Online version at https://www.minervamedica.it

The Journal of Sports Medicine and Physical Fitness 2023 mese;63(0):000–000
DOI: 10.23736/S0022-4707.23.14494-X

ORIGINAL ARTICLE
SECTION

Sleep quality is mediated by physical activity level in adolescents

Alvaro PANO-RODRIGUEZ [1] *, Jose V. BELTRAN-GARRIDO [2, 3], Vicens HERNADEZ-GONZALEZ [1], Javier BUENO-ANTEQUERA [4, 5], Miguel A. OVIEDO-CARO [4, 5], Carmen MAYOLAS-PI [5], Alejandro LEGAZ-ARRESE [5], Joaquin REVERTER-MASIA [1]

[1]Department of Specific Didactics, Faculty of Education, Psychology and Social Work, University of Lleida, Lleida, Spain; [2]Health and Sport Sciences University School (Euses), Rovira I Virgili University, Amposta, Spain; [3]Department of Education and Specific Didactics, Faculty of Humanities and Social Sciences, Universitat Jaume I, Castellón de La Plana, Spain. [4]Section of Physical Education and Sports, Department of Sports and Computer Science, Faculty of Sports Sciences, Physical Performance and Sports Research Center, University Pablo de Olavide, Seville, Spain; [5]Section of Physical Education and Sports, Faculty of Health and Sport Sciences, University of Zaragoza, Zaragoza, Spain

*Corresponding author: Alvaro Pano-Rodriguez, Department of Specific Didactics, Faculty of Education, Psychology and Social Work, University of Lleida, Av. de l'Estudi General 4, 25001 Lleida, Spain. E-mail: alvaro.depano@udl.cat

ABSTRACT

BACKGROUND: Sleep is essential for the adolescent's health and well-being. Despite existing evidence of the positive relationship between physical activity and quality of sleep, some other factors could mediate this association. The purpose of the present study was to clarify the interaction between the level of physical activity and sleep in adolescents depending on their gender.
METHODS: A total of 12,459 subjects 11 to 19 years old (5073 male and 5016 female) reported data regarding their quality of sleep and their level of physical activity.
RESULTS: Better quality of sleep was reported by males regardless of the level of physical activity (d=0.25, P<0.001). Better quality of sleep was reported by active subjects (P<0.05), and it improved in both sexes as the level of physical activity was higher (P<0.001).
CONCLUSIONS: Male adolescents have better sleep quality than females regardless of their competitive level. The higher the adolescents' physical activity level the higher the quality of sleep.

(*Cite this article as*: Pano-Rodriguez A, Beltran-Garrido JV, Hernadez-Gonzalez V, Bueno-Antequera J, Oviedo-Caro MA, Mayolas-Pi C, *et al.* Sleep quality is mediated by physical activity level in adolescents. J Sports Med Phys Fitness 2023;63:000-000. DOI: 10.23736/S0022-4707.23.14494-X)

KEY WORDS: Sleep quality; Adolescent; Exercise; Sports.

Sleep is a physiological process of crucial importance in the health and adequate physical-intellectual development of children and adolescents, widely affecting their quality of life/well-being.[1] This is especially true for young athletes, as sleep is also the gold standard recovery strategy.[2] An association has been observed between inadequate sleep and a wide variety of cardiometabolic diseases in adolescents.[3] Sleep plays an important role in the proper maturation of child's brain, existing solid evidence of the interrelation between brain development, sleep, and cognition.[4] Such is the importance of sleep, that research in sleep quality should be developed and appreciated. The term sleep quality is commonly used in sleep medicine although it represents a complex phenomenon hard to define and measure objectively. It can refer to a collection of quantitative aspects of sleep including Total Sleep Time, Sleep Onset Latency, sleep maintenance, Total Wake Time, Sleep Efficiency, and sometimes sleep disruptive events such as spontaneous arousal or apnea.[5] Nevertheless, the variables determining the quality of sleep could vary between individuals. Surveys to analyse large-scale populations are commonly based on general questions about ha-

