Emirzeoğlu M., Kabahasanoğlu M., Şentürk U., Bayrakcı Tunay V., Comparison of the Running Parameters in Morning and Evening Trainings of Elite Soccer Players, Turk J Physiother Rehabil. 2021; 32(3):15-21. doi: 10.21653/tjpr.775369

ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2021 32(3)15-21

Murat EMİRZEOĞLU, MSc, PT[1]
Mesut KABAHASANOĞLU[2]
Ufuk ŞENTÜRK, Dr. MD[3]
Volga BAYRAKCI TUNAY, PhD, PT[4]

1 Karadeniz Technical University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Trabzon, Turkey
2 Trabzon University, Physical Education and Sport, Trabzon, Turkey
3 Helios Clinic Emil von Behring, Clinic for Orthopedic Surgery and Traumatology, Berlin, Germany
4 Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Ankara, Turkey

Correspondence (İletişim):

Murat Emirzeoğlu, MSc, PT
Address: Karadeniz Technical University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, 61080, Trabzon, Turkey
Phone number: +90 462 377 8842
E-posta: muratemirzeoglu@gmail.com
ORCID: 0000-0001-6351-7937

Mesut KABAHASANOĞLU
E-posta: m_kabahasan@hotmail.com
ORCID: 0000-0003-3981-5592

Ufuk ŞENTÜRK
E-posta: ufukberlin@gmx.de
ORCID: 0000-0003-0434-3089

Volga BAYRAKCI TUNAY
E-posta: volgatunay@hacettepe.edu.tr
ORCID: 0000-0002-0946-9484

Received: *5.08.2020 (Geliş Tarihi)*
Accepted: *18.02.2021 (Kabul Tarihi)*

COMPARISON OF THE RUNNING PARAMETERS IN MORNING AND EVENING TRAININGS OF ELITE SOCCER PLAYERS

ORIGINAL ARTICLE

ABSTRACT

Purpose: Although there are many studies in the literature regarding the running of soccer players, there is a need to examine the running asymmetry of the athletes' actual training, regardless of a specific intervention protocol. The aim of this study was to compare the running asymmetry of healthy elite soccer players in training sessions at different times of the day.

Methods: Sixteen healthy male elite soccer players were included in this study. Global Positioning System units (GPSports, SPI Pro, 5 Hz, GPSport, Canberra, Australia) were used to define training and running details. Fourteen (7 morning, 7 evening) training data were evaluated.

Results: There was no statistical difference between morning and evening trainings in terms of training time, heart rate average and total running distance except for high speed running distance. Running asymmetry was 66% greater in evening training sessions than in morning training sessions (p=0.001; 4.13±1.92, 2.49±1.32 respectively). Running asymmetry did not show any significant correlation with training time, heart rate average, running distance, and high speed running distance (p>0.05).

Conclusion: Running asymmetry is higher in evening training sessions than in morning training sessions. Therefore, for athletes who are particularly at high risk of injury or who are in the process of a return to sports, and from whom high performance is not expected, morning trainings may be preferred instead of evening trainings. If training can not be performed in the morning, clinicians should follow the athletes instantly during evening training.

Key Words: Athletes, Lower extremity, Soccer, Technology

ELİT FUTBOLCULARIN SABAH VE AKŞAM ANTRENMANLARINDAKİ KOŞU PARAMETRELERİNİN KARŞILAŞTIRILMASI

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Futbolcuların koşularına yönelik literatürde birçok araştırma olmasına rağmen, belli bir müdahale protokolüne bağlı kalmaksızın sporcuların gerçek antrenmanlarındaki koşu asimetrisinin incelenmesine ihtiyaç vardır. Bu çalışmanın amacı, sağlıklı elit futbolcuların günün farklı saatlerinde yapılan antrenmanlardaki koşu asimetrilerini karşılaştırmaktı.

Yöntem: Çalışmaya 16 sağlıklı erkek elit futbolcu dâhil edildi. Antrenman ve koşu detaylarını belirlemek için Küresel Konumlama Sistemi (GPSports, SPI Pro, 5 Hz, GPSport, Canberra, Australia) kullanıldı. On dört (sabah yedi, akşam yedi) antrenman verisi değerlendirildi.

