Ita. J. Sports Reh. Po.

Italian Journal of
Sports Rehabilitation and Posturology

Biomechanics of Kicks in Football: A Review

Boško Mihailović[1], Ljubiša Lilić[2], Rosario D'Onofrio[3,4], Tilemachos Koliopoulos[5], Mahendra Pal[6], George Sebastian Iacob[7]

[1]Teacher Education Faculty in Belgrade, Teaching department in Novi Pazar, University of Belgrade, Serbia
[2]Faculty of Sport and Physical Education in Leposavić, University of Priština, Serbia
[3] Member of the Multidisciplinary Medical - Scientific Commission, - L.A.M.I.CA – Italy
[4] UEFA B, Diplome Football Coach, FIGC and UEFA Grassroots C Licence -FIGC- Italy
[5]University of West Attica, Collaborator of the Department of Community Health and Public Health/Managing Director of Telegeco Research Center, Greece
[6]Narayan Consultancy On Veterinary Public Health and Microbiology, Anand, India
[7]Alexandru Ioan Cuza" University of Iaşi, Faculty of Physical Education and Sport, Romania

Abstract. *With the development of modern technology, the biomechanical analysis of the competitive activity of soccer players has become an indispensable aspect in the training process, on which the achievement of top results largely depends. Kicking is a primary activity in soccer, and thus it is necessary to evaluate and highlight its importance through biomechanical scientific research. The aim of this narrative review of the current literature was to examine the biomechanical analysis of kicking in soccer. Put differently, this narrative review of the current literature examines the kick in soccer starting from the way the player approaches the ball to the end of the ball's flight, the point that determines the success of the kick. In order for the shot to be as strong and better as possible, the last step must be long. A few steps away and at an angle to the direction of the ball's flight, skilled kickers perform a curved approach to a stationary soccer ball. Based on the review analysis, it is clear that state-of-the-art biomechanical equipment and analytical methods have been used extensively to advance our understanding of soccer shooting talent, as well as variables that more clearly depict the biomechanics of soccer shooting. The recommendation to future researchers on the topic of football implies the application of original research in order to show as clearly as possible the importance of biomechanics and kicking in football.*

Keywords: *kinematics, electromyography, kinetics, soccer, kicking.*

Citation. Boško Mihailović, Ljubiša Lilić, Rosario D'Onofrio, Tilemachos Koliopoulos , Mahendra Pal, George Sebastian Iacob - Biomechanics of Kicks in Football: A Review - Ita. J. Sports Reh. Po. 2023; 10 (26); 5;(9): 2779 - 2791 ; IBSN 007- 11119-55; CGI J OAJI 0.20; Published Online. Open Access (OA) publishing ; Authorship Credit: *"Criteria authorship scientific article" has been used "Equal Contribution" (EC).*

INTRODUCTION

Achieving top results in all team sports is increasingly conditioned by the application of the latest scientific knowledge in the processes of preparation, planning and guidance of athletes [1-3]. Top athletes and their mastery of sports skills have progressed significantly in the past few decades, and the most significant factor in progress for all professional observers is sports preparation both in football [4,5] and in other sports [6,7].

Football is the most popular sport in the world, but it should be emphasized that further biomechanical studies are necessary in order to fully demonstrate the importance and role of professional football in the modern world [8-11]. It should certainly be emphasized that it is very important to learn and improve soccer skills in primary and secondary schools as part of physical and health education subjects, so that students can carry out their further activity in soccer trainings [12-14].

With the development of modern technology, the biomechanical analysis of competitive activity in football has become an indispensable aspect in the training process, on which the achievement of top results largely depends [10]. The goal of the football game is to score more goals than the opponent, and therefore it is necessary, in relation to characteristics of certain players, to find the most efficient and rational tactical and physical game preparation plan that will achieve the greatest success, and in order to achieve that goal, each team must have an effective way of technical-tactical and physical preparation [11,16].

In the best world leagues, the football season lasts on average 10–11 months [17]. The football season is based on three periods: the preparatory period, the competition period and the transition period (off-season or transition period). The preparation period lasts about seven weeks and for professional teams it starts at the beginning of July and ends in the middle of August. From that moment, the competition period begins and optimally lasts until the middle of May [17-19].

Kicking is the primary activity in football [10,11,20,21,27,28]. This narrative review of the current literature is from a biomechanical perspective as recent developments in biomechanical theory have influenced our understanding of kicking talent. This actually means that this review focuses on soccer, but specifically on kicking the ball, since most of the research that has been published is about this type of soccer and kicking.

