10.2478/hukin-2018-0054

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Cormack, S. (2001). The effect of regular travel on periodisation. *Strength Conditioning Coach*, *9*, 19-24.

Coutts, A.J. (2017). Challenges in developing evidence-based practice in high-performance sport. *International Journal of Sports Physiology and Performance*, *12*(6), 717-718. doi: 10.1123/IJSPP.2017-0455.

Coutts, A.J., Gomes, R.V., Viveiros, L., & Aoki, M.S. (2010). Monitoring training loads in elite tennis. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *12*(3), 217-220.

Coutts, A.J., Rampinini, E., Marcora, S.M., Castagna, C., & Impellizzeri, F.M. (2009). Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *Journal of Science and Medicine in Sport*, *12*(1), 79-84. doi: 10.1016/j.jsams.2007.08.005

Coutts, A.J., Reaburn, P.R.J., Murphy, A.J., Pine, M.J., & Impellizzeri, F.M. (2003). Validity of the session-RPE method for determining training load in team sport athletes. *Journal of Science and Medicine in Sport*, *6*(4), 525.

de Araujo, G.G., Papoti, M., Dos Reis, I.G.M., de Mello, M.A.R., & Gobatto, C.A. (2012). Physiological responses during linear periodized training in rats. *European Journal of Applied Physiology*, *112*(3), 839-852. doi: 10.1007/s00421-011-2020-2.

Delecroix, B., McCall, A., Dawson, B., Berthoin, S., & Dupont, G. (2018). Workload and non-contact injury incidence in elite football players competing in European leagues. *European Journal of Sport Science*, *18*(9), 1280-1287. doi: 10.1080/17461391.2018.1477994

Duarte, J.P., Coelho-e-Silva, M.J., Costa, D., Martinho, D., Luz, L.G., Rebelo-Gonçalves, R., ..., & Malina, R.M. (2019). Repeated sprint ability in youth soccer players: Independent and combined effects of relative age and biological maturity. *Journal of Human Kinetics*, *67*, 209. doi: 10.2478/hukin-2018-0090

Foster, C.A.R.L. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine and Science in Sports and Exercise*, *30*(7), 1164-1168.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., ..., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109-115.

Foster, J.P., Carl, H., Kara, M., Esten, P.L., Brice, G., & Porcari, J.P. (2001). Differences in perceptions of training by coaches and athletes. *South African Journal of Sports Medicine*, *8*(2), 3-7.

Fullagar, H.H., Harper, L.D., Govus, A., McCunn, R., Eisenmann, J., & McCall, A. (2019). Practitioner perceptions of evidence-based practice in elite sport in the United States of America. *Journal of Strength and Conditioning Research*, *33*(11), 2897-2904. doi: 10.1519/JSC.0000000000003348.

Gabbett, T.J. (2016). The training—injury prevention paradox: Should athletes be training smarter and harder?. *British Journal of Sports Medicine*, *50*(5), 273-280. doi: 10.1136/bjsports-2015-095788

Gabbett, T.J., & Whiteley, R. (2017). Two training-load paradoxes: can we work harder and smarter, can physical preparation and medical be teammates?. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), 50-54. doi: 10.1123/ijspp.2016-0321

Gallardo-Fuentes, F., Gallardo-Fuentes, J., Ramírez-Campillo, R., Balsalobre-Fernández, C., Martínez, C., Caniuqueo, A., ..., & Izquierdo, M. (2016). Intersession and intrasession reliability and validity of the My Jump app for measuring different jump actions in trained male and female athletes. *Journal of Strength and Conditioning Research*, *30*(7), 2049-2056. doi: 10.1519/JSC.0000000000001304

Hazir, T., Kose, M.G., & Kin-Isler, A. (2018). The validity of running anaerobic sprint test to assess anaerobic power in young soccer players. *Isokinetics and Exercise Science*, *26*(3), 201-209. doi: 10.3233/IES-182117

Impellizzeri, F.M., Rampinini, E., Coutts, A.J., Sassi, A.L.D.O., & Marcora, S.M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise*, *36*(6), 1042-1047. doi: 10.1249/01.mss.0000128199.23901.2f

Kelly, V.G., & Coutts, A.J. (2007). Planning and monitoring training loads during the competition phase in team sports. *Strength and Conditioning Journal*, *29*(4), 32.

Koo, T.K., & Li, M.Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155-163. doi: 10.1016/j.jcm.2016.02.012

Los Arcos, A., Martínez-Santos, R., & Castillo, D. (2020). Spanish elite soccer reserve team configuration and the impact of physical fitness performance. *Journal of Human Kinetics*, *71*, 211. doi: 10.2478/hukin-2019-0085

Loturco, I., Nakamura, F.Y., Kobal, R., Gil, S., Pivetti, B., Pereira, L.A., & Roschel, H. (2016). Traditional periodization versus optimum training load applied to soccer players: Effects on neuromuscular abilities. *International Journal of Sports Medicine*, *37*(13), 1051-1059. doi: 10.1055/s-0042-107249

