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ORIGINAL RESEARCH

Sleep, health, and well-being in elite athletes from different sports, before, during, and after international competition

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ABSTRACT

Objectives: Limited research has been conducted on sleep problems in elite athletes at international competition, and how this relates to their general health and well-being.

Methods: Sixty-five elite international athletes (37 males, 28 females, 21.8 ± 2.1 years) from different sports completed validated sleep (Athlete Sleep Screening Questionnaire), health (Subjective Health Complaints Inventory) and well-being (Sports Profile of Mood States) questionnaires; 1 month pre-competition, at the end of international competition, and 1 month post-competition.

Results: Twenty-three percent of the elite athletes were identified as having a moderate or severe clinically significant sleep problem during competition, with 82% reporting less than 8 h of sleep per night. Athletes with a moderate or severe clinically significant sleep problem during competition had significantly greater general health complaints (p = 0.002), mood disturbance (p = 0.001) and poorer sleep hygiene (p = 0.002). Swimmers had more sleep difficulty pre and during competition compared to athletics and soccer (p = 0.009).

Conclusion: Sleep disturbance during international competition is common and associated with poorer health and lower mood. Swimmers may be more at risk of sleep difficulty pre and during competition compared to those competing in athletics and soccer. Sleep services may be required to support elite athletes at international competition.

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Sleep disturbance; elite athletes; competition; swimming

Introduction

Sleep is essential for athlete health, well-being, and performance [1]. However, research studies report that athletes are habitually obtaining insufficient sleep due to negotiable (e.g. poor sleep habits and environment) [2,3] and non-negotiable (e.g. competition times and travel) factors [4]. Insufficient sleep quantity (i.e. less than 7 h) is related to compromised athletic performance, as a result of slower reaction times [5], reduced endurance levels [6], decreased accuracy [7], slower sprint times [8], and lower mood [9]. Poor sleep also has been associated with lower general heath [10] and increased risk of infection [11] in the general population. There is emerging evidence highlighting the relationship between sleep and general health in athletes [12,13]. Factors such as sleep that can positively or negatively impact the health, well-being, and performance of athletes are of great interest to coaches, back-room medical staff, and athletes themselves.

Elite international athletes are required to travel for competition, both domestically and internationally, which presents unique challenges to their sleep [14]. Long-haul travel across time zones, poses an even greater challenge, as athletes need to recover from the interrelated effects of travel fatigue and jet lag [15]. Athletes who have a more extreme morning or evening chronotype may face greater sleep challenges [16–-16–18]. Athletes from individual sports are reported to have greater sleep difficulties compared to team sport athletes in their home environment [3,19]. However, a study of Olympic standard athletes reported no sleep difference between individual and team sport athletes [20]. Identifying which athletes have poor habitual sleep patterns and habits, and therefore, may be more at risk of poor sleep when traveling for international competition could enable timely sleep intervention and support for these athletes. There is an absence of research on whether athletes from different sports (e.g. swimming vs athletics) experience similar sleep difficulties when traveling for their sport. Understanding and increasing awareness around the potential differences in sleep difficulties between athletes from different sports may aid a more targeted athlete-specific approach to sleep education, intervention, and support, particularly around contextual factors that are known to disrupt sleep, such as long-haul travel.

A key priority of medical and support staff is to keep athletes well and healthy, in the lead up to and during competition. International long-haul travel, and travel across time zones, increases the risk of infection and illness in the general population [21,22] and in elite athletes [4,23]. There is some

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evidence to suggest that illness risk is not directly related to travel conditions itself (i.e. close contact with fellow passengers and exposure to re-circulated air) but rather environmental conditions and exposure to different populations and pathogens may also play a role [23]. There is evidence in the literature that insufficient sleep is an additional risk factor for illness in athletes [24,25]. An International Olympic Committee (IOC) consensus statement has recommended further investigation into the risk of illness and international travel and sleep deprivation [26]. To date, there is a gap in the literature on the relationship between sleep and general health and well-being in elite athletes when they travel for international competition.

