Abstract

Purpose: The present study proposed to investigate the relationship between sleep quality and quantity and injuries in elite soccer players. A secondary aim was to compare sleep-wake variables and injury characteristics. **Methods:** The current investigation was a prospective cohort study of 23 elite male soccer players competing for two teams over 6 months in the highest level Brazilian competition. The players' sleep behaviour was monitored for 10 days in the pre-season using self-reporting sleep diaries and wrist activity monitors to determine sleep duration and quality. Furthermore, injuries were recorded by the respective club's medical teams into a specific database. Details of injuries recorded including the type, location and severity of each injury. The results were expressed as descriptive statistics, and the significance level was set at 5%. The Mann-Whitney Test (*U* test) was performed to compare the sleep variables between both groups. Spearman's correlation coefficient and linear regression analysis were used. **Results:** The results indicated a moderate negative correlation between sleep efficiency and particular injury characteristics, including absence time, injury severity and amount of injuries. The linear regression analysis indicated that 44% of the total variance in the amount of injuries (number) that can be explained by sleep efficiency, 24% of the total variance in the absence time after injury (days) that can be explained by sleep efficiency and 47% of the total variance in the injury severity that can be explained by sleep efficiency. **Conclusions:** Soccer players who exhibit lower sleep quality or non-restorative sleep show associations with increased amount and severity of musculoskeletal injuries.

Keywords: Sleep, injury, athlete, soccer, actigraphy.

Introduction

Sleep is a basic requirement for human health and given its restorative qualities is recognized as an important component of an athlete's recovery[1]. While both the quantity and quality of sleep are important, sleep quality remains an area lacking research focus when evaluating recovery of high-performance athletes[2,3]. Poor sleep quality is reported as common among athletes, particularly before competitions; for example, a study by Tuomilehto et al. reported that sleep problems are common in professional athletes, such as altered sleep-wake cycle and/or frequent late night social media usage[4]. Such sleep restriction is thought to have a significant impact on performance[5], as insufficient and non-restorative sleep can reduce athletic performance, causing a decline in implementing specific skills in sports[6].

In this context, a study conducted by Leproult and Van Cauter (2015) observed a reduction in testosterone levels of 10 to 15% after a sleep restriction protocol for 5 hours per night during one week in healthy men, thus demonstrating that sleep debt can negatively influence the musculoskeletal tissue[7]. Being that the quantity and quality of sleep interfere in performance and affect muscle recovery[6,8], changes occurring in these sleep variables may favor the appearance of musculoskeletal injuries[8]. The release of growth hormone, testosterone and cortisol occur during sleep as part of the processes regulating protein synthesis and degradation, which in turn assist in post-exercise muscle and metabolic recovery[7,9]. Thus, poor sleep quality is associate with the reduce of anabolic hormones, which in turn may compromise adaptation, integrity and growth muscle[9,10]. Although theoretical in concept, insufficient sleep has been reported in adolescent athletes and a recent study reports an association with an increased risk of sports injuries[11].

Injury in football is endemic and insidious in nature, with a multitude of factors contributing to injury etiology[12]. For example, Junge et al. (2004) analyzed the incidence of injuries in football during international competitions in a period of four years and registered 88.7 injuries every 1000 hours of gameplay[12]. Furthermore, 104 injuries were recorded in the 2014 FIFA World Cup, equivalent to 50.8 injuries every 1000 hours of gameplay[13]. It is concerning when poor recovery may be a contributing factor in athlete susceptibility[14]. For example, in a case study with one professional soccer athlete, Nédelec et al. (2017) reported that poor sleep quality was related to the occurrence of musculoskeletal injury[15]. Even though such case studies are speculative, the physiological rationale for poor sleep to interfere with physiological recovery is evident[8], but evidence for this association between sleep and injury is lacking in the literature.

Considering the above, it is necessary to prospectively investigate the association between objective measures of quality and quantity of sleep with the incidence of musculoskeletal injuries in soccer players. Thus, the present study proposed to investigate the relationship between sleep quality and quantity and injuries in elite soccer players. A secondary aim was to compare sleep-wake variables and injury characteristics between athletes with good and poor sleep quality.

Methods

The authors declare they do not have any potential conflict of interest in this study.