bitual sleep quality and types of sleep disturbances. A very transcendental question in what a sleep quality measurement concerns, is that the rhythm of children's biological development is largely determined by sex differences. These differences trigger a complex interaction of gender in the subtypes of sleep problems.[6] Studies from multiple countries indicate that the increased prevalence of insomnia in women compared to age-matched men is a global phenomenon.[7] Poorer sleep in females than males could emerge after puberty suggesting that hormonal events underlying puberty may be involved.[8] The major gonadal steroids, testosterone in men and estrogens and progestins in women, could be implicated in the modulation of sleep behaviors.[9] Thus, studies analyzing sleep quality during youth should take into consideration this relevant biological parameter. Among the large number of interventions that have been proposed in the bibliography to optimize children's health, physical activity and sleep quality seem to be elements that are frequently taken into consideration. The unanimity on the results regarding the beneficial impact of both on youth health is eloquent.[10, 11] There is also evidence of the positive interrelation between these two important elements of children's growth and development, since physical activity may help to elicit adequate sleep strategies and habits such as earlier bedtimes, lengthen sleep duration, and increase sleep efficiency (ratio of total sleep time to time in bed).[12] For instance, due to its characteristics of discipline and social interaction promotion, in addition to high energy expenditure and physical conditioning, the practice of sports has been related to longer-lasting, quality sleep, bringing benefits to the quality of sleep and life of children and adolescents.[13] Thus, it has been established that adolescents with higher subjective and objective physical activity are more likely to experience good sleep subjectively and objectively.[14] Nevertheless, in what sleep concerns, some research should focus on the influence of peculiarities of competitive sports in contrast with other physical activities like recreational and leisure ones. In sports, as the competition level increases, the greater the responsibilities that the athlete must assume. High sports performance involves many commitments and pressures (*e.g.*, strict schedules, high training demands, competition, travel, stress, anxiety, pain, and muscle soreness).[15] In particular, little research, to our knowledge, has been done regarding the influence of the level of physical activity on the quality of sleep during youth. Moreover, the clear disparity in previous results implies the need for new research focusing on the relationship between sports' competitive level and sleep Saidi *et al.*[16] found that competitive season decreases sleep opportunity time and prevents elite adolescent rugby players from catching up on their sleep at weekends, resulting in a higher level of sleepiness. Along the same line, other researchers reported poor sleep outcomes in young high-competition athletes.[2, 17] On the other hand, another study found that sports practice did not alter sleep patterns,[18] while more controversially, some studies have observed better sleep outcomes in adolescent athletes than in the general adolescent population.[19-22] Taking this open line of research into consideration, it could be of big interest to analyze, in massive adolescent populations, the impact of gender and physical activity *versus* inactive life on sleep quality. Therefore, the objective of the present study was to assess the interrelation of physical activity and sleep quality, clarifying the interaction between the level of physical activity and sleep in young populations depending on gender, regardless of their sports discipline.

Materials and methods

Study design

This is a cross-sectional study based on self-report data conducted in accordance with the Declaration of Helsinki and approved by the committee Clinical Research Ethics of Aragón (PI17/0339). The results presented in this study belong to baseline data obtained between January and March 2018. The project was made known by a group of voluntary independent evaluators formed in health sciences. All secondary education centers in three representative provinces of Spain with a similar number of inhabitants were invited to participate in the study: Zaragoza (northern Spain), Seville (southern Spain), Alicante (coast of Spain). In order to recruit athletes who compete at the national/international level, all the Spanish national and autonomous sports federations, high schools sports performance, and sports technification centers were invited to participate in this study. There was also the participation of the 20 clubs of each sports discipline of the summer Olympics sports program with the highest level of performance, according to sex, in the categories corresponding to adolescence. The process included a brief and clear introduction to the study followed by an exhaustive explanation of the different items on the questionnaires. On one side, in order to assess sleep quality, Pittsburgh questionnaire was used since it englobes adequate psychometric properties, with high internal consistency and test-retest reliability, as well as convergent/divergent validity with sleep, psychological, and sociodemographic variables.[5] On the other side, to obtain information about their sports practice (in the case of non-sedentary

habits), subjects were requested to provide information about the level of competition they were involved in. Besides, height and weight of the participants were recorded to obtain their Body Mass Index. Subjects were instructed about the anonymous and voluntary nature of participation. They had no time limit to complete the forms. The questionnaires took an average of 40 minutes to be completed.

Participants

The present study surveyed a nationally representative sample of Spain's young children and adolescents aged 11 to 19 years old. All participants were recruited following the general inclusion criteria (enrolled in secondary school, free of any chronic disease, at least 2 days/week workouts in the least 6 months, and experience in training and competing in a sports discipline included in the program of the Summer Olympic Games). The whole sample was recruited following the general inclusion criteria (enrolled in secondary school and free of any chronic disease). Additionally, the athletes had to compete and train at least two days a week for at least the last six months. A total of 12459 subjects (5073 male and 5016 female) completed the baseline assessment with valid data for sleep, body composition, and physical activity (Table I).

Outcomes

Sleep quality and duration: Pittsburgh Questionnaire

Pittsburgh Sleep Quality Index (PSQI)[23] is a screening tool for sleep dysfunction in clinical and non-clinical samples with strong reliability and validity, and moderate structural validity in a variety of samples, suggesting the tool fulfills its intended utility.[24] This tool was validated to assess adolescents' sleep quality in young people.[25] It includes 19 questions on 7 components of sleep quality: subjective sleep quality, sleep duration, sleep latency, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. The 7 component scores are rated on a 3-point ascending scale, with 0 points indicating ideal sleep quality and 3 points indicating poor sleep quality. The global score of the PSQI is the sum of all component scores. The minimum possible score is 0, indicating ideal sleep quality, and the maximum possible score is 21, indicating poor sleep quality. The PSQI provides a sensitive measure to identify poor sleep quality if the total PSQI Score is >5,[24] comparable to clinical and laboratory measures (such as polysomnography). Therefore, we defined participants with total scores of 5 and below as "good sleepers," and those with total scores of 6 and above were defined as "poor sleepers."