Previous studies have considered mainly the kicking leg, as well as the kinematic, kinetic and electromyographic characteristics of its segments, joints and muscles [3,4,10,11,20,21]. Although much is known about the biomechanics of the kicking leg, there are a number of other aspects that have been the subject of recent research. The researchers expanded their interest to consider the characteristics of the overall technique and the influences of the upper body, supporting leg and pelvis on the kicking action. In addition, more information is now available about kicking the ball in soccer and the corresponding characteristics of the throw and flight of the ball. This review looks at the shot as a whole starting with how the player approaches the ball to the end of the ball's flight, the point that determines the success of the shot. Thus, the aim of this narrative review of the current literature was to examine the biomechanical analysis of kicking in soccer.

Kicking technique in football

Considering that kicking is the primary activity in soccer, it is necessary to evaluate and point to the scientific research that serves as the basis for our knowledge about this sport. This evaluation extends and extends previous studies with a biomechanical focus. Although the biomechanics of the kicking leg are well understood, there are many more elements to kicking that have recently become the focus of research. Researchers are now more interested in the entire shot, from how the player approaches the ball to when the ball lands and whether or not it was a successful shot. This interest included aspects of general technique, foot contact with the ball and the effects of cleats and soccer balls, ball launch characteristics and ball flight, and the effects of the upper body, supporting legs and pelvis on impact. getting around. This review evaluates them and makes an effort to propose a research agenda for the future.

A few steps away and at an angle to the ball's flight direction, skilled step kickers execute a curved approach to a stationary soccer ball. Players prefer angled approaches, while some studies [11,22] indicate that approach angles of 43.8°, self-selected, produced maximum ball speed, complementing earlier research that found that an approach angle of approximately 45.8°ensures optimal ball speed. Players also prefer to use an approach distance that requires them to take a small number of steps, averaging 2–4 steps. An approach of this type generates a modest approach speed of about 3–4 mss [10,23] . Therefore, the nature of the approach appears to be important for performance.

To kick as hard and as far as possible, the last step or step must be long. Stoner and Ben-Sira observed that compared to mid-range kicks, long (1.69 m) footed professional players had a longer last step length (1.50 m) [24]. According to Lees and Nolan two professional players who performed the maximum kick leg (0.72 m and 0.81 m) had a longer last step length compared to the submaximal kick (0.53 m and 0.55 m). They hypothesized that a longer final stride would result in greater pelvic retraction, which would then allow for greater pelvic protraction (ie, forward rotation on the striking side) [25].

The approach path made by skilled players is curved and as a consequence the body is tilted towards the center of rotation. It is likely that the purpose of the curved run is to ensure that the body produces and maintains a lateral tilt while executing the stroke. One reason is that the angled foot is better able to get under the ball to make better contact with it. Another reason is that a more angled lower body would allow for a more extended knee at impact, and therefore greater foot speed. The third reason is that the curved approach provides a stable position for the shot, thus contributing to the accuracy and consistency of the shot [26].

Dominant leg of a football player

The dominant leg has been widely studied in soccer and recent reviews have provided a good account of the kinematic and kinetic data associated with this limb. It is worth noting that despite the widespread recognition that impact is three-dimensional (3D) in nature, relatively few 3D studies have been conducted and relatively limited kinematic data are available in the abduction/adduction and internal/external axes. There are no normative data and little statistical information available for these important descriptive variables [10,11,22-26].

Many studies have reported a decrease in angular and/or linear velocity of the kicking leg just prior to ball impact [10,11,18-21]. There is a tight relationship between foot swing speed and the resulting ball speed [27] and this implies achieving maximum performance.

The nature of the leg swing observed by many in the final phase of kicking in soccer has left an enigma that some have interpreted as a motor control strategy to improve accuracy [27]. In contrast, coaches often advise players to "kick through the ball." In an attempt to address this situation they reported representative soccer foot-kick kinematics using advanced technology, which included high sampling rates and a novel filtering procedure (time-frequency filtering) [28]. They found that the shaft continued to accelerate until the ball was struck (figure 1), which was very different from the one previously published. They were also able to reproduce the typical decrease in angular velocity of the handle before impact by downsampling the data (to 250 Hz) and applying a conventional low-pass filter (10 Hz).