Sonuçlar: Yüksek hızlı koşu mesafesi dışında sabah ve akşam antrenmanları arasında antrenman süresi, kalp atış hızı ortalaması ve toplam koşu mesafesi açısından istatistiksel olarak fark yoktu. Koşu asimetrisi, akşam antrenmanlarında sabah antrenmanlarına göre %66 daha fazlaydı (p=0,001; sırasıyla: 4,13±1,92; 2,49±1,32). Koşu asimetrisi antrenman süresi, kalp atış hızı ortalaması, koşu mesafesi ve yüksek hızda koşu mesafesi ile anlamlı bir ilişki göstermedi (p> 0,050).

Tartışma: Koşu asimetrisi akşam antrenmanlarında sabah antrenmanlarına kıyasla daha yüksektir. Bu nedenle, özellikle yüksek yaralanma riski olan veya spora geri dönüş sürecinde olup yüksek performans beklenmeyen sporcular için, akşam antrenmanları yerine sabah antrenmanları tercih edilebilir. Eğer antrenmanlar sabah yapılamıyorsa, klinisyenler akşam antrenmanları süresince sporcuları anlık olarak takip etmelidir.

Anahtar Kelimeler: Sporcular, Alt ekstremite, Futbol, Teknoloji

INTRODUCTION

Soccer is one of the most popular sports in the world with more than 265 million athletes (1). Many soccer players are exposed to risk of injury. The incidence of injuries per 1000 hours of exposure is 3.7 in training and 36 in matches (2). These injuries affect team performance, and the health of athletes (3), and can cause economic consequences for the clubs and the players. Not only the healthcare costs of the injury, but also the fact that the athlete is not able to play in a match causes economic expense, even for elite level teams. It has been stated that the monthly cost of injured upper league soccer players is approximately € 500,000 (4). Determining the factors that may present a risk of injury and taking measures against them may reduce the incidence of injury, and contribute to the reduction of such a large economic expenditure for soccer clubs.

Training loads increase the risk of injury to soccer players (5). It is important for athletes, coaches, and the medical staff to reduce the risk of injury in soccer, and to plan the return to sports after injury. Reducing training injuries should be a special focus particularly for elite youth players (6). Factors that may pose a risk for injury should be identified and eliminated as far as possible. As soccer involves running at different intensities and in different directions, examining running asymmetry in training can provide significant benefit. Running asymmetry can be defined as the exposure of athletes to loads at different rates according to the right and left sides of their bodies during running. Since almost all physiological and biochemical processes in the human body follow the circadian rhythm, these asymmetries should be examined according to training at different times of the day.

In the last decade, Global Positioning System (GPS)-based assessments have been used to examine the running of soccer players. This system is field-based technology used to describe the running of athletes in team sports and has an acceptable level of accuracy and reliability for distance, and speed (7). GPS researches in the literature focuses on running distance, high-speed running distance and acute: chronic workload ratio rather than microtechnology sensor studies such as accelerometers (8,9). In these studies, the running performance in the matches is explained (10), evaluations are made in terms of injury risk (9), different sided games are examined (11) and running parameters are evaluated according to the game sequence and player position (12) However, as far as we know, there is no study in the literature that examines running asymmetry using GPS.

In this study, soccer, running and technology titles were gathered together to examine the training at different times of the day. The primary aim of this study was to compare running asymmetries of elite soccer players in morning and evening trainings. Secondarily, the correlations between running asymmetry and training time, heart rate average, running distance and high speed running distance parameters were examined.

METHODS

In this study, the data were evaluated retrospectively. However, measurements were taken routinely by researchers in the training periods. The independent variables of this study were morning and evening trainings. The dependent variables are running asymmetry, training time, heart rate average, running distance, and high speed running distance. All the study procedures were conducted in accordance with the principles of the Declaration of Helsinki. The ethical approval of study was granted by the University of Health Sciences Kanuni Education and Research Hospital Clinical Research Ethics Committee (Approval Date: 07.02.2019, and Approval Number: 2018-32).

Participants

Twenty-five elite male soccer players were included in this study. Four of them were excluded for being goalkeepers. Also, five athletes were not included because they did not have sufficient data selected according to the training criteria in the study. As a result, 16 players (age: 25.31±4.17 years, height: 182.5±6.86 cm, body weight: 79.48±5.73 kg, body mass index: 23.88±0.84 kg/m^2) met the required criteria. Before the measurements, the athletes were evaluated by an orthopedist and a sports physician. Athletes with any health problems were not allowed to participate in the training. In addition, the athletes who were in the process of returning to sports after injury were not allowed to participate directly in the training without fieldwork and evaluation with sport-specific tests. Athletes did not participate in any sporting activity other than trainings and matches.

