THE INFLUENCE OF SPORT-SPECIFIC FACTORS ON SLEEP QUALITY IN YOUNG ELITE ATHLETES: A COMPARATIVE STUDY

Alvaro De Pano-Rodriguez[1], Jose V. Beltran-Garrido[2], Vicens Hernadez-Gonzalez[1], Javier Bueno-Antequera[3,4], Miguel A. Oviedo-Caro[3,4], Carmen Mayolas-Pi[4], Alejandro Legaz-Arrese[4], and Joaquin Reverter-Masia[1]

[1]Faculty of Education, Psychology and Social Work, Department of Specific Didactics, University of Lleida, Lleida, Spain
[2]Department of Education Science, School of Humanities and Communication Sciences, Universidad Cardenal Herrera-CEU, CEU Universities, Calle Grecia 31, 12006 Castellon de la Plana, Spain
[3]Physical Performance & Sports Research Center, Department of Sports and Computer Science, Section of Physical Education and Sports, Faculty of Sports Sciences, University Pablo de Olavide, Seville, Spain
[4]Section of Physical Education and Sports, Faculty of Health and Sport Sciences, University of Zaragoza, Zaragoza, Spain

Abstract:

Sleep is a crucial physiological process that promotes human health and well-being. Physical activity and sports participation are known to improve sleep quality in adolescents. The objective was to investigate how the characteristics of different sports affected this relationship in elite athletes. This cross-sectional study analyzed data from 1,831 young Spanish elite athletes (1,059 males and 772 females) from 11 to 20 years old who self-reported their sleep quality using the Pittsburgh Questionnaire and provided information on their sports practice. Technical sports reported significantly better sleep quality than team sports ($p=.004$, $d=-0.39$, small). Additionally, individual competition sports reported better sleep quality than team competition sports ($p=.033$, $d=-0.15$, trivial). Differences by the type of metabolism were not statistically significant. Better sleep quality was reported in outdoors training environment sports compared to indoors training environment sports ($p=.023$, $d=-0.11$, trivial). The type of sports practiced may influence sleep quality in adolescents and highlights the importance of considering sport characteristics when promoting sleep health. Further research is necessary to explore the underlying mechanisms and to validate these findings across different age groups and populations.

Keywords: sleep quality, adolescents, elite sport, health, athletes

Introduction

Sleep is a vital physiological process that plays a crucial role in promoting human health and well-being (Maquet, 2001). It enables the body to undergo restorative processes, repair tissues, consolidate memories, and regulate biological functions. In children, adequate sleep is essential for growth, development, cognitive function, emotional well-being, and physical health (Hirshkowitz, et al., 2015). During sleep, the body releases growth hormones that facilitate the growth and repair of tissues, muscles, and bones (Van Cauter & Plat, 1996). Sufficient sleep has been shown to improve memory, attention, and learning, which is particularly important for students (Mason, Lokhandwala, Riggins, & Spencer, 2021).

On the other hand, lack of sleep has been associated with various health issues such as obesity, diabetes, cardiovascular disease, and immune system dysfunction (Hale & Guan 2015). Thus, obtaining enough sleep quality is crucial for maintaining overall health and reducing the risk of chronic diseases later in life. The term sleep quality is prevalent in sleep medicine, yet it encompasses

a multifaceted and challenging-to-objectively-measure phenomenon. It encompasses various quantitative aspects, such as total sleep time, sleep onset latency, sleep maintenance, total wake time, sleep efficiency, and, at times, sleep disruptive events like spontaneous arousal or apnea (Fabbri, et al., 2021). However, the factors influencing sleep quality may differ among individuals. Large-scale population surveys frequently rely on general inquiries regarding habitual sleep quality and the presence of sleep disturbances.

The existing body of academic literature provides compelling evidence supporting the beneficial impact of adequate sleep quality on the athletic performance and injury rates of youth athletes. Sufficient sleep duration and quality are associated with enhanced physical and cognitive abilities, leading to improved sports-related outcomes (Bonnar, Bartel, Kakoschke, & Lang, 2018). Moreover, ample sleep has been linked to reduced injury risks and faster injury recovery rates in this population (Viegas, et al., 2022). While the influence of sleep on sports in youth athletes has been extensively examined, there remains a notable gap in research regarding the reciprocal relationship: how sports engagement may affect the quality of sleep among young athletes. Investigating the bidirectional association between sports participation and sleep quality in this demographic would contribute significantly to our comprehensive understanding of the interplay between sleep and sports performance.

Parents and caregivers should prioritize creating a healthy sleep environment and establishing consistent sleep routines for children and adolescents to ensure optimal health and well-being. Emerging research has underscored the significance of adopting appropriate sleep behaviors to achieve optimal sleep quality among young individuals (Rebello, Roberts, Fenuta, Cote, & Bodner, 2022). In this context, sports engagement emerges as a compelling and intriguing factor that could potentially contribute to attaining proper sleep quality. Physical activity can assist in establishing a regular sleep schedule and promoting good sleep hygiene (Brand, et al., 2016). It can be a beneficial strategy as exercise helps regulate the body's circadian rhythm, the internal clock that controls the sleep-wake cycle (Haupt, et al., 2021). Regular physical activity has been associated with improved sleep patterns and duration in various age groups, including youth athletes (Kredlow, Capozzoli, Hearon, Calkins, & Otto, 2015). Exercise also promotes relaxation before bedtime, improves sleep quality, and reduces sleep latency (Kelley & Kelley, 2017; Reid, et al., 2010). Moreover, it has been observed to increase the duration of slow-wave sleep, which is the most restorative stage of sleep (Park, et al., 2021). Nevertheless, while there is promising evidence, additional systematic investigations are warranted to

comprehensively understand the extent to which physical activity can influence sleep behaviors and quality, thus fostering a better grasp of this intriguing association.

While it is generally acknowledged that physical activity and sports positively impact sleep quality in adolescents, recent research suggests that the higher the competition level, the better the sleep quality may be due to increased physical exertion and improved sleep hygiene linked to mental focus during competition (Pano-Rodriguez, et al., 2023). Therefore, it would be valuable to analyze how the characteristics of different sports mediate this positive influence on sleep quality. Factors such as the types of movements involved, the intensity and duration of the movements, and the social dynamics of competition and workouts could potentially influence sleep quantity and quality. Investigating these factors could provide insights into optimizing the sleep benefits of sports participation for adolescents.