Subjects

All participants in the study gave their informed consent. This study was approved by the Ethical Committee of the *Universidade Federal de Minas Gerais* (*UFMG*) (Protocol number# 64492016.8.0000.5149). Forty-two (42) players from two clubs at the highest level of Brazilian competition were invited to participate in the study. Of these, seven players reported (regular conversation) some sleep disorder symptom or sleep complaints (insomnia, snoring and sleep apnoea), and twelve who did not use the actigraph correctly (less than 5 days). Thus, 19 were excluded from the analysis of the present study. Therefore, the current investigation was a prospective cohort study of 23 elite soccer players (Mean ± SD, age: 26.5 ± 5.2 years; height: 185 ± 6 cm; body mass: 74 ± 8.2 kg) over a period of six months. The researchers initially presented the technical details of the study to the players and gained informed consent following an outline of the procedures and the main investigator answered any questions. Regular informal conversations with the player and support staff at the club (sports scientists and medical staff) contributed to full adherence to the protocol.

Design

The study was conducted in the training centers of both soccer teams in the city of Belo Horizonte, MG, Brazil. Players were assessed for ten days in the pre-season (sleep wake-cycle) and injuries were evaluated over the next six months. The researchers initially held a talk for soccer players and for the technical commission on the study proposal and importance of the research. The procedures were started after direction by the team.

Methodology

Actigraphy

In the present study, the players's sleep behaviour was monitored using an *Actiwatch* 2 wrist activity monitor actigraph (*Philips Respironics*®, *Andover*, MA), which continuously measured the athletes' rest-activity or sleep-wake cycles (sleep/wake thresholds > 80 counts)[16]. The actigraph contains an internal accelerometer that registers body movements at regular intervals. Self-reporting sleep diaries were used to help the actigraph analysis. Recent studies have demonstrated a high correlation (0.81-0.92) between actigraphy and polysomnography[16]. Therefore, this instrument reliably registers sleep parameters and is agreed to be a tool to monitor the sleep of elite athletes[1,16]. The actigraph was worn on the non-dominant wrist of each athlete beginning on the first day of the assessment and remained there for 10 consecutive days. Athletes were instructed to use the actigraph during periods of rest and activity (awake time/24h), except when they were in training or taking a shower. The data collected at 60-second intervals were transferred to a computer and analyzed by the *Actiware* software (*Philips Respironics*®, *Andover,* MA). The analyzed variables were time awake, sleep duration, WASO (Wake After Sleep Onset), sleep efficiency and sleep latency.

Record of Musculoskeletal Injuries

A specific database for recording injury was created and completed in conjunction with the medical team of each team on the day of the athlete's injury. These data were collected in a similar way in both clubs, since the medical team pre-matched these data in the state of Minas Gerais for professional soccer players. An injury is defined as: any physical complaint sustained by a player that results from a soccer match or soccer training, irrespective of the need for medical attention or absence time from soccer activities. The current definition mirrors that employed by Fuller et al. (2006) for the consensus of injury definitions proposed for soccer players[17]. All injuries were categorised by injury type (description), body side (injury location) and mechanism of injury (traumatic or overuse), and whether the injury was a recurrence[17]. The amount of injuries, the injury severity, and the absence time of each athlete were also recorded for six months. The severity injury variables were classified by numbers (1, 2, 3, 4) as: minimal severity (0-3 days) = 1; mild severity (4-7 days) = 2; moderate severity (8-28 days) = 3; severe severity (>28 days) = 4.

Statistical Analysis

The athletes were separated into two groups for the statistical analysis: a group was composed of athletes with good sleep quality, and the other group was composed by athletes with poor sleep quality. The results were expressed as descriptive statistics for the data analysis: mean (M), error standard (SE), 95% confidence interval ($CI_{95\%}$), absolute frequency (%) and effect size (ES), and the significance level was set at 5% ($p < 0.05$). The Mann-Whitney Test (*U* test) was performed to compare the sleep variables (Time awake, sleep duration, sleep efficiency, sleep latency and WASO) between both groups (Poor sleep quality *vs.* Good sleep quality). Spearman's correlation coefficient was used to calculate the correlation between the following variables: sleep variables x injury severity, sleep variables x amount of injuries, and sleep variables x absence time after injury. Linear regression analysis was conducted to analyze the relationship between the sleep variables (Sleep efficiency and WASO) and injury variables (severity, amount of injuries and absence time after injury). The sleep variables (Sleep efficiency and WASO) were considered the independent variables, and severity and amount of injuries, and absence time after injury were considered the dependent variables. All statistical analyses were conducted using SPSS software for Windows, version 20.0.