Trainings

Trainings from September to December were examined. The data of training sessions held between 10.00-12.30 for morning training, and 18.00-20.30 for evening training were used. Players did not participate in the field training outside these hours. The training session lasted 60-90 minutes (warm up, training, cool down). But, GPS data were not recorded during warm-up (jogging, limb movements, short passing, passing, and so on) and cooling (jogging, stretching, and so on).

The content of all training sessions was determined by the coaches, and the trainings were carried out by them. However, the trainings to be examined within the scope of the current study were determined by the researchers according to the following rules: 1) morning and evening trainings with similar content (game, run, sprint) were included 2) if both morning and evening training sessions were held on the same day, the data for that day were not used so that fatigue caused by morning training would not affect evening training 3) the data of the training sessions performed one day before and after a match were not evaluated because they were generally at a low intensity (foot tennis, passing, jogging, and so on) 4) similarly, first trainings after long rest (>36 hour) were not included as they were not comprehensive, and 5) the trainings performed on the day after the match were not evaluated with the idea that it was regeneration training and the match fatigue could affect the results of the study

Of the 45 training examined, it was decided that 7 morning and 13 evening training sessions were suitable for the study. In order to have similar total duration of morning and evening trainings, seven evening trainings showing maximum homogeneity with seven morning trainings were randomly selected regardless of running asymmetries. Training details are shown in table 1.

Procedures

Training and running data were collected by GPS units (GPSports, SPI Pro, 5 Hz, GPSport, Canberra, Australia) measuring the forces on ground contact. According to the GPSsports quick start guide, "GPSports uses integrated GPS and accelerometer data to complete this analysis. The software identifies, quantifies, and compares the forces at ground contact (foot strike) on the right and left sides during running." Although there are some doubts, the validity and reliability of GPS tools have been shown in different studies (13-15).

Runnings above 10 km/h were examined in running asymmetry calculations. Asymmetry of seven morning and seven evening training sessions was recorded as % difference between left and right foot strikes. The positive value of the formula below was used for this. [(Right foot strike - Left foot strike)/left foot strike)] x 100 = asymmetry. According to the GPSsports quick start guide, "A score of '0' represents a symmetrical running. A '5% right' score reflects an asymmetrical stride, specifically a 5% greater load on the right side, compared with the left." In our study, the asymmetry between the extremities was recorded without distinguishing between left and right. The final result was obtained by taking the mean of the seven values.

Fourteen training session data were used together to evaluate the correlation between running asymmetry and training time, heart rate average, running distance and high speed running distance parameters.

Before the training session, the GPS units were turned on and held stationary outdoors to receive satellite signals (16), and each athlete was prepared by the analyst. The athletes wore a specially designed vest with the GPS fixed on the back of the vest. During the training session, the data of all the athletes were continuously monitored on a laptop. The measurements was followed by physiotherapist and analyst.

Statistical analysis

The data were evaluated with the SPSS 22.0 program (Statistical Package for Social Sciences Inc. Chicago, IL, USA). Firstly, the data were evaluated using histogram, coefficient of variation, Kurtosis, Skewness, Detrended plot graph and the Shapiro-Wilks test to determine whether the obtained

Table 1: Training Details.

Training		Time (min)	Heart Rate Average (bpm)	Running Distance (m)	High Speed Running distance (m)	Running Asymmetry (%)
Morning	1	36.90	150.40	3566.18±301.77	143.93±49.02	3.26±3.51
	2	57.40	135.13	5704.87±516.29	145.00±66.03	2.20±1.65
	3	44.97	132.00	3650.25±239.89	26.86±18.11	1.86±4.08
	4	78.00	140.93	6594.25±747.78	189.50±100.26	3.93±2.59
	5	64.93	137.13	4885.31±561.10	125.00±83.30	2.81±2.83
	6	69.00	138.20	5097.56±599.73	82.20±47.17	1.73±1.86
	7	59.90	122.21	2546.31±236.04	3.14±6.09	1.42±1.74
Evening	1	41.90	153.18	4061.43±424.70	213.31±110.34	4.12±3.79
	2	57.00	129.33	3728.73±933.85	82.33±26.82	4.86±5.18
	3	58.26	147.85	3987.71±363.81	63.00±37.96	3.42±3.79
	4	48.15	127.07	2923.30±1062.95	85.07±68.94	4.46±3.07
	5	72.58	126.56	4503.56±968.75	101.06±95.83	3.12±4.03
	6	70.95	139.60	5171.60±501.85	86.93±69.05	5.53±4.77
	7	61.96	134.56	6365.00±1258.39	173.68±108.11	3.87±3.11