One factor that may influence sleep quality in sports is the nature of social interactions involved in competition (team or individual sports). Social support has consistently been shown to have a positive impact on sleep quality and it reduces sleep disturbances (van Schalkwijk, Blessinga, Willemen, Van Der Werf, & Schuengel, 2015). Team sports, which involve collaboration and social support among group members, may have an even greater beneficial effect on sleep quality compared to individual sports or disciplines. However, negative interactions and conflicts within team sports could lead to heightened stress levels and potentially impact negatively sleep quality. Additionally, individual sports may also involve collaboration and social support among athletes, albeit in different ways. Further research should be done to examine the impact of variations in social interactions within sports on sleep outcomes.

The metabolic demands specific to each sport may also be a significant factor that strongly influences sleep quality in adolescent athletes. Different sports require varying levels and types of physical exertion, which may have distinct effects on the physiological and psychological mechanisms underlying sleep. Both aerobic and anaerobic metabolism have been shown to be effective in promoting sleep (Kovacevic, Mavros, Heisz, & Fiatarone, 2018). However, more studies are required to establish strong evidence regarding which type of metabolism is more effective in promoting sleep quality.

The impact of the training environment on sleep quality has not been extensively studied in scientific literature. Yet, it is an important factor of sports that may have significant implications for children's sleep health. Differences in light exposure due to factors such as indoor versus outdoor training facilities could affect sleep quality, as light plays a crucial role in regulating circadian rhythms

(Czeisler 2013). Future research should explore the relationship between the training environment and sleep quality to better understand their potential impact on athletes' well-being and performance.

In conclusion, various factors related to the nature of sports can influence sleep quality in practitioners, particularly adolescents for whom adequate rest is crucial. Therefore, this study aims to compare the sleep quality among young elite athletes participating in various sports disciplines.

Methods

Study design

This study was designed as a cross-sectional investigation based on self-reported data and was conducted following the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Clinical Research Ethics Committee of Aragón (PI17/0339). The presented results correspond to the baseline data collected between January and March 2018.

The study was widely disseminated by a group of volunteer independent evaluators who specialize in health sciences. Invitations were extended to all Spanish national and autonomous sports federations, high schools sports performance programs, and sports technification centers. Furthermore, 20 clubs per summer Olympic sports discipline were invited to participate, selected based on their ranking or performance level in national or international competitions among young athletes, and stratified by sex.

The study began with a concise and explicit introduction, which was followed by a thorough explanation of the various components of the questionnaires. To evaluate sleep quality, the Pittsburgh Questionnaire was utilized, as it has appropriate psychometric characteristics, including high internal consistency and test-retest reliability as well as convergent/divergent validity with sleep, psychological, and sociodemographic variables

(Fabbri, et al., 2021). For individuals, information regarding their sports involvement was collected by requesting information regarding the level of competition. In addition, participants reported their height and weight to calculate their body mass index. The participants were informed about the anonymous and voluntary nature of their participation and were given an unlimited amount of time to complete the questionnaires, which took an average of 40 minutes to complete.

Participants

The current investigation conducted a survey using a representative sample of Spanish children and adolescent elite athletes aged between 11 and 20 years. All participants were selected based on general inclusion criteria. These criteria required the absence of any chronic diseases as well as the engagement in elite training and competition for a sports discipline included in the Summer Olympic Games program for at least two days per week for a minimum of six months. Additionally, participants were required to compete in the highest national category for their age in their respective sports. Among a total of 1,836 potentially eligible participants, 1,831 adolescent elite athletes (1059 males and 772 females) were included in the study sample by completing the baseline evaluation and providing valid data for sleep quality, body composition, and physical activity, as depicted in Table 1. Based on the level of competition, 193 athletes competed at the international level, and 1638 athletes competed at the national level.

Outcomes

Sleep quality (Pittsburgh Questionnaire)

The Pittsburgh Sleep Quality Index (PSQI) is a reliable and valid screening tool used to assess sleep dysfunction in both clinical and non-clinical samples (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). It has been found to have moderate

Table 1. Sample characteristics

Variable	All (N =1831)	Male (n = 1059)	Female (n = 772)
Age (year) [a]	15.51±1.98	15.64±1.94	15.33±2.03
Tanner stage, I–V [b]	50 / 143 / 569 / 853 / 201	31 / 101 / 373 / 445 / 100	19 / 42 / 196 / 408 / 101
Height (cm) [a]	169.32±11.19	173.80±10.64	163.17±8.73
Weight (kg) [a]	59.75±13.08	64.06±13.39	53.8±9.98
BMI (kg·m^{-2}) [a]	20.64±3.00	21.02±3.03	20.12±2.89
Years of practice [a]	7.08±3.40	7.24±3.45	6.86±3.31
Hours per week [c]	10.00 (6.00–15.00)	10.00 (6.00–15.00)	10.00 (6.00–15.00)
Days per week [c]	5.00 (4.00–6.00)	5.00 (4.00–6.00)	5.00 (4.00–6.00)

Note. [a] Data are presented as mean (± SD), and differences between type-of-sport categories were examined by the analysis of the variance. [b] Data are presented as frequency (%), and differences between type-of-sport categories were examined by the independent-samples chi-square test. [c] Data are presented as median (IQR), and differences between type-of-sport categories were examined by the Kruskal-Wallis test.

structural validity across various populations, indicating that it is effective in fulfilling its intended purpose (Mollayeva, et al., 2016). The PSQI consists of 19 questions that cover seven components of sleep quality, including subjective sleep quality, sleep duration, sleep latency, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. Each of these components is rated on a 3-point scale, with higher scores indicating poorer sleep quality. The total score, which ranges from 0 to 21, is the sum of all component scores. This tool has been validated for use in assessing the sleep quality of adolescents as well (de la Vega, et al., 2015). The PSQI is a sensitive measure that can identify individuals with poor sleep quality, comparable to more invasive clinical and laboratory measures such as polysomnography. Good sleep quality was considered when PSQI Score≤5, while poor sleep quality was considered when PSQI Score>5.