Results

Our results indicated a moderate negative correlation between reduced sleep efficiency, the higher absence time after injury, severity and amount of injuries (Table 1). In contrast, the WASO variable presented positive moderate correlation with higher WASO, the higher severity and amount of injuries. Sleep latency also presented positive moderate correlation with amount of injuries, demonstrating higher sleep latency than the higher the amount of injuries (Table 1). However, no significant correlations were observed between time awake, sleep duration and any injury characteristic (Table 1).

TABLE 1

Linear regression analysis indicated that 44% of the total variance in the amount of injuries (number) that can be explained by sleep efficiency ($R^2 = 0.44$; $\beta = 0.06$). Likewise, 24% of the total variance in the absence time after injury (days) that can be explained by sleep efficiency ($R^2 = 0.24$; $\beta = 1.43$), and 47% of the total variance in the injury severity that can be explained by sleep efficiency

(R^2 = 0.47; β = 0.07). Additionally, 30% of the total variance in the amount of injuries (number) that can be explained by WASO (R^2 = 0.30; β = 0.02). The confidence limits (0.09, 0.03; 2.60, 0.26; 0.07, 0.02; 0.01, 0.04) respectively indicated a 95% confidence that the slope for the soccer players were between these limits, and the $F_{(1,23)}$ test = 16.77; $F_{(1,23)}$ test = 6.47; $F_{(1,23)}$ test = 18.92; $F_{(1,23)}$ test = 8.87 presented an associated probability level of $p < 0.01$; $p = 0.02$; $p < 0.01$; $p = 0.01$, respectively.

After the data analysis, we separated 23 soccer players into two groups based on the results of the data collected from the actigraphy (see below):

Good sleep quality (n = 5): (Sleep duration ≥ 7h; Sleep Efficiency > 85% and Sleep Latency < 30 minutes)[14,18].

Poor sleep quality (n = 18): (Sleep duration < 7h; Sleep Efficiency < 85% and Sleep Latency > 30 minutes)[14,18].

Tables 2 and 3 show the overall player data and the comparison of the sleep-wake cycle variables and injury characteristics of both groups (Good sleep quality *vs*. Poor sleep quality) of the elite soccer players. As expected, we found that poor sleep quality compared to good sleep quality presented significantly less sleep efficiency, higher sleep latency, severity and amount of injuries, and absence time after injury.

TABLE 2

TABLE 3

In relation to the amount of injuries, 21.7% of the athletes were injured once, 39.1% were injured twice, 34.8% were injured three times, and 4.3% were injured four times during the six months of injury recording. Overuse was the cause of most injuries (69.6%), and 30.4% were caused by specific trauma. The most frequent type of injury was muscle strain (overall n=28; good sleep quality n=1; poor sleep quality n=27); followed by knee contusion (overall n=3; good sleep quality n=3; poor sleep quality n=0); muscle fatigue of the lower limbs (overall n=9; good sleep quality n=0; poor sleep quality n=9); meniscal injury (overall n=2; good sleep quality n=0; poor sleep quality n=2); knee and ankle sprains (overall n=4; good sleep quality n=1; poor sleep quality n=3); acromioclavicular dislocation (overall n=3; good sleep quality n=0; poor sleep quality n=3); and nose fracture (overall n=2; good sleep quality n=0; poor sleep quality n=2).

Discussion

The results in the current study showed that reduced sleep quality was associated with the number of injuries, injury severity and longer absence time in these elite soccer athletes. Furthermore, players with poorer sleep quality showed greater absence time, greater severity and number of injury incidences when compared to the group with better sleep quality. Thus, low sleep efficiency, high sleep latency and sleep fragmentation in football players should be of concern for practitioners because it may have a relationship with injuries in soccer players.