International multi-sport competitions such as the Olympics, the Commonwealth Games and the World University Games add another unique sleep challenge, where athletes live in purpose-built Athletes' Villages, sharing rooms & living space. To the authors' knowledge, there is no published research on the sleep profiles of elite athletes living in this type of environment at an international multi-sport competition. Anxiety around competition can also contribute to sleep disturbance, with 64% of the elite Australian athletes reporting disturbed sleep prior to important competition [20]. A recent consensus statement from the IOC recommended that Olympic villages and similar areas should be designed and assessed with sleep hygiene in mind [27]. Understanding the sleep profiles of athletes in this type of environment could potentially aid recovery and optimize performance for athletes at these types of events. It has also been recommended that future research should investigate the sleep profiles of athletes during the three stages of competition (i.e. before, during, and after competition) [28].

Therefore, the aims of this study were to investigate

(1) The prevalence of clinically relevant sleep problems of elite athletes at three distinct timepoints: 1-month pre-competition, during competition, and 1-month post-competition.
(2) Associations between sleep, general health, well-being, and sleep hygiene and to investigate the potential difference in these factors between sports during international competition.

Methods

Design

A longitudinal cohort study in elite international standard athletes at home, at international competition, and at 1 month post-international competition.

Participants

Sixty-five elite X athletes from four different sports (athletics, swimming, men's soccer, women's soccer) participated in the study. All participants had achieved international qualification for the World University Games in Taiwan in 2017. Participants were recruited via convenience sampling where the lead author was the head physiotherapist for Team Irelandat the World University Games (WUGs). Participants provided informed consent and ethics approval was granted by the local university human research ethics committee (ethics number 2017_04_17).

Methodology

The WUGs 2017 took place in Taiwan over a period of 3 weeks. Participants completed online questionnaires at three timepoints: 1 month prior to competing at the 2017 WUGs, on the last day of the WUGs competition, and at 1 month post-competition. The questionnaires took approximately 15 minutes to complete and explored parameters of; sleep, sleep hygiene, general health, mood, and chronotype.

Sleep

Clinically relevant sleep problems were assessed using the 16-item Athlete Sleep Screening Questionnaire (ASSQ) which is the only sleep screening questionnaire validated in an athletic population [29]. The ASSQ evaluates both sleep and circadian factors related to sleep quantity, sleep quality, sleep timing, insomnia, sleep-disordered breathing, and sleep disturbance related to travel, during the recent past. Five items are used to calculate a 'sleep difficulty score' which classifies athletes into a category of clinical sleep problem; from no problem (score 0–4), to mild (score 5–7), to moderate (score 8–10) and severe (score 11–17). Those categorized in the no and mild clinical sleep problem categories are deemed to not need further sleep assessment from a sleep professional but instead require education and monitoring [29]. Those in the moderate to severe clinical sleep problem categories additionally require sleep assessment by a sleep professional [30]. Questions related to naps, caffeine use, and electronic device use are also included.

Sleep hygiene

Sleep hygiene was assessed using the Sleep Hygiene Index (SHI) [31]. The SHI consists of 13 items related to inappropriate sleep behavior, in the recent past, which is based on the diagnostic criteria for poor sleep hygiene proposed by the International Classification of Sleep Disorders [32]. Each item is rated on a five-point Likert scale (0–4) where 0 = never, 1 = rarely, 2 = sometimes, 3 = frequent and 4 = always. Item scores are summed providing a global assessment of sleep hygiene. Higher scores are indicative of more maladaptive sleep hygiene [33].

General health

General health was assessed using the validated Subjective Health Complaints Inventory (SHC) [34]. The SHC questionnaire includes common health conditions and reasons for an encounter with a general practitioner and is an indicator of overall general health [35]. Participants were asked to report if they had experienced any of the following 12 complaints in the recent past: palpitations/extra heartbeats, chest pain, breathing difficulties, heartburn, stomach discomfort, diarrhea, constipation, eczema, tiredness, dizziness, anxiety, and depression. Items related to sleeping problems were removed as they were covered elsewhere in the questionnaire. Severity of each complaint is rated on a four-point Likert scale where 0 = none,1 = some,

2 = much, 3 = severe, giving a total score ranging from 0 to 36 where a higher score is indicative of lower general health [34].