Type of sport

The adapted classification system proposed by Sundgot-Borgen and Larsen (2007) was applied to differentiate between different types of sports, including endurance, power, team, racket, combat, gymnastic, and technical sports (see Table 1 in the supplemental material).

Type of competition

The adapted guidelines for coding sports as team or individual (Zhou, Heim, &O'Brien, 2015) were applied to classify the sports in the study. Team sports were differentiated into those with opponents and those without opponents based on whether the practitioners competed simultaneously on the same competition ground. Additionally, the study identified a group of athletes who indicated that they primarily competed both individually and in a non-opponent team sport (see Table 2 in the supplemental material).

Type of metabolism

This study applied the classification system proposed by Spencer, Bishop, Dawson, Goodman, and Duffield (2006) and Spencer and Gastin (2001), which categorizes sports based on their predominant metabolism into alactic, lactic, aerobic, and mixed metabolism. This system enabled a more comprehensive analysis of the physiological demands of each sport (see Table 3 in the supplemental material).

Training environment

A differentiation was made between sports that are typically trained and competed outdoors and those that are typically done indoors (see Table 4 in the supplemental material).

Control variables

To ensure the validity of the findings, the analysis controlled for several potential confounding factors such as sex, biological age, pubertal status (Petersen, et al., 1988), province where participant lives, number of population of the participants' zone of living, socioeconomic status (Moreno-Maldonado, Ramos, Moreno, & Rivera, 2019), physical activity level (Voss, Dean, Gardner, Duncombe, & Harris, 2017), years of training, hour per week of training, and days per week of training (McMahon, et al., 2017). The control variables were selected based on their known influence on the outcomes and their potential to impact the relationship between the independent and dependent variables. By accounting for these variables, the study aimed to isolate the effect of the independent variable on the dependent variables and reduce the risk of spurious associations.

Statistical analysis

Continuous variables are presented as mean (SD), and categorical variables are presented as absolute frequency. Normality distribution of the data was checked using the Kolmogorov-Smirnov test, the Anderson-Darling test, and exploring the Q-Q plots. Homogeneity was assessed by Levene's and Bartlett's tests. Data not following normal distribution were log-transformed (Hopkins, Marshall, Batterham, & Hanin, 2009) before further analysis.

To assess the effect of type of sport (endurance, explosive sport, team sport, racquet, combat sport, gymnastics, technical), type of competition (individual, team, team without opponent, individual and team without opponent), predominant metabolism of the sport (alactic, lactic, aerobic, mixed) and training environment (outdoors, indoors) on the sleep quality scores (PSQI), an analysis of covariance (*ANCOVA*), using sex, age, pubertal status, province, population, economic status, physical activity, years of experience, hours per week of training and days per week of training, values as covariates were used. When a significant difference was found between the groups, Bonferroni *post-hoc* tests were used to determine the source. Effect sizes were calculated using Cohen's *d* to further quantify between-group differences and were interpreted as: <0.2= *trivial*; 0.2-0.6=*small*; 0.6-1.2=*moderate*; 1.2-2.0=*large*; >2.0=*very large* (Hopkins, et al., 2009). Adjusted marginal means with 95% CI were reported.

The level of significance was set at 0.05 for all tests. All statistical analyses were performed using JAMOVI for Mac (version 2.3.22; Sidney, Australia; retrieved from https://www.jamovi.org) (The Jamovi project, 2022). Data are presented as mean (SD), median (Mdn), and the interquartile range (IQR) Q1 (25th)–Q3 (75th), or frequency, depending upon the type of data.
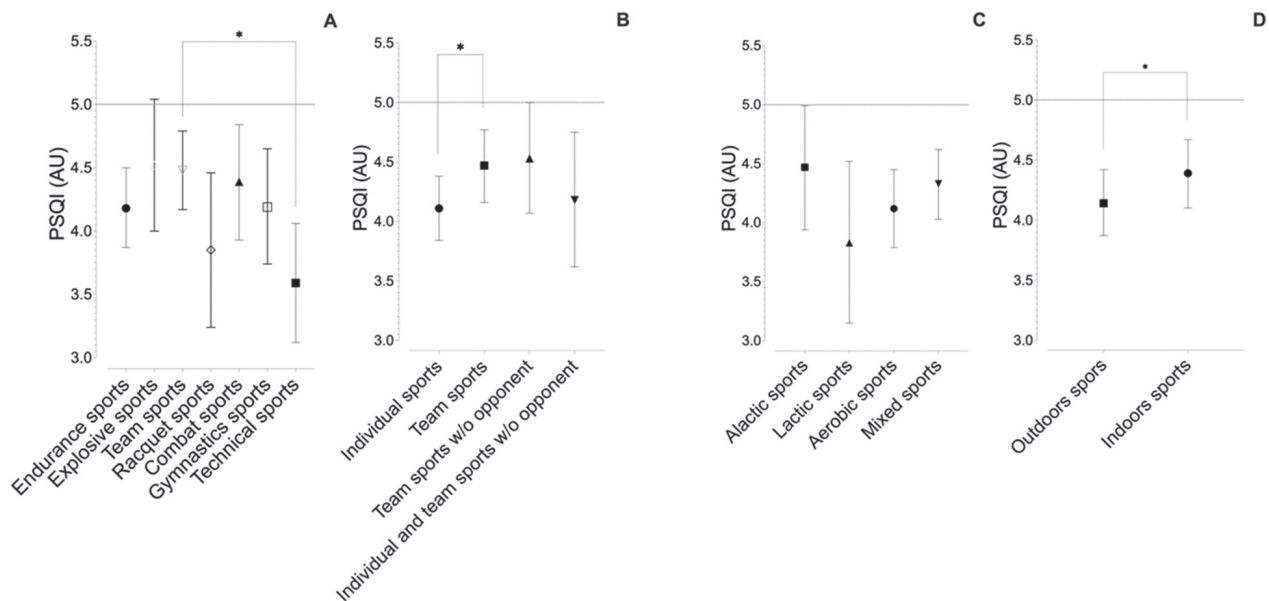
Note. Data are presented as adjusted means and 95% confidence interval. Estimated mean and 95% confidence intervals (CIs; error bars) represent values after adjusting by sex, age, pubertal status, province, population, economic status, physical activity, years of experience, hours per week of training and days per week of training of the participants. The dashed lines indicate the good/poor sleep quality threshold according to the Pittsburgh Sleep Quality Index questionnaire (PSQI). Good sleep quality: PSQI Score ≤5; poor sleep quality: PSQI Score>5. * Shows statistically significant differences between the categories (p Bonferroni ≤.05).