Running distance and asymmetry data are reported as mean±standard deviation.

data showed normal distribution. As the data were normally distributed, the Paired-Samples T test was used. The relationship between running asymmetry and training time, heart rate avarage, running distance, high-speed running distance was evaluated with the Pearson correlation test. The confidence interval was taken as 95% throughout the statistical analyses. A value of p<0.05 was accepted as statisticlly significant. The power of the current study was calculated as 0.94 (G.Power 3.1.9.4 software; t test, difference between two dependent means; effect size: 0.96; error: 0.05, and sample size: 16).

RESULTS

It was observed that morning and evening training sessions were quite homogeneous regardless of heart rate average. Also, there were no statistical difference between morning and evening training in terms of total running distance. The high-speed running distance of the athletes in the evening training sessions were significantly higher than in the morning sessions (p=0.032) (Table 2). A statistically significant difference was found between the running asymmetry of morning and evening training sessions (p=0.001). Running asymmetry did not show any significant correlation with training time (r=0.055; p=0.852) heart rate average (r=0.234; p=0.420), total running distance (r=0.150; p=0.609), and high speed running distance (r=0.375 p=0.186).

DISCUSSION

The results of this study demonstrated that elite soccer players had more asymmetry in evening training sessions than the mornings. Also, there were no correlation between running asymmetry and training time, heart rate average, running distance and high speed running distance parameters. The human body experiences different biochemical and cardiovascular changes at different times of the day due to circadian rhythm. It has been previ-

Table 2: Comparison of Morning and Evening Training Data.

Training	Training Time (min)	Heart Rate Average (bpm)	Running distance (m)	High Speed Running Distance (m)	Running asymmetry (%)
Morning	58.89±0.67	136.54±6.67	4577.82±373.00	102.23±34.90	2.49±1.32
Evening	58.89±1.86	136.82±7.92	4445.30±444.85	118.15±40.60	4.13±1.92
p	0.994	0.833	0.129	**0.032***	**0.001***

*p<0.05. Data are reported as mean±standard deviation.

ously reported that athletes perform better in the evenings than in the mornings in respect of performance parameters such as agility, sprint, reactive force and jump (16-18). This situation is similar in terms of high speed running distance in our study. Although the total running distance in morning training is higher than in evening training, the high speed running distance is more in the evening in our study. In terms of running asymmetry, high-speed running distance is the only other parameter that differs between morning and evening trainings. Therefore, we consider that running asymmetry may increase with increasing high speed running distance. However, the lack of correlation between these two parameters in our study makes this situation confusing. This is similar for other research results in the literature.

From a biomechanical point of view, high-speed running increases the load on the knee joints (19). This also results in increased ankle plantar flexor moment, and increased biomechanical load in the hip extensor and knee flexor muscle groups in the terminal swing phase (20,21). Increased loads on the lower extremity may reflected in the increase in forces of ground contact measured by the GPS. Even if athletes run in the morning pattern, the load difference between the extremities may increase as the load increases in the evening. This may cause an increase in running asymmetry. But, in order to clearly demonstrate this situation, it is necessary to examine the loads on the support, and active feet according to the training tasks.

Studying the literature from a different perspective, we can see studies stating that high speed running does not cause an increase in running asymmetry. Girard et al. (22) compared well-trained runners' running at different speeds on the treadmill for one minute, and they stated that running speed did not affect lower extremity asymmetry. In a different study conducted on healthy male individuals, it was stated that the preferred running speed and ± 20% of this speed did not affect the asymmetry (23). In a study of Mo et al. (24), they were stated that running asymmetry decreases as speed increases from 8 to 12 km/h. The results of these studies are both similar and different with the results in our study. Considering that these studies evaluate running for a few minutes, and are not conducted in a chaotic environment such as training, it is understood that this issue should be viewed from a different perspective. Beato and Drust (25) showed that a different acceleration intensity (2.12 $m.s^{-2}$, 1.66 $m.s^{-2}$) affects the external and internal training load parameters. According to this research, increasing the intensity of acceleration increases the training load. Given that athletic performance may be higher in evening trainings, this supports why running asymmetry may be higher in evening tranings.