Machado, J.C., Ribeiro, J., Palheta, C.E., Alcântara, C., Barreira, D., Guilherme, J., ..., & Scaglia, A.J. (2019). Changing rules and configurations during soccer small-sided and conditioned games. How does it impact teams' tactical behavior?. *Frontiers in Psychology*, *10*, 1554. doi: 10.3389/fpsyg.2019.01554

Martín-García, A., Díaz, A.G., Bradley, P.S., Morera, F., & Casamichana, D. (2018). Quantification of a professional football team's external load using a microcycle structure. *Journal of Strength and Conditioning Research*, *32*(12), 3511-3518. doi: 10.1519/JSC.0000000000002816

Mujika, I., Halson, S., Burke, L.M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International Journal of Sports Physiology and Performance*, *13*(5), 538-561. doi: 10.1123/ijspp.2018-0093

Oliveira, R., Brito, J., Martins, A., Mendes, B., Calvete, F., Carriço, S., ... & Marques, M.C. (2019a). In-season training load quantification of one-, two- and three-game week schedules in a top European professional soccer team. *Physiology and Behavior*, *201*, 146-156. doi: 10.1016/j.physbeh.2018.11.036

Oliveira, R., Brito, J.P., Martins, A., Mendes, B., Marinho, D.A., Ferraz, R., & Marques, M.C. (2019b). In-season internal and external training load quantification of an elite European soccer team. *PloS One*, *14*(4), e0209393. doi: 10.1371/journal.pone.0209393

Rago, V., Brito, J., Figueiredo, P., Krustrup, P., & Rebelo, A. (2019). Relationship between external load and perceptual responses to training in professional football: Effects of quantification method. *Sports*, *7*(3), 68. doi: 10.3390/sports7030068

Rebelo, A.N.C., Silva, P., Rago, V., Barreira, D., & Krustrup, P. (2016). Differences in strength and speed demands between 4v4 and 8v8 small-sided football games. *Journal of Sports Sciences*, *34*(24), 2246-2254. doi: 10.1080/02640414.2016.1194527

Redkva, P.E., Gregorio da Silva, S., Paes, M.R., & Dos-Santos, J.W. (2017). The relationship between coach and player training load perceptions in professional soccer. *Perceptual and Motor Skills*, *124*(1), 264-276. doi: 10.1177/0031512516678727

Robertson, S., & Joyce, D. (2018). Evaluating strategic periodisation in team sport. *Journal of Sports Sciences*, 36(3), 279-285. doi: 10.1080/02640414.2017.1300315

Rossi, A., Perri, E., Pappalardo, L., Cintia, P., & Iaia, F.M. (2019). Relationship between external and internal workloads in elite soccer players: Comparison between rate of perceived exertion and training load. *Applied Sciences*, *9*(23), 5174. doi: 10.3390/app9235174

Rowntree, D. (1981). *Statistics without tears: A primer for non-mathematicians*. Scribner Book Company.

Stevens, T.G., de Ruiter, C.J., Twisk, J.W., Savelsbergh, G.J., & Beek, P.J. (2017). Quantification of in-season training load relative to match load in professional Dutch Eredivisie football players. *Science and Medicine in Football*, *1*(2), 117-125. doi: 10.1080/24733938.2017.1282163

Turner, A.N., Bishop, C., Marshall, G., & Read, P. (2015). How to monitor training load and mode using sRPE. *Professional Strength and Conditioning*, *39*, 15-20.

Vaeyens, R., Lenoir, M., Williams, A.M., & Philippaerts, R.M. (2008). Talent identification and development programmes in sport. *Sports Medicine*, *38*(9), 703-714. doi: 10.2165/00007256-200838090-00001

Valente-dos-Santos, J., Coelho-e-Silva, M.J., Martins, R.A., Figueiredo, A.J., Cyrino, E.S., Sherar, L.B., ..., & Malina, R.M. (2012). Modelling developmental changes in repeated-sprint ability by chronological and skeletal ages in young soccer players. *International Journal of Sports Medicine*, *33*(10), 773-780. doi: 10.1055/s-0032-1308996

Wang, C., Vargas, J.T., Stokes, T., Steele, R., & Shrier, I. (2020). Analyzing activity and injury: Lessons learned from the acute:chronic workload ratio. *Sports Medicine*, *50*(7), 1243-1254. doi: 10.1007/s40279-020-01280-1

Wing, C. (2018). Monitoring athlete load: Data collection methods and practical recommendations. *Strength and Conditioning Journal*, *40*(4), 26-39. doi: 10.1519/SSC.0000000000000384

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Sciences*, *30*(15), 1573-1580. doi: 10.1080/02640414.2012.709265

Submitted: October 5, 2021
Accepted: February 3, 2022
Published Online First: March 18, 2022

Correspondence to:
Assoc. Prof. Nihan Ozunlu Pekyavas, P.T., Ph.D.
Address: Bağlıca Kampüsü Fatih Sultan Mahallesi
Eskişehir Yolu 18.km Etimesgut / ANKARA
Zip Code: 06790
Phone: +90 507 153 50 28
Fax: +90 312 246 66 74
e-mail address: nihan_2002@hotmail.com