Figure 1. Differences in sleep quality by A) type of sport, B) type of competition, C) metabolism, and D) place of training.

Results

Sleep quality scores by the type of sport

Results for PSQI score by the type of sport are shown in Figure 1A and Table 5 (in the supplemental material). A total of 1,787 participants were included in this analysis due to different reasons detailed in Table 1 of the supplemental material. Statistically significant differences between the types of sports were reported (F=3.09, p=.005) and *post-hoc* test revealed lower PSQI scores in technical sports than in team sports (3.59 AU 95% *CI* [3.12, 4.06] vs. 4.48 AU 95% *CI* [4.17, 4.79], *p*=.004, *d*=- 0.39 95% *CI* [-0.59, -0.18], small).

Sleep quality scores by the type of competition

Results for PSQI score by the type of competition are shown in Figure 1B and Table 6 (in the supplemental material). The whole sample was included in this analysis. Statistically significant differences between the types of competition were reported (F=3.30, *p*=.020) and *post-hoc* test revealed lower PSQI scores in individual competition sports than in team competition sports (4.11 AU 95% *CI* [3.84, 4.38] vs. 4.47 AU 95% *CI* [4.16, 4.77], *p*=.032, *d* =- 0.15 95% *CI* [-0.26, -0.05], trivial).

Sleep quality scores by the type of metabolism

Results for PSQI score by the type of metabolism are shown in Figure 1C and Table 7 (in the

supplemental material). A total of 1,644 participants were included in this analysis due to different reasons explained in Table 3 (in the supplemental material). Non-statistically significant differences between the types of metabolism were reported (F=1.55, *p*=.200).

Sleep quality scores by the training environment

Results for PSQI score by the training environment are shown in Figure 1D and Table 8 (in the supplemental material). The whole sample was included in this analysis. Statistically significant differences between training environments were reported (F=4.63, *p*=.032) and *post-hoc* test revealed lower PSQI scores in outdoors training environment sports than in indoors training environment (4.14 AU 95% *CI* [3.87, 4.42] vs. 4.39 AU 95% *CI* [4.10, 4.67], *p*=.032, *d*=- 0.11 95% *CI* [-0.20, -0.01], trivial).

Discussion and conclusions

The present study aimed to investigate the influence of different sports on sleep quality among young elite athletes, with a focus on examining the potential mediating role of the type of competition, predominant metabolism of the sport, and training environment. Specifically, we sought to explore how the nature of different sports may impact sleep outcomes in this population and to identify potential underlying mechanisms that could help explain these effects. By examining these

factors, we aimed to gain a better understanding of the complex relationships between sports participation and sleep quality in adolescents and to identify potential avenues for promoting healthy sleep behaviors within this group. The results of this investigation suggest that adolescents who participate in elite sports generally exhibit good sleep quality, regardless of the specific nature of their sport. Previous analyses have even found a positive correlation between competition level and both sleep quality and regularity (Alves Facundo, et al., 2022; Pano-Rodriguez, et al., 2023).

In summary, our analysis revealed that sleep quality varies based on the type of sport, with higher sleep quality observed among individuals involved in technical sports compared to team sports. This may be attributed to the fact that technical sports, such as golf (57% of the total), horse riding, surfing, archery, and Olympic shooting, require a higher socioeconomic level, making them less accessible to the general population, especially adolescents. While we controlled for socioeconomic level statistically, it appears to be the clear reason for better sleep quality and other related factors such as nutritional aspects, etc. Another aspect that could explain these differences is that more than 90% of the subjects who compete in technical sports do their sports outdoors, which do not occur with the same percentage in other sports.

The results of this study showed that athletes participating in individual sports had better sleep quality than those in team sports, likely because technical sports are typically individual based. Different theories could explain why individual sports are associated with better sleep than team sports. One of them is that individual sports could imply higher aerobic metabolism and therefore more energy expenditure than team sports (in our database of 936 categorized individual athletes, 355 of them, or 37.9%, were also categorized as aerobic sports athletes; in contrast, none of the 668 categorized team sport athletes, or 0%, were categorized as aerobic sports athletes). This higher energy expenditure may lead to increased fatigue at bedtime, promoting better sleep quality. Furthermore, out of the 936 categorized individual athletes, 574 of them (61.3%) were also categorized as outdoor sports athletes. In contrast, only 245 out of the 668 categorized team sport athletes (36.7%) were categorized as outdoor sports athletes. These findings suggest that the main theory behind the significant differences in sleep quality between individual and team sports is associated, at least in part, with two controlled variables: type of metabolism and training environment.

Driller et al. (2022) obtained findings slightly differing from those of this study. The authors found that athletes involved in team sports exhibited lower sleep quality scores (1.1±0.6) compared to those engaged in individual sports (1.0±0.7), but they found no statistically significant difference between the groups (p=.38). Their results, different compared to ours, could be attributed to their considerably smaller sample size (N=407). Besides, it is important to consider that the average age of their sample was six years older than ours. The age difference between the two studies could potentially be a contributing factor to the variation in results, as age has been known to influence sleep patterns and behaviors among athletes.

Alves Facundo et al. (2022) found similar results to those in our study, despite using a different tool to assess the sleep. They observed better sleep parameters in individual sports in relation to sleep regularity in their cross-sectional study consisting of 172 athletes (25 ± 7 years) of different sports. Similar to our study, most of their sample were international and national athletes. Nevertheless, some new research needs to be done to deeply investigate the differences in sleep quality among young practitioners of team and individual sports and identify the factors that may influence their sleep patterns.