Mood

Mood was assessed using the abbreviated 40-item Sports – Profile of Mood States (sPOMS), which has been reported to be more time-sensitive and appropriate for competitive athletes [36]. This abbreviated version of the POMS consists of 40 adjectives related to participants experience of seven mood states of tension, depression, fatigue, vigor, confusion, anger, and esteem-related affect, in the recent past. Participants are asked to score each adjective from 0 to 4; 0 = not at all, 1 = a little, 2 = moderately, 3 = quite a lot, 4 = extremely. Total Mood Disturbance (TMD) is calculated by summing the totals for the negative subscales (tension, depression, anger, fatigue, confusion) and then subtracting the totals for the positive subscales (vigor, esteem-related affect). A constant (100) is then added to remove negative scoring for the final overall score, with a higher score is indicative of a greater mood disturbance.

Chronotype

Chronotype was assessed using the MEQ [37]. The MEQ is a 19-item questionnaire used to determine the natural propensity of an individual to be active across a 24-h period. The questions are multiple choice, framed in a preferential manner, with each answer providing a value from 0 to 6. The items are summed give a final score ranging between 16 and 86, where <41 = 'evening-type', 42–58 = 'intermediate' and ≥59 = 'morning-type'.

Travel to international competition

Participants traveled economy class for all flights. The departure and arrival times for outbound flights were 13:50 h Irish Standard Time (IST) and 16:15 h the next day China Standard Time (CST [IST +7 h]). There were two flights for outbound travel, with 19 h 10 min of travel (16 h 10 mins flight duration, 3 h stopover) across seven time-zones. The departure and arrival times for inbound flights were 23:35 h CST and 12:05 the next day IST. There were two flights for inbound travel with 19 h 30 min of travel (16 h 30 mins flight duration, 3 h stopover) across seven time-zones.

Statistical analysis

Descriptive statistics are presented as mean ±(standard deviation (SD)) or number (percentage). Quantitative data were assessed for skewness visually using histograms and Shapiro–Wilks normality test. The ASSQ was categorized into none-mild and moderate-severe. SHI, SHC, and sPOMS were compared between the none-mild and moderate-severe ASSQ categories during competition using the independent sample *t*-test. Linear mixed regression models were used to examine differences in ASSQ, SHI, SHC, and sPOMS scores between the sports across the three timepoints, accounting for within-person correlations. Main effects for sport and time, and a time-by- sport interaction term were included in the models. Estimated marginal means for the time-by-sport term with associated 95% confidence intervals are reported from the analyses. SPSS (Statistics for Windows, Version 26.0. Armonk, NY:IBM Corp) was used for all analyses. Statistical significance was indicated by a *p*-value of <0.05.

Results

Sixty-five elite X athletes (37 = male, 28 = female) from four different sports groups (athletics, $n = 11$; swimming, $n = 12$; men's soccer, $n = 22$; women's soccer, $n = 20$) participated in this study (mean ± SD age 21.8 ± 2.1 years). The descriptive statistics for the ASSQ, SHI, sPOMS, and SHC outcome measures are presented in Table 1.

Chronotype (MEQ): Seven percent ($n = 4$) were evening-type, 19% ($n = 10$) were morning-type, and 74% ($n = 40$) were intermediate. No significant differences were found in ASSQ scores when grouped by chronotype classification ($p = 0.623$).

Less than 8 h of sleep per night was reported by 66% ($n = 39$) of participants pre-competition, 82% ($n = 50$) during competition, and 65% ($n = 38$) post-competition. Greater than 9 h of sleep per night was reported by 5% ($n = 3$) of participants pre-competition, 3% ($n = 2$) during competition, and 7% ($n = 4$) post-competition (Figure 1).

Associations between clinically relevant sleep problems and measures of health, well-being, and sleep hygiene during competition

Worse SHI, SHC, and sPOMS scores were associated with the ASSQ moderate-severe classification compared to none-mild (Table 2).

Differences in sleep problems and associated general health, well-being, and sleep hygiene measures between sports

Participant characteristics across the sports are described in Table 3. Over half the swimmers were identified as having moderate-severe sleep problem during the competition, 45% pre-competition and this returned to less than 10% post-competition. During the competition, less than 10% of the athletics, 10% of men's soccer and less than 30% of the women's soccer were identified as having moderate-severe sleep problem (Figure 2).