Biomechanics of kicking in soccer

Kinetic data, represented by joint moments, have been of interest for some time with two-dimensional (2D) flexion/extension moments being widely reported. Nunome et al. were the first to report full 3D joint moments (ie, for abduction/adduction and internal/external axes) for the kicking leg [29]. Further 3D joint Kawamoto et al. have recently published torque data for leg kick [30], which attributed the better performance of experienced players to heir greater hip joint moments (hip flexion, adduction, and external rotation were 168, 100, and 41 Nm, respectively) compared to inexperienced players (94, 115 and 26 Nm respectively) [30].

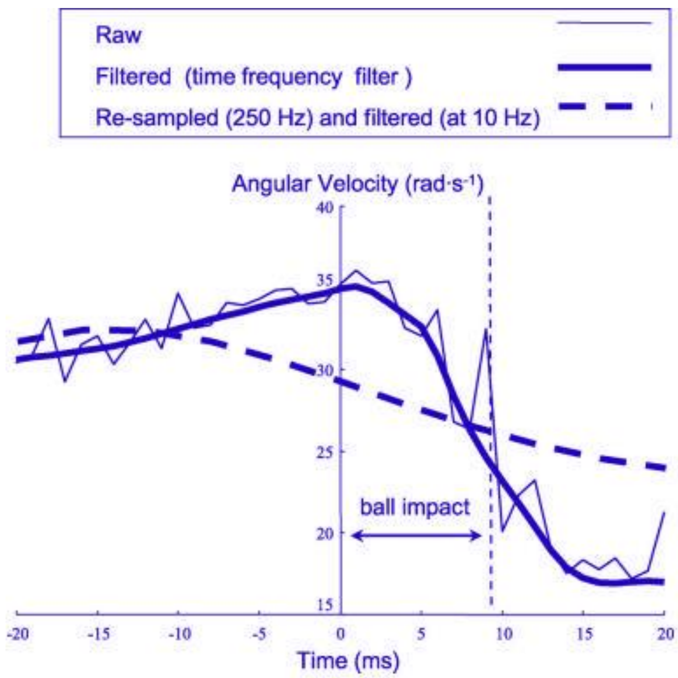

Figure 1. Comparison of changes in shaft angular velocity due to ball impact calculated from three different filtering and sampling techniques by Nunome et al. [28].

Inconsistencies between joint moment and segmental motion have been reported (eg, knee flexor moment while the knee is extended) [11]. Aziz and Bylbyl termed this unique phenomenon the "soccer paradox", related to Lombard's paradox found in the early years of the last century for standing movement from a chair. However, from another point of view, this paradox implies that kinetic sources, other than muscle moments, are partially responsible for the characteristic pattern of segment movement during the kick [31]. Putnam (1991) was the first to discover the significant influence of "movement-dependent" moments on football blows. Dorgeet al. were the first to apply Putnam's procedure to a soccer kick from a step and quantify the amount of work done by the motion-dependent torque due to the angular velocity of the thigh. This corresponded to 20% of the work done by the knee extension moment [32].

These studies have significantly improved our understanding of the effectiveness of segmental interaction in kicking. However, they did not admit to tampering with the change of moments just before the ball was struck. As mentioned earlier, the change of joint moments near the impact of the ball is very sensitive to data treatments, and this is especially emphasized in soccer. The positive effects of different football programs, both recreational and professional, on the functional abilities of athletes [33-38], and therefore also football players [10, 11, 20, 24, 27, 28]. To date, a study by Nunoma et al. is the only one that has addressed such problems using reasonable data treatments and clearly demonstrated detailed time series changes of both joint and motion-dependent moments [27,28]. In their study, the knee extension moment decreased rapidly during the final phase of the kick and finally began to show a reverse (flexion) moment just before ball impact, while the motion-dependent moment increased rapidly to show an extension moment at ball impact (Figure 2). It is possible that the movement-dependent torque helps to compensate for the inhibition of the muscle torque, thus increasing the angular velocity during the final phase of the impact. From these changes, Nunome et al. have speculated that as the angular velocity of the handle exceeds the inherent force-velocity limitation of the muscle just prior to ball impact, the muscle system becomes unable to generate any concentric force. It appears that the coach's advice to "hit through the ball" should focus on muscle groups other than the knee, with the hip and trunk muscles most likely to contribute [27].