This study did not find any significant differences in sleep quality based on the predominant metabolism of the sports practiced. The mechanisms underlying the beneficial effects of aerobic and anaerobic exercise on sleep are not yet fully understood, but several hypotheses have been proposed. It seems that both of them could interfere with sleep by increasing levels of brain chemicals such as serotonin and endorphins (Di Liegro, Schiera, Proia, & Di Liegro, 2019), which are associated with improved mood and relaxation and may promote better sleep. Regarding aerobic exercise, it has been shown to have a cumulative effect on reducing cortisol levels, which can lead to long-term improvements in sleep quality (Beserra, et al., 2018; De Nys, et al., 2022). Concerning anaerobic exercise, it could potentially improve sleep by decreased symptoms of depression or anxiety, alterations in energy expenditure, increase in body temperature, or relief of musculoskeletal pain (Uchida, et al., 2012). Our results suggest a possible trend towards better sleep quality in sports with a higher prevalence of aerobic metabolism. This tendency is aligned with a review conducted by Vlahoyiannis et al. (2021), which found that athletes in anaerobic sports had slightly less rapid eye movement (REM) sleep compared to athletes in aerobic or mixed sports, based on sleep architecture.

Athletes training in outdoor environments showed significantly better sleep quality than those training in indoor facilities. A recent research established that low daytime light exposure is a noteworthy environmental variable that has been demonstrated to impact sleep and circadian rhythm negatively (Burns, et al., 2021). Low daytime light exposure refers to a lack of exposure to natural

light during the day, particularly in the morning and early afternoon (Khalsa, Jewett, Cajochen, & Czeisler, 2003). This can occur when individuals spend most of their time indoors or in dimly lit environments, such as office buildings or indoor training facilities. Therefore, engaging in indoor physical activity could potentially affect sleep quality in a less effective way than outdoor physical activity due to the reduced exposure to natural light.

While the present study does not directly explore the implications of sleep quality on athletic performance, we believe that a comprehensive understanding of the interplay between sleep and sports performance is integral. Research findings indicate that the extension of sleep duration yielded the most advantageous outcomes for subsequent performance. Adequate sleep has been extensively linked to various physiological and cognitive processes crucial for optimal athletic functioning, including muscle recovery, energy restoration, reaction times, and overall mental acuity (Bonnar, et al., 2018). Future research endeavors could delve into investigating how variations in sleep patterns, sleep duration, and sleep disturbances might impact the training, competition outcomes, and long-term development of young athletes. By considering both perspectives, we can gain a more holistic insight into the dynamic relationship between sleep and sports, thus enabling more informed recommendations for enhancing athletic achievement and overall well-being among youth athletes.

This study has notable strengths that increase confidence in the results. Specifically, the large sample size improves the accuracy of the findings, and the recruitment of participants from across the entire country provides insight into the sleep and physical habits of the entire Spanish elite youth population. However, there are also some limitations to consider. For instance, the study did not account for other factors that might affect the results, such as training schedules, nutrition, or screen time. Additionally, some might argue that the study lacked objective measurements of activity and sleep. Nevertheless, previous research has shown that subjective reports of sleep quality are reliable, and the methods used in this study to assess sleep quality have been validated (de la Vega, et al., 2015). One last limitation of the present study could be the omission of consideration for competition schedules when assessing athletes' sleep patterns. While the study aimed to comprehensively capture athletes' sleep behaviors in their daily lives, the exclusion of competitive events—a pivotal but limited aspect of athletes' routines—neglects potential disruptions to sleep quality that are well-documented in the literature. The impact of competitions on sleep quality is established, particularly within elite athletes. There-

fore, not accounting for competition-related sleep disturbances represents a limitation as it overlooks potentially unique sleep dynamics associated with these events.

To enhance the practical implications of our findings, we recognize the significance of exploring sport-specific sleep characteristics as a basis for targeted intervention strategies. Utilizing established tools like the Athlete Sleep Screening Questionnaire (ASBQ) by Samuels, James, Lawson, and Meeuwisse (2016) could offer a systematic approach to assess and manage sleep in elite athletes. By considering sport-specific sleep patterns and employing validated assessment tools, practitioners and researchers could tailor interventions to address unique sleep challenges within different sports. This approach could maximize the potential impact of our findings, providing a comprehensive framework to improve sleep quality and overall well-being among athletes.

In conclusion, adolescents who participate in elite sports generally exhibit good sleep quality, with higher sleep quality observed among individuals involved in technical and individual sports compared to team sports. However, no significant differences were found in sleep quality based on the predominant metabolism of the sports practiced. Athletes training in outdoor environments showed significantly better sleep quality than those training in indoor facilities. The findings of this study have several implications for promoting healthy and individualized sleep behaviors among young elite athletes. Firstly, coaches, parents, and healthcare professionals could consider encouraging talented adolescents with sleep disorders by increasing the opportunities for outdoor training, which may promote better sleep quality compared to indoor sports. Additionally, participating mainly in individual sports could have a positive impact on sleep.

Recognizing the relationship between modifiable sleep behaviors and sleep difficulty is crucial when considering our study's implications. Emerging evidence highlights the vital link between adaptable sleep habits and increased sleep difficulties (Mason, Stewart, Kniewasser, & Zech, 2022). This insight holds relevance for actionable insights in future research and for practitioners aiming to enhance sleep quality in athletes and the broader population. Identifying specific modifiable sleep behaviors linked to sleep difficulty informs intervention strategies and enhances the practical value of our findings. Acknowledging this dimension expands the potential impact of our study, guiding targeted interventions and evidence-based recommendations to promote improved sleep hygiene and overall well-being of the youth.