In this sense, the group with good sleep quality showed a mean of 1.0 injuries in the six months, while the group with poor sleep quality showed a mean of 2.5 injuries, representing that good quality sleep and sufficient amount can reduce the risk of injury in athletes[19], in addition to other intrinsic and extrinsic factors, as well as provide an optimal physical and cognitive recovery. Furthermore, the group with poor sleep quality had a mean of 17.5 days of lost training and games, and the group with good sleep quality showed a mean of 5.0 days of absence, which representes injuries from mild to moderate severity, respectively[17]. In a study in animal models, Dattilo et al. (2011) hypothesized that sleep debt seems to affect the physiology of musculoskeletal tissues due to the increase in protein degradation and decreased protein synthesis. Muscle recovery seems to remain committed because these processes are regulated by anabolic hormones (testosterone and GH) and catabolic hormones (cortisol and myostatin) which are strongly influenced by sleep[20]. Athletes who do not have restorative sleep or of low quality do not enjoy the metabolic benefits of sleep, which can be decisive for sporting performance and injury prevention[21]. Studies performed with several athletes showed that periods next to the competitions tend to have negative impacts on the quality and duration of sleep[22].

A moderate negative correlation between sleep efficiency with the absence time, the severity and the amount of injuries was observed in the present study. In addition, a moderate positive correlation was found between WASO and severity and number of injuries, as well as positive moderate correlation between sleep latency and amount of injuries. Corroborating our findings, Luke et al. (2011) demonstrated that a night of sleep with less than or equal to 6 hours was associated to injuries caused by fatigue in athletes of different modalities, including soccer[23]. However, in the study by Milewski et al. (2014), it was demonstrated that athletes who slept less than 8 hours per night are 1.7 times more likely to get injured[11].

A linear regression analysis was performed in the present study, in which it was found that reduced sleep efficiency was negatively associated with three characteristics of injuries (amount of injuries, injury severity and absence time) of soccer players. In addition, greater WASO were negatively associated with the injury characteristics in soccer players. In spite of these variables presenting a cause-and-effect relationship with values from low to moderate correlation (44%, 23%, 47% and 30%), these numbers represent a considerable negative impact in clinical practice and sports. In addition to the physiological and behavioral impacts of sleep debt, a study in England showed that the average cost of an elite athlete away for a month to recover from an injury is approximately 50 thousand euros[24]. For this reason, and mainly in high performance sport where decisions on returning to competition and training have important financial consequences, it is necessary to detect musculoskeletal, psychomotor and behavioral factors related to risk of injury.

Sleep efficiency greater than or equal to 85% is considered an appropriate indicator of good sleep quality[22] for healthy individuals, which did not occur with poor sleep quality in the present sample (74.84%). In relation to sleep latency, only good sleep quality showed sleep latency within the recommended parameters (< 30 minutes)[18]. When comparing the groups, it can also be noted that poor sleep quality demonstrated greater difficulty in initiating sleep. However, both groups showed a greater awake time after sleep onset (Good sleep quality=29.4 minutes; Poor sleep quality=48.6 minutes) than is recommended by the scientific literature (≤ 20 minutes)[18].

Difficulty in initiating sleep and increased WASO (sleep fragmentation) may be signs of sleep disorders or non-restorative sleep, and may also cause losses in physical and cognitive performance[22]. Elite athletes usually have a high prevalence of insomnia complaints, shorter sleep duration and poor sleep quality when compared to non-athlete populations[1]. This fact can be a consequence of several environmental and psychobiological factors not evaluated in this study, such as high load of transmeridional training, travel, stress and anxiety before competitions[14]. In addition, it is common that Brazilian football games start around 09:45p.m.[25], extending the sleep of the players to much later, and consequently delaying their sleep phase. Sleep later than the usual time due to sports practice can cause a delay in melatonin hormone secretion[26] and delay the fall (nadir) of the central temperature. These changes in circadian schedule may occur due to light exposure at night and the increase in temperature during and immediately after physical exercise[27]; in this case after the game, thus hindering sleep onset in this population.

In relation to the awake-sleep cycle, good sleep quality presented a mean duration of sleep from 07h:40 minutes, while poor sleep quality presented 06h:20 minutes per night. There are different ranges of classification in relation to the total sleep time in the general population, which can be classified as: short sleepers who require about 6 hours of sleep per night; indifferent who vary from 6 to 8 hours of sleep per night; or long sleepers who require more than 8 hours of sleep per night[28]. Regarding athlete populations, recent studies suggest that they need to sleep around 9 to 10 hours for restorative sleep and good health[6,14], as long as they are not classificated as short sleepers. The reduction of total sleep time, the increase in the latency time and the increase in the number of WASO may impair the state of mood, increase fatigue and sleepiness, in addition to decreasing logical reasoning, decision making[3] and increase the risk of musculoskeletal injuries.