Level of physical activity

Participants reported data concerning the level of physical activity by fulfilling the Physical Activity Questionnaire for Adolescents PAQ-A.[26] When reporting the practice of physical/sportive activity, they had to specify whether they were involved in competition or not. If so, they had to indicate which sentence was closer to their current level of competition": 1) I compete at a LOCAL and/or regional level, or 2) I compete at a national and/or international level.

Inactive

The subjects classified in our study as inactive were those who fulfilled these three conditions; 1) Not doing competitive sports; 2) Being categorized as having low levels of physical activity according to PAQ-A criteria, less than 3 points; and 3) Being categorized as having low levels of physical activity according to criteria: 0 to 2 days a week with at least 60 minutes of moderate and vigorous physical activity.[27]

Statistical analysis

Normality distribution of the data was checked using the Kolmogorov-Smirnov Test, the Anderson-Darling Test, and exploring the Q-Q plots. The homogeneity was as-

TABLE I.—*Frequencies of sex by competition level.*

Sex	Inactive	Non-competitive	Regional	Nationa/international
Male	272	1412	1882	1066
Female	719	1885	829	770

TABLE II.—*Participant's characteristics splitted by competition level and sex.*

	Inactive		Non-competitive		Regional		National/international	
	Male (N.=272)	Female (N.=719)	Male (N.=1412)	Female (N.=1885)	Male (N.=1882)	Female (N.=829)	Male (N.=1066)	Female (N.=770)
Age (y)	15.19±1.59	15.04±1.68	14.61±1.74	14.38±1.74	14.26±1.76	14.17±1.79	15.19±1.96	14.86±2.06
BMI (kg/m^2)	21.81±4.38	20.78±3.66	21.08±3.86	20.19±3.16	20.17±3.17	19.79±2.83	21.01±3.02	20.11±2.90
PSQI (AU)	5.09±2.78	5.57±2.82	4.57±2.62	5.25±2.90	4.02±2.50	4.46±2.67	3.79±2.37	4.48±2.75

Values are presented as mean±SD.
BMI: Body Mass Index; y: years; PSQI: Pittsburg Questionnaire Index; AU: arbitrary units.

sessed by Levene's and Bartlett's tests. Data not following normal distribution were log-transformed[28] before further analysis. To assess the effect of sex (Male, female) and level of physical activity (inactive, non-competitive, regional, national/international) on the sleep quality scores (PSQI) an analysis of covariance (ANCOVA), using age and Body Mass Index (BMI) values as covariates were used. When a significant difference was found between the groups, Tukey *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.[28] The level of significance was set at 0.05 for all tests. All statistical analyses were performed using JAMOVI for Mac (version 2.3.0; The Jamovi Project, Sidney, Australia).[29]

Results

The characteristics of the participants are presented in Table II. Results for PSQI Score by sex, by level of physical activity and by sex*physical activity are shown in Figure 1. Effect sizes of the different pairwise comparisons are shown in Figure 2. Adjusted means and effects sizes for sleep quality scores of different sexes and levels of physical activity are shown in Table III, IV, V. Statistically significant differences with a small effect size were reported between sexes. Females achieved higher PSQI Score than males (Figure 1A, 2; Table III). Statistically significant differences with a small effect size were reported between Inactive and Regional, and between Inactive and National/International levels of physical activity. The PSQI Scores were higher in inactive participants (Figure 1B, 2; Table IV). Statistically significant differences with a small effect size were reported between Non-competitive and Regional, and between Non-competitive and National/international levels of physical activity. The PSQI Scores were higher in Non-competitive participants (Figure 1B, 2; Table IV). Statistically significant differences with a small effect size were reported between Regional and National/International levels of physical activity. The PSQI Scores were higher in Regional participants (Figure 1B, 2; Table IV). Statistically significant differences with small effect sizes were reported between sexes in Non-competitive, Regional and National/International physical activity levels. The PSQI Scores were higher in Female participants (Figure 1C, 2; Table V).