The linear mixed model analysis, Table 4, found that changes in ASSQ scores differed significantly between the sports (time-by-sport interaction *p*-value = 0.018), suggesting that swimmers had higher ASSQ scores pre and during competition which returned to similar levels to the other sports post-competition

Discussion

This is the first study to investigate elite athletes sleep at an international multi-sport competition using a validated athlete sleep questionnaire. One of our main findings was that athlete sleep difficulty scores were highest at competition compared to pre-competition and post-competition. Twenty-three percent of athletes were categorized with a clinically relevant sleep problem at competition, compared to 16%

Table 1. Descriptive statistics for the ASSQ, SHC, sPOMS, and SHC at pre-competition, during competition, and post-competition.

	Pre-competition	During competition	Post-competition
ASSQ	4.9 ± 2.5	5.5 ± 2.9	4.5 ± 2.1
ASSQ categories			
None (0–4)	25 (43%)	26 (43%)	29 (50%)
Mild (5–7)	24 (41%)	21 (34%)	24 (41%)
Mod (8–10)	9 (16%)	10 (16%)	5 (9%)
Severe (11–17)	0 (0%)	4 (7%)	0 (0%)
SHC	16.12 ± 3.2	17.77 ± 4.41	16.97 ± 3.54
sPOMS	97.47 ± 21.19	95.78 ± 22.79	95.84 ± 20.52
SHI	29.26 ± 5.96	28.98 ± 5.95	30.29 ± 5.41
Nap frequency			
No naps	17(29%)	16(26%)	21(37%)
1–2/week	30(52%)	27(44%)	30(53%)
3–4/week	7(12%)	13(21%)	4(7%)
5–7/week	4(7%)	5(8%)	2(4%)
Nap length			
<30 min	17(29%)	9(15%)	20 (35%)
31–60 min	7(12%)	35(57%)	13 (23%)
61–90 min	23(40%)	5(8%)	20(35%)
>90 min	3(5%)	0(0%)	0(0%)
Caffeine use/day			
<1	16(28%)	18(30%)	17(30%)
1–2	27(47%)	32(53%)	23(40%)
>3	15(26%)	11(18%)	17(30%)
Electronic device use before bed			
Never	1(2%)	1(2%)	2(4%)
1–3/week	3(5%)	8(13%)	5(9%)
4–6/week	11(19%)	8(13%)	11(19%)
Everyday	43(74%)	44(72%)	39(68%)
Bluelight blocking software/device			
Yes	17(29%)	23(38%)	25(44%)
No	41(71%)	38(62%)	32(56%)

ASSQ, Athlete Sleep Screening Questionnaire; SHC, Subjective Health Complaints Inventory; sPOMS, Sports Profile of Mood States; SHI, Sleep Hygiene Index.

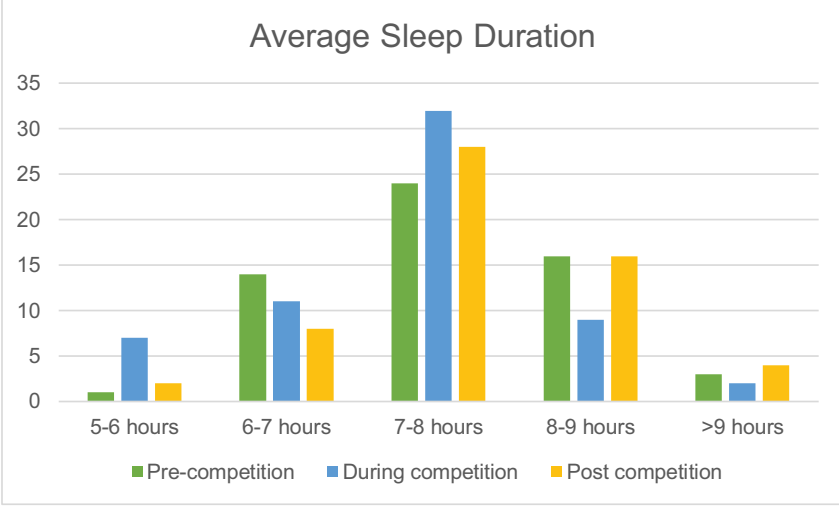

Figure 1. Average self-reported sleep duration at three timepoints: pre-competition, during competition, and post-competition.