References

Alves Facundo, L., Brant, V.M., Guerreiro, R.C., Andrade, H. de A., Louzada, F.M., Silva, A., & Mello, M.T. de. (2022). Sleep regularity in athletes: Comparing sex, competitive level and sport type. *Chronobiology International*, *39*(10), 1381-1388. https://doi.org/10.1080/07420528.2022.2108716

Beserra, A.H.N., Kameda, P., Deslandes, A.C., Schuch, F.B., Laks, J., & Moraes, H.S.D. (2018). O exercício físico pode modular os níveis de cortisol em indivíduos com depressão? Uma revisão sistemática e metanálise. [Can physical exercise modulate cortisol level in subjects with depression? A systematic review and meta-analysis. In Portuguese.] *Trends in Psychiatry and Psychotherapy*, *40*, 360-368. https://doi.org/10.1590/2237-6089-2017-0155

Bonnar, D., Bartel, K., Kakoschke, N., & Lang, C. (2018). Sleep interventions designed to improve athletic performance and recovery: A systematic review of current approaches. *Sports Medicine* 48(3), 683703. doi: 10.1007/s40279-017-0832-x

Brand, S., Kalak, N., Gerber, M., Clough, P.J., Lemola, S., Pühse, U., & Holsboer-Trachsler, E. (2016). During early and mid-adolescence, greater mental toughness is related to increased sleep quality and quality of life. *Journal of Health Psychology*, *21*(6), 905-915. doi: 10.1177/1359105314542816

Burns, A.C., Saxena, R., Vetter, C., Phillips, A.J., Lane, J.M., & Cain, S.W. (2021). Time spent in outdoor light is associated with mood, sleep, and circadian rhythm-related outcomes: A cross-sectional and longitudinal study in over 400,000 UK Biobank participants. *Journal of Affective Disorders*, *295*, 347-352. doi: 10.1016/j.jad.2021.08.056

Buysse, D.J., Reynolds III, C.F., Monk, T.H., Berman, S.R., & Kupfer, D.J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. doi: 10.1016/0165-1781(89)90047-4

Czeisler, C.A. (2013). Perspective: Casting light on sleep deficiency. *Nature,* 497(7450), S13. doi: 10.1038/497S13a

De Nys, L., Anderson, K., Ofosu, E.F., Ryde, G.C., Connelly, J., & Whittaker, A.C. (2022). The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis. *Psychoneuroendocrinology*, *143*, 105843. doi: 10.1016/j.psyneuen.2022.105843

Di Liegro, C.M., Schiera, G., Proia, P., & Di Liegro, I. (2019). Physical activity and brain health. *Genes*, *10*(9), 720. doi: 10.3390/genes10090720

Driller, M.W., Suppiah, H., Rogerson, D., Ruddock, A., James, L., & Virgile, A. (2022). Investigating the sleep habits in individual and team-sport athletes using the Athlete Sleep Behavior Questionnaire and the Pittsburgh Sleep Quality Index. *Sleep Science*, *15*(1), 112-117. doi: 10.5935/1984-0063.20210031

Fabbri, M., Beracci, A., Martoni, M., Meneo, D., Tonetti, L., & Natale, V. (2021). Measuring subjective sleep quality: A review. *International Journal of Environmental Research and Public Health,* *18*(3), 1082. doi: 10.3390/ijerph18031082

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*, *21*, 50-58. doi: 10.1016/j.smrv.2014.07.007.

Haupt, S., Eckstein, M.L., Wolf, A., Zimmer, R.T., Wachsmuth, N.B., & Moser, O. (2021). Eat, train, sleep—retreat? Hormonal interactions of intermittent fasting, exercise and circadian rhythm. *Biomolecules*, *11*(4), 516. doi: 10.3390/biom11040516.

Hirshkowitz, M., Whiton, K., Albert, S.M., Alessi, C., Bruni, O., DonCarlos, L., ..., & Hillard, P.J.A. (2015). National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep health*, *1*(1), 40-43. doi: 10.1016/j.sleh.2014.12.010

Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-12. doi: 10.1249/MSS.0b013e31818cb278

Kelley, G.A., & Kelley, K.S. (2017). Exercise and sleep: A systematic review of previous meta-analyses. *Journal of Evidence-Based Medicine*, *10*(1), 26-36. doi: 10.1111/jebm.12236

Khalsa, S.B S., Jewett, M.E., Cajochen, C., & Czeisler, C.A. (2003). A phase response curve to single bright light pulses in human subjects. *The Journal of Physiology*, *549*(3), 945-952. doi: 10.1113/jphysiol.2003.040477

Kovacevic, A., Mavros, Y., Heisz, J.J., & Singh, M.A.F. (2018). The effect of resistance exercise on sleep: A systematic review of randomized controlled trials. *Sleep Medicine Reviews*, *39*, 52-68. doi: 10.1016/j.smrv.2017.07.002

Kredlow, M.A., Capozzoli, M.C., Hearon, B.A., Calkins, A.W., & Otto, M.W. (2015). The effects of physical activity on sleep: A meta-analytic review. *Journal of Behavioral Medicine*, *38*, 427-449. doi: 10.1007/s10865-015-9617-6

Maquet, P. (2001). The role of sleep in learning and memory. *Science,* 294(5544), 1048.1052. doi: 10.1126/science.1062856

Mason, G.M., Lokhandwala, S., Riggins, T., & Spencer, R.M. (2021). Sleep and human cognitive development. *Sleep Medicine Reviews*, *57*, 101472. doi: 10.1016/j.smrv.2021.101472

Mason, J., Stewart, A., Kniewasser, C., & Zech, A. (2022). Tracking sleep in the field: Sleep quality and sleep behaviours of elite track and field athletes during preparation and competition. *Journal of Sports Sciences*, *40*(24), 2741-2749. doi: 10.1080/02640414.2023.2191089

McMahon, E.M., Corcoran, P., O'Regan, G., Keeley, H., Cannon, M., Carli, V., ..., & Wasserman, D. (2017). Physical activity in European adolescents and associations with anxiety, depression and well-being. *European Child and Adolescent Psychiatry,* 26, 111-122. doi: 10.1007/s00787-016-0875-9

Mollayeva, T., Thurairajah, P., Burton, K., Mollayeva, S., Shapiro, C.M., & Colantonio, A. (2016). The Pittsburgh Sleep Quality Index as a screening tool for sleep dysfunction in clinical and non-clinical samples: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *25*, 52-73. doi: 10.1016/j.smrv.2015.01.009