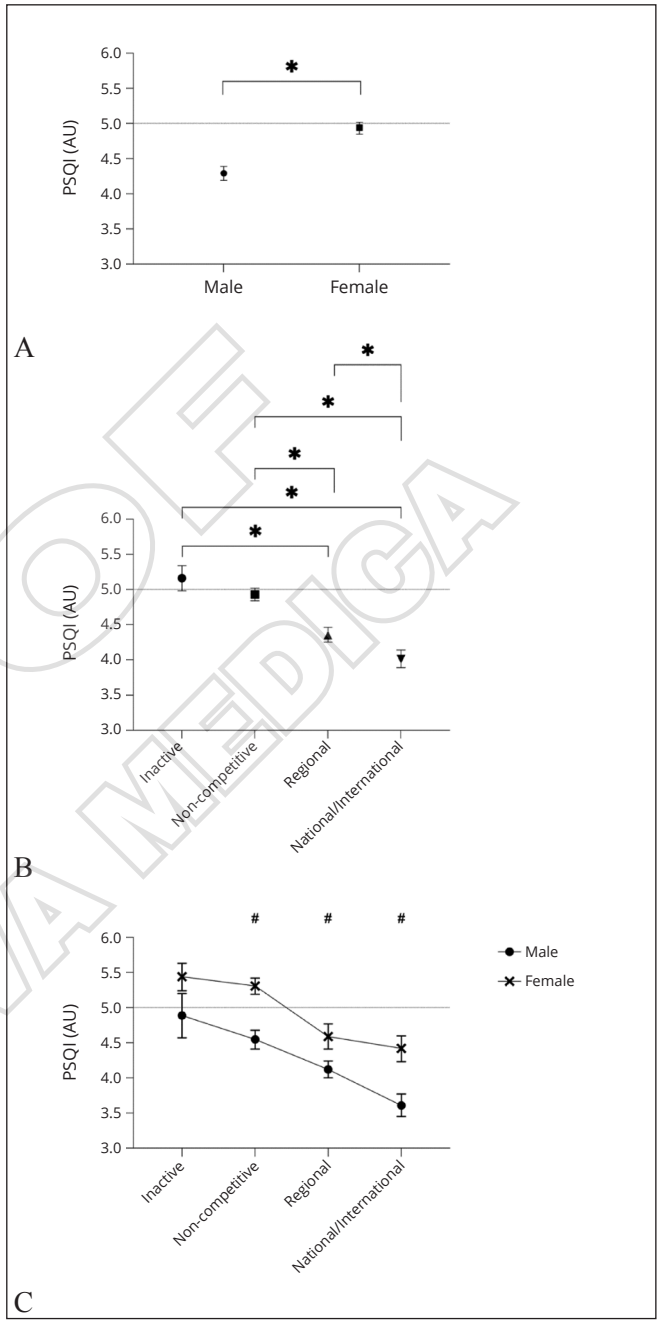

Figure 1.—Comparison of adjusted mean values of sleep quality scores by A) sex (male, female), by B) level of physical activity (inactive, non-competitive, regional, national/international) and by C) sex*physical activity.
Estimated mean and 95% confidence intervals (CIs; error bars) represent values after adjusting by Body Mass Index and age 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.
*P>Tukey<0.001 differences between levels; #PTukey 0.001 differences between sexes.

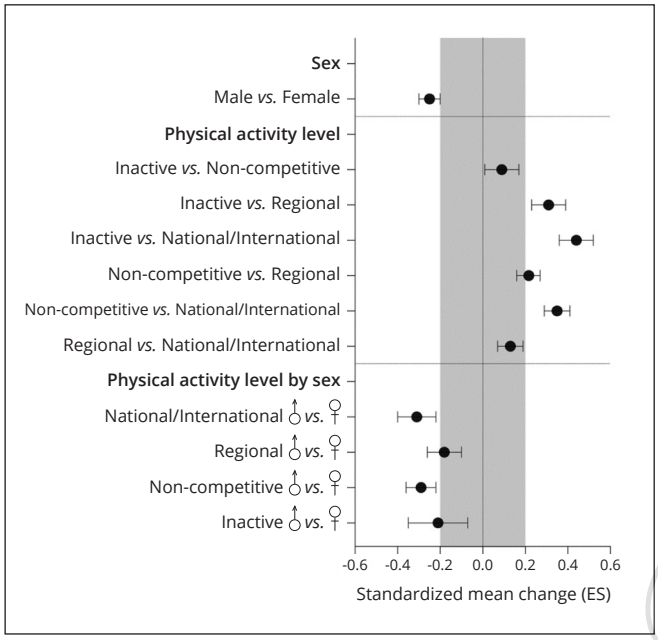

Figure 2.—Effect sizes and 95% confidence intervals values of the sleep quality scores comparing sexes and physical activity levels.
Values are presented as effect size (95% CI). Shaded grey area represents trivial effect size values from -0.20 to 0.20. Negative effect size values mean higher sleep quality scores for the condition of the right side and vice versa.