It is important to balance the stress of training and games with effective recovery[29] in elite athletes in soccer in order to have good performance within the team, as well as to reduce risk factors for injuries. Good quality sleep is one of the essential components of recovery due to its restorative effects[6], as well as anabolic and psychomotor consolidation[20,29]. Moreover, in an attempt to minimize the deleterious effects caused by a lack of sleep in the musculoskeletal system, resistance exercises in turn can be an effective strategy to reverse these deleterious effects, such as those observed in the study by Mônico-Neto et al. (2013)[8].

Sports injury is an emerging complex phenomenon and the risk factors of injury include non-linear relationships between various factors such as the biomechanics, training characteristics, as well as psychological and physiological aspects[30]. Therefore, some limitations of this study should be considered. First, psychological, hormonal and biomechanical aspects were not analyzed, and the training environment was not controlled. Furthermore, the athletes should be evaluated in an integral and complex way, analyzing the relationships between various predictors of injury[30], and also be evaluated in relation to the duration and quality of sleep.

Practical Applications

In order to prevent poor quality sleep from having an impact on musculoskeletal injuries in soccer athletes, it is necessary to:

- Conduct a multifactorial assessment of the risks for the incidence of musculoskeletal injuries through an evaluation of athletes' sleep;
- Implement strategies which improve the sleep quality of athletes for an effective recovery in order to provide good performance.

Conclusions

The present study has shown that the quality and quantity of sleep are associated with musculoskeletal injuries in elite football players, and may be important variables to evaluate. Further, reduced sleep efficiency and increased nighttime WASO culminated in greater absence time for sport practice, greater severity and higher incidence of musculoskeletal injuries in soccer players. Aditionally, the poor sleep quality group presented less sleep efficiency, higher sleep latency, severity and amount of injuries, and absence time after injury compared to the good sleep quality group. Therefore, it is important to emphasize the care in relation to sleep and injuries of athletes so that it does not influence training, the recovery process, the sports performance of the athlete or their team in competitions.

Acknowledgements

The authors want to thank the Universidade Federal de Minas Gerais (UFMG), Centro de Estudos em Psicobiologia e Exercício (CEPE), Centro Multidisciplinar em Sonolência e Acidentes (CEMSA), Fundo de Amparo à Pesquisa de Minas Gerais (FAPEMIG), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Pesquisa (CNPQ).

References

1. Leeder J, Glaister M, Pizzoferro K, Dawson J, Pedlar C. Sleep duration and quality in elite athletes measured using wristwatch actigraphy. *J Sports Sci*. 2012;30(6):541-545.
2. Rodrigues DF, Silva A, Rosa JPP, et al. Sleep quality and psychobiological aspects of Brazilian Paralympic athletes in the London 2012 pre-Paralympics period. *Motriz Rev Educ Fis*. 2015;21(2):168-176.
3. Silva A, Queiroz SS, Winckler C, et al. Sleep quality evaluation, chronotype, sleepiness and anxiety of Paralympic Brazilian athletes: Beijing 2008 paralympic games. *Br J Sports Med*. 2012;46(2):150-154.
4. Tuomilehto H, Vuorinen VP, Penttilä E, et al. Sleep of professional athletes: Underexploited potential to improve health and performance. *J Sports Sci*. 2017;35(7):704-710.
5. Fullagar HHK, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med*. 2014;45(2):161-186.
6. Bonnar D, Bartel K, Kakoschke N, Lang C. Sleep Interventions Designed to Improve Athletic Performance and Recovery: A Systematic Review of Current Approaches. *Sport Med*. 2018;48(3):1-21.
7. Leproult R. Effect of 1 Week of Sleep Restriction on Testosterone Levels in Young Healthy MenFREE. *JAMA*. 2015;305(21):2173-2174.
8. Mônico-Neto M, Antunes HKM, Dattilo M, et al. Resistance exercise: A non-pharmacological strategy to minimize or reverse sleep deprivation-induced muscle atrophy. *Med Hypotheses*. 2013;80(6):701-705.
9. Van Cauter E, Spiegel K, Tasali E, Leproult R. Metabolic consequences of sleep and sleep loss. *Sleep Med*. 2008;9 .
10. Prinz PN, Moe KE, Dulberg EM, et al. Higher Plasma IGF-1 Levels Are Associated With Increased Delta Sleep in Healthy Older Men. 1995;50(4):222-226.
11. Milewski MD, Skaggs DL, Bishop GA, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop*. 2014;34(2):129-133.
12. Junge A, Dvorak J, Graf-Baumann T, Peterson L. Football Injuries during FIFA Tournaments and the Olympic Games, 1998-2001: Development and Implementation of an Injury-Reporting System. *Am J Sports Med*. 2004;32.
13. Junge A, Dvořák J. Football injuries during the 2014 FIFA World Cup. *Br J Sports Med*. 2015;49(9):599-602.
14. Watson AM. Sleep and Athletic Performance. *Curr Sports Med Rep*. 2017;16(6):413-418.
15. Nédélec M, Leduc C, Dawson B, Guilhem G, Dupont G. Case study: sleep and injury in elite soccer. A mixed method approach. *J Strength Cond Res*. 2017.
16. Sargent C, Lastella M, Halson SL, Roach GD. The validity of activity monitors for measuring sleep in elite athletes. *J Sci Med Sport*. 2016;19(10):848-853.
17. Fuller CW, Molloy MG, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby

union. *Clin J Sport Med*. 2006;17(3):177-181.

18. Ohayon M, Wickwire EM, Hirshkowitz M, et al. National Sleep Foundation's sleep quality recommendations: first report. *Sleep Heal*. 2017;3(1):6-19.
19. Watson A, Brickson S. Impaired Sleep Mediates the Negative Effects of Training Load on Subjective Well-Being in Female Youth Athletes. 2018;10(3):244-249.
20. Dattilo M, Antunes HKM, Medeiros A, et al. Sleep and muscle recovery: Endocrinological and molecular basis for a new and promising hypothesis. *Med Hypotheses*. 2011;77(2):220-222.
21. Samuels C. Sleep, Recovery, and Performance: The New Frontier in High-Performance Athletics. *Phys Med Rehabil Clin N Am*. 2009;20(1):149-159.
22. Gupta L, Morgan K, Gilchrist S. Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sport Med*. 2017;47(7):1317-1333.
23. Luke A, Lazaro RM, Bergeron MF, et al. Sports-related injuries in youth athletes: Is overscheduling a risk factor? *Clin J Sport Med*. 2011;21(4):307-314.
24. Hägglund M, Waldén M, Ekstrand J. Risk factors for lower extremity muscle injury in professional soccer: The UEFA injury study. *Am J Sports Med*. 2013;41(2):327-335.
25. Alvito M. «A parte que te cabe neste latifúndio»: O futebol brasileiro e a globalização. *Anal Soc*. 2006;41(179):451-474.
26. Yamanaka Y, Hashimoto S, Tanahashi Y, Nishide S, Honma S, Honma K. Physical exercise accelerates reentrainment of human sleep-wake cycle but not of plasma melatonin rhythm to 8-h phase-advanced sleep schedule. *Am J Physiol Integr Comp Physiol*. 2010;298(3):681-691.
27. Atkinson G, Edwards B, Reilly T, Waterhouse J. Exercise as a synchroniser of human circadian rhythms: An update and discussion of the methodological problems. *Eur J Appl Physiol*. 2007;99(4):331-341.
28. Leng Y, Cappuccio FP, Wainwright NWJ, et al. Sleep duration and risk of fatal and nonfatal stroke: a prospective study and meta-analysis. *Neurology*. 2015;84(11):1072-1079.
29. Fullagar H, Skorski S, Duffield R, Meyer T. The effect of an acute sleep hygiene strategy following a late-night soccer match on recovery of players. *Chronobiol Int*. 2016;33(5):490-505.
30. Bittencourt NFN, Meeuwisse WH, Mendonça LD, Nettel-Aguirre A, Ocarino JM, Fonseca ST. Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition—narrative review and new concept. *Br J Sports Med*. 2016;50(21):1309-1314.