Effective movement-dependent torque action can be considered an index of better segmental coordination. This index was used to elucidate the influence of intersegmental coordination on limb preferences and fatigue [39]. Movement-dependent torque appears to be independent of joint torque and largely depends on the action of joint torques generated at other joints, mostly proximal joints. This implies that adjacent or even distant joints are effectively connected to each other through the action of motion-dependent moments. Putnam's equation allows the effect of linear hip motion (acceleration) on the motion-dependent moment acting on the knee [32] to be extracted.

To date, conflicting results have been reported for the effect of hip motion on movement-dependent torque.Dorgeet al. showed no positive hip motion work [32] , while Putnam showed a small but positive contribution (16% of average net moment magnitude) [40] , and Nunome et al. showed a more dominant contribution of upward hip movement. In these cases, ball impact interference and its treatment would not explain these differences because the impact from ball impact is not considered to be transmitted to the hip [27] .

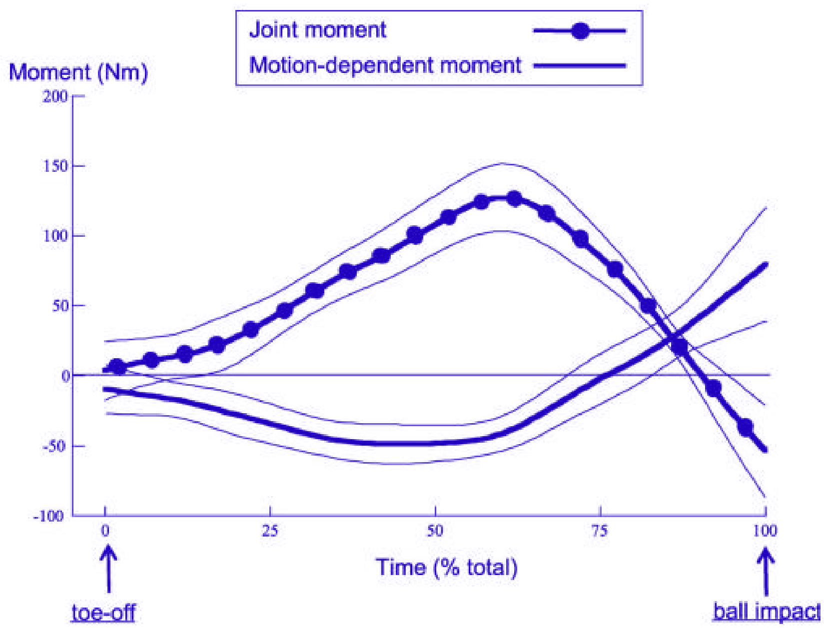

Figure 2. Motion-dependent mean joint and moment changes at the knee joint during the soccer kick leg swing from the stride of Nunome et al. [27].

CONCLUSION

It is clear that state-of-the-art measurement equipment and analytical methods have been used extensively to advance our understanding of football kicking talent and the variables that affect how well it works. In general, the focus has expanded beyond the interest of the kicking leg to include the effects of other parts of the body and other aspects of movement. The idea that the whole body is involved in foot strike speed is becoming accepted. Although they are often studied separately, a comprehensive view is created using qualitative analytical techniques, particularly the application of movement principles and technical levels. We have tried to address both broader interests related to the art of kicking, as well as to bring the reader closer to a number of contemporary topics that are currently of interest to researchers in this field. The recommendation to future researchers on the subject of football involves the application of original research in order to show as clearly as possible the importance of the biomechanics of kicking in football.

Declaration of conflicting interests

Declaration of conflicting interests The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article. All authors have read and agreed to the published version of the manuscript.