Discussion

The present study considered the relationship between physical activity and sleep in the young population. It also analyzed if the level of sports competition or gender had any influence on sleep quality. The main findings were that males showed better sleep quality than females (*d*=-0.25 [-0.30, -0.20]; Table III). This phenomenon occurs regardless of the competitive level they were involved (Figure 1C). Besides, those who practice physical activity no matter their level of competition, show better sleep quality than those who report an inactive lifestyle (Table IV; Figure 1B). In addition, national/international competitors showed better sleep quality than regional ones, and in turn, those showed better sleep quality than no competitors, and lastly, no competitors showed better sleep quality than inactive (Table IV; Figure 1B). Differences in sleep quality between sexes are something previously observed in the literature. Our results agree with those found in a recent review of Elkhatib Smidt *et al.*[30] who also conclude that those differences in sleep appear to emerge mainly in adolescence. Concerning young humans' self-reported research, even though few studies found no sex differences in sleep duration among adolescents,[31, 32] several studies have consistently observed shorter sleep duration among female adolescents.[33-37] In concordance with it, other researches analyzing sleep night awakenings also concluded that females show lower sleep efficiency than males[38-40] more trouble falling asleep/maintaining sleep,[40] and higher daytime sleepiness.[39] It is speculated that these sleep differences between sexes could be due to the unparallel development of sexes during adolescence. There are sex-specific patterns in terms of the timing of the growth spurt as well as age at skeletal maturity.[41] The rise in estrogen

TABLE III.—*Adjusted means and effect sizes for sleep quality scores of different sex groups.*

	Male	Female	P Tukey	*d* (95% CI)
$PSQI_{(AU)}$	4.29 (4.19, 4.39)	4.94 (4.85, 5.02)	<0.001	-0.25 (-0.30, -0.20)

Adjusted means and effect sizes for sleep quality scores of different sex groups. Sleep quality score values (PSQI) of both sexes are presented as estimated mean with 95% confidence interval.
d: Cohen's *d* effect size.

TABLE IV.—*Adjusted means and effect sizes for sleep quality scores of different levels of physical activity groups.*

	Inactive	Non-competitive	Regional	National/international
$PSQI_{(AU)}$	5.16 (4.98, 5.34)	4.93 (4.84, 5.02)	4.35 (4.25, 4.46)*#	4.01 (3.89, 4.14)*#^

Sleep quality score values (PSQI) of different levels of physical activity are presented as estimated mean with 95% confidence interval.
d: *Cohen's* d *effect size.*
*P Tukey <0.05 different from inactive group; #P Tukey <0.05 different from non-competitive group; ^PTukey <0.05 different from regional group.

TABLE V.—*Adjusted means and effect sizes for sleep quality scores of different sexes and levels of physical activity.*

Group	Male	Female	P Tukey	*d* (95% CI)
Inactive	4.89 (4.57, 5.20)	5.44 (5.24, 5.63)	0.065	-0.21 (-0,35, -0.07)
Non-competitive	4.55 (4.41, 4.68)	5.31 (5.19, 5.42)	<0.001	-0.29 (-0.36, -0.22)
Regional	4.12 (4.00, 4.24)	4.59 (4.41, 4.77)	<0.001	-0.18 (-0.26, -0.10)
National/international	3.61 (3.45, 3.77)	4.42 (4.23, 4.60)	<0.001	-0.31 (-0.40, -0.22)

Sleep quality score values (PSQI) of different sexes and levels of physical activity are presented as estimated mean with 95% confidence interval.
d: Cohen's *d effect size.*

concentrations that drives an increase in growth rate is an early feature of female puberty[42] since this natural sex hormon rise occurs during puberty between ages 9–14 years in males and 8–12 y in females youth.[43] In light of this information, it is reasonable to relate primary female sex hormones to sleep modulation.[44] In addition, further causes of these sleep sex differences could be the higher internalization of problems that females experience during adolescence.[45] The way in which females assumed the social role assigned to them and perhaps their greatest concern for being accepted by their peers[46] could affect their sleep more than it does on their counterparts. Nevertheless, it is fair to point out that through the bibliography, those differences between sexes on sleep quality are not as clear when drawing from actigraphy as it is in self-report data.[30] This divergence of results depending on the method measurement could be an indicator of gender-based perceptions about sleep, which enlights the enormous difficulty in the assessment of gender differences regarding sleep. The mechanism of the positive impact of physical activity on sleep quality could be based on the changes in neurotransmitters and biochemical processes.[12] It has been widely evidenced in previous studies which also contrasted the sleep between active and sedentary subjects.[12-14] The novelty of this study is the analysis of the influence of the different levels of competition in sports on sleep quality. While other studies had previously shown that implication on highly competitive sports had a positive impact on sleep quality,[19-22] the present study went one step further by determining the impact of the different levels of competition on sleep, observing that the higher the competition level is the more quality of sleep is detected. It occurs regardless of sex and age. These findings are controversial with those studies of athletes which have demonstrated increased levels of stress and anxiety around competition which are thought to impair sleep quality and duration, with a recent review reporting a prevalence of precompetition insomnia symptoms between 37% and 78% in elite athletes.[47] The divergence of our findings could be explained by the age of our sample. Most of it is made up of subjects in whose sports there is no professionalization at these ages, not even at an international level. This would relieve sensibly the mentioned stress and anxiety. Our results could be also explained by the fact that high-intensity exercise is also related to lower stress and increased mental health in adolescents.[21, 48] It has been affirmed that youth and collegiate athletes may experience, due to competition, additional threats to sleep duration and quality as a function of concomitant academic pressures additionally to sleep. It could be related to the simultaneous training and competition schedules, which would mean that athletes are required to sacrifice sleep time to fully accommodate academic and athletic commitments, such that younger athletes may be at an even greater risk of sleep deprivation.[49] However, the results found in our study are more aligned with Brand *et al*.[21] who found that high-performance athletes reported better sleep patterns including higher sleep quality, shortened sleep onset latency, and fewer awakenings after sleep onset, as well as less tiredness and increased concentration during the day. It could be assumed that the benefit of sleep as an essential component of recovery from and preparation for high-intensity training could probably motivate the sample of this study to establish good sleep habits. What is clear, is that the skills to confront efficaciously the psychological and physiological demands of high-performance sports are highly particular in each subject and might be mediated by the profound changes occurring during adolescence,[50] so its impact on sleep might be different between participants. In the present study, it could be supposed that the individual strategies adopted by adolescents could have mitigated the effects of high competition sports involvement.