Moreno-Maldonado, C., Ramos, P., Moreno, C., & Rivera, F. (2019). Direct and indirect influences of objective socioeconomic position on adolescent health: The mediating roles of subjective socioeconomic status and lifestyles. *International Journal of Environmental Research and Public Health*, *16*(9), 1637. doi: 10.3390/ijerph16091637

Pano Rodriguez, Á., Beltran-Garrido, J.V., Hernandez-Gonzalez, V., Bueno-Antequera, J., Oviedo-Caro, M.A., Mayolas Pi, C., Legaz-Arrese, A., & Reverter-Masia, J. (2023). Sleep quality is mediated by physical activity level in adolescents. *Journal of Sports Medicine and Physical Fitness, 63*. doi: 10.23736/S0022-4707.23.14494-X

Park, I., Díaz, J., Matsumoto, S., Iwayama, K., Nabekura, Y., Ogata, H., ..., & Vogt, K. E. (2021). Exercise improves the quality of slow-wave sleep by increasing slow-wave stability. *Scientific Reports*, *11*(1), 4410. doi: 10.1038/s41598-021-83817-6

Petersen, A.C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence*, *17*(2), 117-133. doi: 10.1007/BF01537962

Rebello, L.J., Roberts, A.W., Fenuta, A.M., Cote, A.T., & Bodner, M.E. (2022). Sleep quality and sleep behaviors in varsity athletes: A pilot study. *Frontiers in Sports and Active Living*, *4*, 906663. doi: 10.3389/fspor.2022.906663

Reid, K.J., Baron, K.G., Lu, B., Naylor, E., Wolfe, L., & Zee, P.C. (2010). Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. *Sleep Medicine*, *11*(9), 934-940. doi: 10.1016/j.sleep.2010.04.014

Samuels, C., James, L., Lawson, D., & Meeuwisse, W. (2016). The Athlete Sleep Screening Questionnaire: A new tool for assessing and managing sleep in elite athletes. *British Journal of Sports Medicine*, *50*(7), 418-422. doi: 10.1136/bjsports-2014-094332

Van Schalkwijk, F.J., Blessinga, A.N., Willemen, A.M., Van Der Werf, Y.D., & Schuengel, C. (2015). Social support moderates the effects of stress on sleep in adolescents. *Journal of Sleep Research*, *24*(4), 407-413. doi: 10.1111/jsr.12298

Spencer, M., Bishop, D., Dawson, B., Goodman, C., & Duffield, R. (2006). Metabolism and performance in repeated cycle sprints: Active versus passive recovery. *Medicine and Science in Sports and Exercise*, *38*(8), 1492-1499. doi: 10.1249/01.mss.0000228944.62776.a7

Spencer, M.R., & Gastin, P.B. (2001). Energy system contribution during 200- to 1500-m running in highly trained athletes. *Medicine and Science in Sports and Exercise*, *33*(1), 157-162. doi: 10.1097/00005768-200101000-00024

Sundgot-Borgen, J., & Larsen, S. (1993). Pathogenic weight-control methods and self-reported eating disorders in female elite athletes and controls. *Scandinavian Journal of Medicine and Science in Sports*, *3*(3), 150-155. doi: 10.1111/j.1600-0838.1993.tb00379.x

The jamovi project. (2022). *jamovi* (Version 2.3.22) [Computer Software]. Retrieved from https://www.jamovi.org

Uchida, S., Shioda, K., Morita, Y., Kubota, C., Ganeko, M., & Takeda, N. (2012). Exercise effects on sleep physiology. *Frontiers in Neurology*, *3*, 48. doi: 10.3389/fneur.2012.00048

Van Cauter, E., & Plat, L. (1996). Physiology of growth hormone secretion during sleep. *The Journal of Pediatrics*, *128*(5), S32-S37. doi: 10.1016/S0022-3476(96)70008-2

de la Vega, R., Tomé-Pires, C., Solé, E., Racine, M., Castarlenas, E., Jensen, M.P., & Miró, J. (2015). The Pittsburgh Sleep Quality Index: Validity and factor structure in young people. *Psychological Assessment*, *27*(4), e22. doi: 10.1037/pas0000128

Viegas, F., Ocarino, J.M., de Sousa Freitas, L., Pinto, M.C., Facundo, L.A., Amaral, A.S., ..., & Silva, A. (2022). The sleep as a predictor of musculoskeletal injuries in adolescent athletes. *Sleep Science*, *15*(03), 305-311. doi: 10.5935/1984-0063.20220055

Vlahoyiannis, A., Aphamis, G., Bogdanis, G.C., Sakkas, G.K., Andreou, E., & Giannaki, C. (2021). Deconstructing athletes' sleep: A systematic review of the influence of age, sex, athletic expertise, sport type, and season on sleep characteristics. *Journal of Sport and Health Science*, *10*(4), 387-402. https://doi.org/10.1016/j.jshs.2020.03.006

Voss, C., Dean, P.H., Gardner, R.F., Duncombe, S.L., & Harris, K.C. (2017). Validity and reliability of the Physical Activity Questionnaire for Children (PAQ-C) and Adolescents (PAQ-A) in individuals with congenital heart disease. *PloS One*, *12*(4), e0175806. doi: 10.1371/journal.pone.0175806

Zhou, J., Heim, D., & O'Brien, K. (2015). Alcohol consumption, athlete identity, and happiness among student sportspeople as a function of sport-type. *Alcohol and Alcoholism*, *50*(5), 617-623. doi: 10.1093/alcalc/agv030

Correspondence to:
Alvaro De Pano-Rodriguez, Ph.D.
Department of Exercise and Specific Didactics,
University of Lleida
Av. de I'Estudi General, 4, 25001 Lleida, Spain
Phone: 973 70 65 01
E-mail: alvaro.depano@udl.cat

SUPPLEMENTAL MATERIAL

Type of sport

Table 1. Classification of sports according to type of sport

Endurance sports (n = 512)	Calm water canoeing, cycling, long distance athletics running, middle-distance athletics running, race athletics walking, rowing, swimming, triathlon.
Explosive sports (n = 105)	Athletics combined events, athletics jumping events, athletics sprints (< 15 sec), athletics throwing events, weightlifting.
Team sports (n = 666)	Baseball, basketball, beach volleyball, field hockey, football, handball, rugby, volleyball, water polo.
Racquet sports (n = 65)	Badminton, table tennis, tennis.
Combat sports (n = 143)	Boxing, fencing, judo, karate, taekwondo, wrestling.
Gymnastic sports (n = 167)	Artistic gymnastics, artistic swimming, rhythmic gymnastics, trampoline gymnastics.
Technical sports (n = 129)	Archery, equestrian, golf, shooting, surfing.