REFERENCES

1. Stojanovic E, Aksovic N, Stojiljkovic N, Stankovic R, Scanlan AT, Milanovic Z. Reliability, usefulness, and factorial validity of change-of-direction speed tests in adolescent basketball players. The Journal of Strength & Conditioning Research. 2019 Nov 1;33(11):3162-73.
2. Aksović N, Bjelica B, Milanović F, Jovanović N, Zelenović M. Plyometric training effects on explosive power, sprint and direction change speed in basketball: A review. Turkish Journal of Kinesiology. 2021;7(2):73-9.
3. Riboli A, Esposito F, Coratella G. Small-sided games in elite football: practical solutions to replicate the 4-min match-derived maximal intensities. The Journal of Strength & Conditioning Research. 2023 Feb 1;37(2):366-74.
4. Pajović L, Toskić L, Stanković V, Lilić L, Cicović B. Muscle Contractile Properties Measured by the Tensiomyography (TMG) Method in Top-Level Football Players of Different Playing Positions: The Case of Serbian Super League. International Journal of Environmental Research and Public Health. 2023 Jan;20(2):924.
5. Mohr M, Nassis GP, Brito J, Randers MB, Castagna C, Parnell D, Krustrup P. Return to elite football after the COVID-19 lockdown. Managing Sport and Leisure. 2022 Mar 4;27(1-2):172-80.
6. Aksović N, Bjelica B, Milanović F, Cicović B, Bubanj S, Nikolić D, Skrypchenko I, Rozhechenko V, Zelenović M. Evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players. Pedagogy of Physical Culture and Sports. 2022;26(2):126-33.
7. Aksović N, Bjelica B, Milanović F, Milanović Lj, Jovanović N. Development of explosive power in basketball players. Turkish Journal of Kinesiology. 2021;7(1):44-52.
8. Milanovic L, Bjelica B, Fulurija D, Aksović N, Alempijevic R. Physical Composition And Motor Skills Of Footballers. International Journal of Academic Health and Medical Research; 6(1):139-145.
9. Webb T. The future of officiating: Analysing the impact of COVID-19 on referees in world football. Soccer & Society. 2021 Feb 17;22(1-2):12-8.
10. Lees A, Asai T, Andersen TB, Nunome H, Sterzing T. The biomechanics of kicking in soccer: A review. Journal of Sports Sciences. 2010 Jun 1;28(8):805-17.
11. Lees A, Nolan L. The biomechanics of soccer: a review. Journal of Sports Sciences. 1998 Jan

1;16(3):211-34.

12. Aksović N, Bjelica B, Jovanović L, Zelenović M, Milanović Lj.. Didactic-methodological principles in physical education teaching; Ita. J. Sports Reh. Po. 2023; 10 (24); 3; 1; 2422–2435; ISSN 2385-1988 [online]; IBSN 007-11119-55; CGI J OAJI 0.201). Published Online. Open Access (OA) publishing. 2023.
13. Aksović N, Jovanović Lj, Bjelica B, Zelenović M, D'Onofrio R. Methodological-organizational forms of work in physical education teaching; Ita. J. Sports Reh. Po. 2023; 10 (24); 3; 2; 2436–2451; ISSN 2385-1988 [online]; IBSN 007-11119-55; CGI J OAJI 0.201). Published Online. Open Access (OA) publishing.
14. Aksović N, Bjelica B, Jovanović Lj, Milanović Lj, Zelenović M. Teaching methods in teaching physical education; Ita. J. Sports Reh. Po. 2023; 10 (24); 3; 3; 2452–2464; ISSN 2385-1988 [online]; IBSN 007-11119-55; CGI J OAJI 0.201). Published Online. Open Access (OA) publishing.
15. Milanović Lj, Živković D, Pantelić S, Bjelica B, Pržulj R, Aksović N, Perović T. Physical and body images of the working population. Facta Universitatis, Series: Physical Education and Sport. 2022 Jan 8:211-21.
16. Ferasat R. Investigation of biomechanical and anthropometric variables of football players according to their playing position. Journal of Sport Biomechanics. 2021 Jun 10;7(1):2-13.
17. Reilly T, Lees A, Davids K, Murphy WJ, editors. Science and Football: Proceedings of the First World Congress of Science and Football Liverpool, 13-17th April 1987. Routledge; 2011 Dec 15.
18. Requena B, González-Badillo JJ, de Villareal ES, Ereline J, García I, Gapeyeva H, Pääsuke M. Functional performance, maximal strength, and power characteristics in isometric and dynamic actions of lower extremities in soccer players. The Journal of Strength & Conditioning Research. 2009 Aug 1;23(5):1391-401.
19. Olivares-Jabalera J, Fílter-Ruger A, Dos' Santos T, Afonso J, Della Villa F, Morente-Sánchez J, Soto-Hermoso VM, Requena B. Exercise-based training strategies to reduce the incidence or mitigate the risk factors of anterior cruciate ligament injury in adult football (soccer) players: a systematic review. International Journal of Environmental Research and Public Health. 2021 Dec 18;18(24):13351.
20. Katis A, Giannadakis E, Kannas T, Amiridis I, Kellis E, Lees A. Mechanisms that influence accuracy of the soccer kick. Journal of Electromyography and Kinesiology. 2013 Feb