Limitations of the study

This study has remarkable strengths, such as[1] the considerable size of its sample, which is a guarantee of the validity of the results obtained, and[2] the recruitment of individuals from all around the country, which allows the knowledge of the sleep and physical habits from the complete Spanish young population. However, certain limitations can be taken into consideration. First, the direction of causality between physical activity and sleep patterns could not be determined due to the cross-sectional design of the study. Also, this kind of design does not allow detect daily or weekly changes in sleep quality. Second, we did not consider other potential confounders in the analyses such as training schedules or caffeine consumption. Third, one might object that no objective activity or sleep data were collected. However, there is evidence that subjective sleep data from sleep logs fit well with sleep-electroencephalography recordings.[25]

Conclusions

The analysis of the interaction between sex and the level of competition on sleep quality in a big sample of adolescents shows that males have better sleep quality than females regardless of the competitive levels they were involved in. Besides, those who practice physical activity no

matter their level of competition, show better sleep quality than those who report an inactive lifestyle. In addition, the higher the level of competition, the more quality of sleep is detected. It occurs regardless of sex and age.

References

1. Matricciani L, Paquet C, Galland B, Short M, Olds T. Children's sleep and health: A meta-review. Sleep Med Rev 2019;46:136–50.

2. Vlahoyiannis A, Aphamis G, Bogdanis GC, Sakkas GK, Andreou E, Giannaki CD. Deconstructing athletes' sleep: A systematic review of the influence of age, sex, athletic expertise, sport type, and season on sleep characteristics. J Sport Health Sci 2021;10:387–402.

3. Quist JS, Sjödin A, Chaput JP, Hjorth MF. Sleep and cardiometabolic risk in children and adolescents. Sleep Med Rev 2016;29:76–100.

4. Mason GM, Lokhandwala S, Riggins T, Spencer RM. Sleep and human cognitive development. Sleep Med Rev 2021;57:101472.

5. Fabbri M, Beracci A, Martoni M, Meneo D, Tonetti L, Natale V. Measuring Subjective Sleep Quality: A Review. Int J Environ Res Public Health 2021;18:1082.

6. Chen YL, Tseng WL, Yang LK, Gau SS. Gender and Age Differences in Sleep Problems in Children: Person-Oriented Approach With Multigroup Analysis. Behav Sleep Med 2019;17:302–13.

7. Grewal R, Doghramji K. Epidemiology of Insomnia. In: Attarian HP, Schuman C, editors. Clinical Handbook of Insomnia. Totowa, NJ: Humana Press; 2010. p.13–22.

8. Mong JA, Cusmano DM. Sex differences in sleep: impact of biological sex and sex steroids. Philos Trans R Soc Lond B Biol Sci 2016;371:20150110.

9. Lord C, Sekerovic Z, Carrier J. Sleep regulation and sex hormones exposure in men and women across adulthood. Pathol Biol (Paris) 2014;62:302–10.

10. Hosker DK, Elkins RM, Potter MP. Promoting Mental Health and Wellness in Youth Through Physical Activity, Nutrition, and Sleep. Child Adolesc Psychiatr Clin N Am 2019;28:171–93.

11. Saunders TJ, Gray CE, Poitras VJ, Chaput JP, Janssen I, Katzmarzyk PT, *et al.* Combinations of physical activity, sedentary behaviour and sleep: relationships with health indicators in school-aged children and youth. Appl Physiol Nutr Metab 2016;41:S283–93.