Changes in postural control are effective in terms of running asymmetry. Keeping these changes within certain limits during a dynamic activity such as running can prevent asymmetry between the extremities. However, it may not be possible for athletes to achieve equal postural control during morning and evening training sessions. In support of the current study, Gribble et al. (26) stated that the results obtained in the morning were better in terms of dynamic postural control than those obtained in the afternoon or evening. Heinbaugh et al. (27) showed similar results in terms of static balance. This may be due to better cognitive ability in the morning, which plays an important role in balance. The desire to achieve high performance with lower cognitive control in evening training sessions may cause loss of control over balance.

Finally, it may be necessary to mention that running asymmetry is not correlated with other parameters in our study. When examined in terms of running asymmetry and training time, Borghi et al. (12) explained that in the second half of the match, a significant decrease was observed in GPS variables such as running distance in all game positions. This prevents running asymmetry from occurring even if the training time increases. This situation is similar for heart rate average, total running distance and high speed running distance. For this reason, we recommend that researchers examine the trainings in sections for future studies. In addition, factors such as player position (12), playing formation (28), fatigue (29), task/procedures, loading protocol, anthropometry, fitness level, injury history (30) in training should be evaluated.

In conclusion, the findings from this study showed that there was more running asymmetry in evening training sessions. Therefore, especially for athletes who are at high risk of injury or who are in the process of returning to sports after rehabilitation, and from whom high performance is not expected, morning training sessions may be preferred instead of evening training sessions. If training can not be performed in the morning, clinicians should follow the athletes instantly during evening training. Considering the relationship between dynamic postural control and injuries, the results obtained in this study can be considered to contribute to the current literature, and programs related to training and rehabilitation. Since the results of this study were obtained from real training sessions of elite soccer players, they are of greater value to clinicians and researchers.

Sources of Support: None.

Conflict of Interest: There is no conflict of interest.

Ethical Approval: The ethical approval of the study was gathered from the Clinical Research Ethics Committee of the University of Health Sciences Kanuni Education and Research Hospital (Approval Date: 07.02.2019, Approval Number: 2018/32).

Informed Consent: Since this study is a retrospective archive research, an informed consent was not obtained.

Peer-Review: Externally peer-reviewed.

Author Contributions: Concept – ME, MK, UŞ, VBT; Design – ME, MK, UŞ, VBT; Supervision – ME, MK, UŞ, VBT; Resources and Financial Support – ME, MK, UŞ; Materials- MK; Data Collection and/or Processing – ME, MK, UŞ, VBT; Analysis and/or Interpretation – ME, MK, UŞ, VBT; Literature Research – ME, VBT; Writing Manuscript – ME, VBT; Critical Review – ME, MK, UŞ, VBT.

Acknowledgments: Part of this research was presented as a poster presentation at the IX. International Congress of Sports Physiotherapists and was published as an abstract in the Journal of Exercise Therapy and Rehabilitation. The authors thanks the soccer players, staff and club.