1;23(1):125-31.
21. Rahnama N, Lees A, Bambaecichi E. A comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. Ergonomics. 2005 Sep 15;48(11-14):1568-75.
22. Barfield WR. The biomechanics of kicking in soccer. Clinics in Sports Medicine. 1998 Oct 1;17(4):711-28.
23. Kellis E, Katis A. Biomechanical characteristics and determinants of instep soccer kick. Journal of Sports Science & Medicine. 2007 Jun;6(2):154.
24. Stoner LJ, Ben-Sira D. Variation in movement patterns of professional soccer players when executing a long range and a medium range in-step soccer kick. Biomechanics VII-B. 1981:337-41.
25. Lees A, Nolan L. Three-dimensional kinematic analysis of the instep kick under speed and accuracy conditions. Science and Football IV. 2002:16-21.
26. Lees A, Steward I, Rahnama N, Barton G. Lower limb function in the maximal instep kick in soccer. In Contemporary sport, leisure and ergonomics 2009 Mar 24 (pp. 161-172). Routledge.
27. Nunome H, Ikegami Y, Kozakai R, Apriantono T, Sano S. Segmental dynamics of soccer instep kicking with the preferred and non-preferred leg. Journal of Sports Sciences. 2006 May 1;24(05):529-41.
28. Nunome H, Lake M, Georgakis A, Stergioulas LK. Impact phase kinematics of instep kicking in soccer. Journal of Sports Sciences. 2006 Jan 1;24(1):11-22.
29. Nunome H, Asai T, Ikegami Y, Sakurai S. Three-dimensional kinetic analysis of side-foot and instep soccer kicks. Medicine and Science in Sports and Exercise. 2002 Dec 1;34(12):2028-36.
30. Kawamoto R, Miyagi O, Ohashi J, Fukashiro S. Kinetic comparison of a side-foot soccer kick between experienced and inexperienced players. Sports Biomechanics. 2007 May 1;6(2):187-98.
31. Aziz D, Bylbyl S. The free kick kinematics of elite football players. Education. 2019 Aug 16;4(2):18-27.
32. Dörge HC, Andersen TB, Sørensen H, Simonsen EB. Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. Journal of Sports Sciences. 2002 Jan 1;20(4):293-9.
33. Bjelica B, Milanović Lj, Aksović N, Zelenović M, Božić D. Effects of physical activity to cardiorespiratory changes. Turkish Journal of Kinesiology. 2020;6(4):164-74.

34. Zećirović A, Bjelica B, Pajović L, Aksović N. Postural status and kyphosis in school-age children. International Journal of Academic Health and Medical Research. 2021;5(11):90-7.
35. D'Onofrio R. Padalasala M, Manzi V,, Bojan B, Aksović N. The final stage (late) of sport rehabilitation: critical analysis of quality of movement and injury risk factors during return to sport, Ita. J Sports Reh Po. 2021;8(Suppl 1):13-30.
36. Zelenović M, Kontro T, Dumitru RC, Aksovic N, Bjelica B, Alexe DI, Corneliu DC. Leisure-time physical activity and all-cause mortality: A systematic review. Revista de Psicología del Deporte. 2022;31(1).
37. Gardašević N, Joksimović M, Martinović M, Gadžić A, Bjelica B, Aksović N. Nutritional status and gender differences of adolescent students. Journal of Physical Education and Sport. 2021 May 1;21(3):1354-60.
38. Koliopoulos T, Papakonstantinou D, Ciarkowska K, Antonkiewicz J, Gambus F, Mebarek-Oudina F, Milanovic L, Bjelica B, Aksovic N, Alempijevic R, Pal M. Green Designs in Hydraulics—Construction Infrastructures for Safe Agricultural Tourism and Sustainable Sports Tourism Facilities Mitigating Risks of Tourism in Crisis at Post COVID-19 Era. InAdvances in Tourism, Technology and Systems: Selected Papers from ICOTTS 2021, Volume 2 2022 May 28 (pp. 37-47). Singapore: Springer Nature Singapore.
39. Apriantono T, Nunome H, Ikegami Y, Sano S. The effect of muscle fatigue on instep kicking kinetics and kinematics in association football. Journal of Sports Sciences. 2006 Sep 1;24(9):951-60.
40. Putnam CA. A segment interaction analysis of proximal-to-distal sequential segment motion patterns. Medicine and Science in Sports and Exercise. 1991 Jan 1;23(1):130-44.