12. Master L, Nye RT, Lee S, Nahmod NG, Mariani S, Hale L, *et al.* Bidirectional, Daily Temporal Associations between Sleep and Physical Activity in Adolescents. Sci Rep 2019;9:7732.

13. Rosa CC, Tebar WR, Oliveira CB, Farah BQ, Casonatto J, Saraiva BT, *et al.* Effect of Different Sports Practice on Sleep Quality and Quality of Life in Children and Adolescents: Randomized Clinical Trial. Sports Med Open 2021;7:83.

14. Lang C, Kalak N, Brand S, Holsboer-Trachsler E, Pühse U, Gerber M. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. Sleep Med Rev 2016;28:32–45.

15. Lopes Dos Santos M, Uftring M, Stahl CA, Lockie RG, Alvar B, Mann JB, *et al.* Stress in Academic and Athletic Performance in Collegiate Athletes: A Narrative Review of Sources and Monitoring Strategies. Front Sports Active Living 2020;2:42.

16. Saidi O, Pereira B, Peyrel P, Maso F, Doré E, Rochette E, *et al.* Sleep pattern and staging in elite adolescent rugby players during the in-season competitive phase compared to an age matched non-athlete population. Eur J Sport Sci 2022;22:499–510.

17. Fox JL, Scanlan AT, Stanton R, Sargent C. Insufficient Sleep in Young Athletes? Causes, Consequences, and Potential Treatments. Sports Med 2020;50:461–70.

18. Beltran-Valls MR, García Artero E, Capdevila-Seder A, Legaz-Arrese A, Adelantado-Renau M, Moliner-Urdiales D. Regular Practice of Competitive Sports Does Not Impair Sleep in Adolescents: DADOS Study. Pediatr Exerc Sci 2018;30:229–36.

19. Brand S, Gerber M, Beck J, Hatzinger M, Pühse U, Holsboer-Trachsler E. Exercising, sleep-EEG patterns, and psychological functioning are related among adolescents. World J Biol Psychiatry 2010;11:129–40.

20. Brand S, Beck J, Gerber M, Hatzinger M, Holsboer-Trachsler E. 'Football is good for your sleep': favorable sleep patterns and psychological functioning of adolescent male intense football players compared to controls. J Health Psychol 2009;14:1144–55.

21. Brand S, Gerber M, Beck J, Hatzinger M, Pühse U, Holsboer-Trachsler E. High exercise levels are related to favorable sleep patterns and psychological functioning in adolescents: a comparison of athletes and controls. J Adolesc Health 2010;46:133–41.

22. Harris A, Gundersen H, Andreassen PM, Thun E, Bjorvatn B, Pallesen S. A Comparative Study of Sleep and Mood Between Young Elite Athletes and Age-Matched Controls. J Phys Act Health 2017;14:465–73.

23. Mollayeva T, Thurairajah P, Burton K, Mollayeva S, Shapiro CM, Colantonio A. 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 Med Rev 2016;25:52–73.

24. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193–213.

25. de la Vega R, Tomé-Pires C, Solé E, Racine M, Castarlenas E, Jensen MP, *et al.* The Pittsburgh Sleep Quality Index: validity and factor structure in young people. Psychol Assess 2015;27:e22–7.

26. Voss C, Dean PH, Gardner RF, Duncombe SL, Harris KC. Validity and reliability of the Physical Activity Questionnaire for Children (PAQ-C) and Adolescents (PAQ-A) in individuals with congenital heart disease. PLoS One 2017;12:e0175806.

27. McMahon EM, Corcoran P, O'Regan G, Keeley H, Cannon M, Carli V, *et al.* Physical activity in European adolescents and associations with anxiety, depression and well-being. Eur Child Adolesc Psychiatry 2017;26:111–22.

28. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009;41:3–13.

29. The Jamovi Project. Jamovi; 2022 [Internet]. Available from: https://www.jamovi.org/ [cited 2023, Jan 12]

30. Elkhatib Smidt SD, Hitt T, Zemel BS, Mitchell JA. Sex differences in childhood sleep and health implications. Ann Hum Biol 2021;48:474–84.

31. Williams JA, Zimmerman FJ, Bell JF. Norms and trends of sleep time among US children and adolescents. JAMA Pediatr 2013;167:55–60.

32. Mitchell JA, Rodriguez D, Schmitz KH, Audrain-McGovern J. Sleep duration and adolescent obesity. Pediatrics 2013;131:e1428–34.

33. Short MA, Gradisar M, Lack LC, Wright H, Carskadon MA. The discrepancy between actigraphic and sleep diary measures of sleep in adolescents. Sleep Med 2012;13:378–84.

34. Keyes KM, Maslowsky J, Hamilton A, Schulenberg J. The great sleep recession: changes in sleep duration among US adolescents, 1991-2012. Pediatrics 2015;135:460–8.