Note. Out of the initial sample of participants, 44 subjects were excluded from the analysis for various reasons. 15 subjects who were competing in sailing and 13 subjects who were competing in whitewater canoeing were excluded because their sports could not be clearly categorized. Additionally, 12 subjects who were competing in athletics and 4 subjects who were competing in climbing were excluded because they primarily competed in sports that could fit into multiple categories depending on the specific type of sport.

Type of competition

Table 2. Classification of sports according to type of competition

Individual sports (n = 936)	Archery, artistic gymnastics, athletics, badminton, boxing, canoeing, climbing, cycling, equestrian, fencing, golf, judo, karate, rhythmic gymnastics, rowing, shooting, surfing, swimming, table tennis, taekwondo, tennis, trampoline gymnastics, triathlon, weightlifting, wrestling.
Team sports with opponents (n = 668)	Baseball, basketball, beach volleyball, field hockey, football, handball, rugby, volleyball, water polo.
Team sports without opponents (n = 142)	Flatwater canoeing, rhythmic gymnastics, rowing, sailing, synchronized swimming.
Individual and team sports without opponents (n = 85)	Flatwater canoeing, rhythmic gymnastics, rowing, synchronized swimming.

Type of metabolism

Table 3. Classification of sports according to their predominant metabolism

Alactic sports (n = 104)	Athletics combined events, athletics jumping events, athletics speed events (< 15 sec), athletics throwing events, weightlifting.
Lactic sports (n = 51)	Athletics speed events (15-60 sec), BMX cycling, calm water canoeing (15-60 sec), swimming speed events (15-60 sec).
Aerobic sports (n = 448)	Athletics long-distance events, athletics middle-distance events (> 60 sec), calm water canoeing (> 60 sec), mountain biking, race athletics walking, road cycling, rowing, swimming long-distance events, track cycling, triathlon.
Mixed sports (n = 1041)	Artistic gymnastics, badminton, baseball, basketball, beach volleyball, boxing, fencing, field hockey, handball, judo, karate, rhythmic gymnastics, rugby, soccer, synchronized swimming, taekwondo, tennis, trampoline gymnastics, volleyball, water polo, whitewater canoeing, wrestling.

Note. A total of 187 subjects were excluded from the analysis for various reasons, including: 15 subjects competing in archery, 15 subjects competing in equestrian, 73 subjects competing in golf, 15 subjects competing in sailing, 14 subjects competing in surfing, 12 subjects competing in shooting and 13 subjects competing in table tennis were excluded because their sports were deemed to have no direct relationship with metabolism as a determinant of sports performance. In addition, 16 subjects who competed in athletics and 10 subjects who competed in swimming were excluded because they primarily competed in sports modalities that could fit into multiple categories depending on the specific type of metabolism.

Training environment

Table 4. Classification of sports according to the training environment

Outdoors (n = 935)	Archery, athletics, baseball, BMX cycling, canoeing, equestrian, field hockey, football, golf, mountain biking, road cycling, rowing, rugby, sailing, surfing, tennis, triathlon.
Indoors (n = 896)	Artistic gymnastics, artistic swimming, badminton, basketball, boxing, fencing, handball, judo, karate, rhythmic gymnastics, shooting, swimming, table tennis, taekwondo, track cycling, trampoline gymnastics, volleyball, water polo, weightlifting, wrestling.

Table 5. Differences in sleep quality between the types of sport

Variable	Endurance sports (n = 512)	Explosive sports (n = 105)	Team sports (n = 666)	Racquet sports (n = 65)	Combat sports (n = 143)	Gymnastics sports (n = 167)	Technical sports (n = 129)
PSQUI (AU)	4.18 (3.87, 4.50)	4.52 (4.00, 5.04)	4.48 (4.17, 4.79)	4.18 (3.87, 4.50)	4.39 (3.93, 4.84)	4.19 (3.74, 4.65)	3.59 (3.12, 4.06) *S

Note. Data are presented as adjusted marginal mean (95% CI). * Shows statistically significant differences from the team sport category ($p \leq .05$). S small effect size. AU: arbitrary units.

Table 6. Differences in sleep quality between the types of competition

Variable	Individual sports (n = 936)	Team sports with opponents (n = 668)	Team sports without opponent (n = 142)	Individual and team sports without opponents (n = 85)
PSQUI (AU)	4.11 (3.84, 4.38) *T	4.47 (4.16, 4.77)	4.53 (4.07, 5.009)	4.18 (3.62, 4.75)

Note. Data are presented as adjusted marginal mean (95% CI). * Shows statistically significant differences from the team category ($p \leq .05$). T trivial effect size. AU: arbitrary units.

Table 7. Differences in sleep quality between the predominant metabolisms.

Variable	Alactic sports (n = 104)	Lactic sports (n = 51)	Aerobic sports (n = 448)	Mixed sports (n = 1041)
PSQUI (AU)	4.47 (3.94, 4.99)	3.83 (3.15, 4.52)	4.12 (3.79, 4.45)	4.33 (4.03, 4.62)

Note. Data are presented as adjusted marginal mean (95% CI). AU: arbitrary units.

Table 8. Differences in sleep quality between places of training

Variable	Outdoors sports (n = 935)	Indoors sports (n = 896)
PSQUI (AU)	4.14 (3.87, 4.42) *T	4.39 (4.10, 4.67)

Note. Data are presented as adjusted marginal mean (95% *CI*). * Shows statistically significant differences from the indoors category ($p \leq .05$). T trivial effect size. AU: arbitrary units.