REFERENCES

1. FIFA. FIFA Big Count 2006: 270 million people active in football. FIFA Communications Division, Information Services. 2007;31:1–12.
2. López-Valenciano A, Ruiz-Pérez I, Garcia-Gómez A, Vera-Garcia FJ, De Ste Croix M, Myer GD, et al. Epidemiology of injuries in professional football: a systematic review and meta-analysis. Br J Sports Med. 2020;54(12):711-718.
3. Hägglund M, Waldén M, Magnusson H, Kristenson K, Bengtsson H, Ekstrand J. Injuries affect team performance negatively in professional football: An 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013;47(12):738–42.
4. Ekstrand J. Keeping your top players on the pitch : the key to football medicine at a professional level. Br J Sports Med. 2015;47(12):2013–16.
5. Watson A, Brickson S, Brooks A, Dunn W. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. Br J Sports Med. 2017;51(3):194-13.
6. Pfirrmann D, Herbst M, Ingelfinger P, Simon P, Tug S. Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review. J Athl Train. 2016;51(5):410-24.
7. Coutts AJ, Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. J Sci Med Sport. 2010;13(1):133-35.
8. Cummins C, Orr R, O'Connor H, West C. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. Sports Med. 2013;43(10):1025-42.
9. Kupperman N, Hertel J. Global Positioning System-Derived Workload Metrics and Injury Risk in Team-Based Field Sports: A Systematic Review. J Athl Train. 2020;55(9):931-943.
10. Palucci Vieira LH, Carling C, Barbieri FA, Aquino R, Santiago PRP. Match Running Performance in Young Soccer Players: A Systematic Review. Sports Med. 2019;49(2):289-318.
11. Clemente FM, Sarmento H, Rabbani A, Van Der Linden CMIN, Kargarfard M, Costa IT. Variations of external load variables between medium- and large-sided soccer games in professional players. Res Sports Med. 2019;27(1):50-59.
12. Borghi S, Colombo D, La Torre A, Banfi G, Bonato M, Vitale JA. Differences in GPS variables according to playing formations and playing positions in U19 male soccer players. Res Sports Med. 2020;1-15. Epub ahead of print.
13. Waldron M, Worsfold P, Twist C, Lamb K. Concurrent validity and test-retest reliability of a global positioning system (GPS) and timing gates to assess sprint performance variables. J Sports Sci. 2011;29(15):1613-19.
14. McLellan CP, Lovell DI, Gass GC. Performance analysis of elite Rugby League match play using global positioning systems. J Strength Cond Res. 2011;25(6):1703-10
15. Petersen C, Pyne D, Portus M, Dawson B. Validity and reliability of GPS units to monitor cricket-specific movement patterns. Int J Sports Physiol Perform. 2009;4(3):381-93.
16. di Cagno A, Battaglia C, Giombini A, Piazza M, Fiorilli G, Calcagno G et al. Time of Day – Effects on Motor Coordination and Reactive Strength in Elite Athletes and Untrained Adolescents. J Sci Med Sport. 2013;12(1):182-89.
17. López-Samanes Á, Moreno-Pérez D, Maté-Muñoz JL, Domínguez R, Pallarés JG, Mora-Rodriguez R, et al. Circadian rhythm effect on physical tennis performance in trained male players. J Sports Sci. 2017;35(21):2121-28.
18. Mhenni T, Michalsik LB, Mejri MA, Yousfi N, Chaouachi A, Souissi N, et al. Morning-evening difference of team-handball-related short-term maximal physical performances in female team handball players. J Sports Sci. 2017;35(9):912–20.
19. Petersen J, Sørensen H, Nielsen RØ. Cumulative Loads Increase at the Knee Joint With Slow-Speed Running Compared to Fast-

er Running: A Biomechanical Study. J Orthop Sports Phys Ther. 2015;45(4):316-22.

20. Petersen J, Nielsen RO, Rasmussen S, Sørensen H. Comparisons of increases in knee and ankle joint moments following an increase in running speed from 8 to 12 to 16km·h(-1.). Clin Biomech (Bristol, Avon). 2014;29(9):959-64.
21. Schache AG, Blanch PD, Dorn TW, Brown NA, Rosemond D, Pandy MG. Effect of running speed on lower limb joint kinetics. Med Sci Sport Exer. 2011;43(7):1260-71.
22. Girard O, Morin JB, Ryu J, Read P, Townsend N. Running Velocity Does Not Influence Lower Limb Mechanical Asymmetry. Front Sports Act Living. 2019;1:36.
23. Furlong LM, Egginton NL. Kinetic Asymmetry during Running at Preferred and Nonpreferred Speeds. Med Sci Sports Exerc. 2018;50(6):1241-1248.
24. Mo S, Lau FOY, Lok AKY, Chan ZYS, Zhang JH, Shum G, et al. Cheung RTH. Bilateral asymmetry of running gait in competitive, recreational and novice runners at different speeds. Hum Mov Sci. 2020;1-10.
25. Beato M, Drust B. Acceleration intensity is an important contributor to the external and internal training load demands of repeated sprint exercises in soccer players. Res Sports Med. 2021;29(1):67-76.
26. Gribble PA, Tucker WS, White PA. Time-of-day influences on static and dynamic postural control. J Athl Train. 2007;42(1):35-41.
27. Heinbaugh EM, Smith DT, Zhu Q, Wilson MA, Dai B. The effect of time-of-day on static and dynamic balance in recreational athletes. Sport Biomech. 2015;14(3):361-73.
28. Tierney PJ, Young A, Clarke ND, Duncan MJ. Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. Hum Mov Sci. 2016;49:1-8.
29. Garrett JM, Gunn R, Eston RG, Jakeman J, Burgess DJ, Norton K. The effects of fatigue on the running profile of elite team sport athletes. A systematic review and meta-analysis. J Sports Med Phys Fitness. 2019;59(8):1328-1338.
30. Heil J, Loffing F, Büsch D. The Influence of Exercise-Induced Fatigue on Inter-Limb Asymmetries: a Systematic Review. Sports Med Open. 2020;6(1):39.