35. Bauducco SV, Flink IK, Jansson-Fröjmark M, Linton SJ. Sleep duration and patterns in adolescents: correlates and the role of daily stressors. Sleep Health 2016;2:211–8.

36. Seo WH, Kwon JH, Eun SH, Kim G, Han K, Choi BM. Effect of socio-economic status on sleep. J Paediatr Child Health 2017;53:592–7.

37. Lewin DS, Wang G, Chen YI, Skora E, Hoehn J, Baylor A, *et al.* Variable School Start Times and Middle School Student's Sleep Health and Academic Performance. J Adolesc Health 2017;61:205–11.

38. Hysing M, Pallesen S, Stormark KM, Lundervold AJ, Sivertsen B. Sleep patterns and insomnia among adolescents: a population-based study. J Sleep Res 2013;22:549–56.

39. Matthews KA, Hall M, Dahl RE. Sleep in healthy black and white adolescents. Pediatrics 2014;133:e1189–96.

40. Vollmer C, Jankowski KS, Díaz-Morales JF, Itzek-Greulich H, Wüst-Ackermann P, Randler C. Morningness-eveningness correlates with sleep time, quality, and hygiene in secondary school students: a multilevel analysis. Sleep Med 2017;30:151–9.

41. Nahhas RW, Sherwood RJ, Chumlea WC, Towne B, Duren DL. Predicting the timing of maturational spurts in skeletal age. Am J Phys Anthropol 2013;150:68–75.

42. Wood CL, Lane LC, Cheetham T. Puberty: normal physiology (brief overview). Best Pract Res Clin Endocrinol Metab 2019;33:101265.

43. Abreu AP, Kaiser UB. Pubertal development and regulation. Lancet Diabetes Endocrinol 2016;4:254–64.

44. Mong JA, Cusmano DM. Sex differences in sleep: impact of biological sex and sex steroids. Philos Trans R Soc Lond B Biol Sci 2016;371:20150110.

45. Bor W, Dean AJ, Najman J, Hayatbakhsh R. Are child and adolescent mental health problems increasing in the 21st century? A systematic review. Aust N Z J Psychiatry 2014;48:606–16.

46. Guyer AE, Caouette JD, Lee CC, Ruiz SK. Will they like me? Adolescents' emotional responses to peer evaluation. Int J Behav Dev 2014;38:155–63.

47. Gupta L, Morgan K, Gilchrist S. Does Elite Sport Degrade Sleep Quality? A Systematic Review. Sports Med 2017;47:1317–33.

48. Brand S, Kalak N, Gerber M, Clough PJ, Lemola S, Sadeghi Bahmani D, *et al.* During early to mid adolescence, moderate to vigorous physical activity is associated with restoring sleep, psychological functioning, mental toughness and male gender. J Sports Sci 2017;35:426–34.

49. Taylor L, Chrismas BC, Dascombe B, Chamari K, Fowler PM. The Importance of Monitoring Sleep within Adolescent Athletes: Athletic, Academic, and Health Considerations. Front Physiol 2016;7:101.

50. Casey BJ, Jones RM, Levita L, Libby V, Pattwell SS, Ruberry EJ, *et al.* The storm and stress of adolescence: insights from human imaging and mouse genetics. Dev Psychobiol 2010;52:225–35.

Conflicts of interest.—Javier Bueno-Antequera received a research grant from the Spanish Ministry of Education (grant number FPU13/05130). Javier Bueno-Antequera and Miguel A. Oviedo-Caro were supported by the Government of Aragón through the European Fund of Regional Development-Operative program FEDER Aragón 2014-2020 "Construyendo Europa desde Aragón" (grant number: PUI/2018-337, and PUI/2018-336, respectively). Joaquin Reverter-Masia received a research grant from Universidad de Lleida, Cátedra ASISA and Human Movement research group Generalitat de Catalunya.

Funding.—This research was funded by the University of Zaragoza, Spain (grant number UZ2016-BIO-03), and the Government of Aragón (grant number S25-D17) through the European Fund of Regional Development-Operative program FEDER Aragón 2014–2020 "Construyendo Europa desde Aragón."

Authors' contributions.—Alvaro Pano-Rodriguez and Carmen Mayolas-Pi have given substantial contributions to the study conception and design; Javier Bueno-Antequera, Vicens Hernadez-Gonzalez, Alejandro Legaz-Arrese, Miguel A. Oviedo-Caro, and Jose V. Beltran-Garrido contributed to data acquisition, analysis and interpretation; all authors have participated to the manuscript draft, Joaquin Reverter-Masia revised it critically. All authors read and approved the final version of the manuscript.

History.—Article first published online: _____. - Manuscript accepted: January 11, 2023. - Manuscript revised: December 16, 2022. - Manuscript received: August 23, 2022.