and 9% at pre-competition and post-competition, respectively. In this regard, the sleep profiles of the cohort in the present study at the international competition are similar to, in-season Canadian elite athletes [29] and, age-matched but non-elite student athletes [38], who both reported 25% of their cohort with a clinically relevant sleep problem using the ASSQ. A systematic review of sleep in elite sport has identified competition as a factor associated with sleep disturbance [14]. The negative effect of competition on sleep could be related to shared rooms in a new environment [19], late-night competition [14], or thoughts and nervousness about competition [19]. A higher prevalence (73%) of sleep difficulty 9 months prior to competition has been reported in Olympic standard athletes [39]; however, this was classified using the Pittsburgh Sleep Quality Index which may overestimate sleep difficulty in athletes [40]. The use of a validated athlete-specific sleep questionnaire, such as that used in this study, is likely to provide a truer reflection of sleep difficulties athletes face in both home and competition environment.

Table 2. Comparison of athletes' general health, mood, and sleep hygiene when categorized into clinically relevant sleep problem (none/mild and moderate/severe) during competition.

	ASSQ classification			
	None/mild (n = 47) Mean (sd)	Moderate/severe (n = 14) Mean (sd)	p Value	Effect size
SHC	17.2 ± 3.5	20.8 ± 4.0	.002	1.0
sPOMS	84.4 ± 16.3	117.2 ± 28.5	.000	1.7
SHI	28.0 ± 5.5	33.2 ± 4.1	.002	1.0

ASSQ, Athlete Sleep Screening Questionnaire; SHC, Subjective Health Complaints Inventory; sPOMS, Sports Profile of Mood States; SHI, Sleep Hygiene Index; sd, standard deviation; Cohen's D effect size.

Table 3. Participant characteristics by type of sport.

	Type of sport			
	Swimming (n = 12)	Athletics (n = 11)	Women's soccer (n = 20)	Men's soccer (n = 22)
Female sex, n (%)	1 (8.3)	6 (54.4)	20 (100%)	0 (0)
Age	21.6 ± 1.6	23.9 ± 2.3	21.9 ± 2.2	20.8 ± 1.3
Years at elite level	3.5 ± 1.2	5.6 ± 3.3	4.9 ± 1.7	3 ± 1.2

Eight-two percent of athletes reported less than 8 h of sleep per night during competition, compared to 67% and 65% at pre and post-competition, respectively. Current international guidelines recommend that non-athletes sleep 7 h or more per night [41], with recommendations suggesting athletes require 8–10 h of sleep per night to facilitate both physiological and psychological recovery from intense training sessions and competition [25,42]. The discrepancy between athlete sleep recommendations and the reality of athlete sleep duration has been previously highlighted in an actigraphy study of 124 athletes in their home environment, who reported athletes obtained only 6.8 h of sleep/night [3]. A study of elite cyclists reported a significant decrease in sleep duration during competition (6.8 h/night) compared to pre-competition (7.4 h/night) [28]. Conversely, a recent review reported decreases in sleep duration during heavy training phases compared to pre-season/tapering phases or competition phases (6.7 h vs. 7.3 h vs. 7.4 h, respectively) [42]. Our findings combined with other research suggest that a significant number of athletes are getting less than 8 h of sleep as is routinely recommended. There have been mixed findings on the relationship between sleep duration and performance in athletes, with some aspects of performance, such as speed, tactical strategy, and technical skill more affected than anaerobic performance [43]. Sleep health in athletes encompasses good quality sleep, minimal daytime dysfunction, strategic napping, and positive sleep hygiene behavior, not a fixation on an arbitrary length of sleep per night. Athletes who are required to travel for international competition may require additional sleep support, education, and intervention as highlighted by the sleep difficulties reported in the current study and it is likely that this need will vary greatly between individuals. Interestingly, these athletes are continuing to perform at an elite level.

Sleep hygiene in competition was significantly worse in those with a clinically relevant sleep problem compared to those without. Poor sleep hygiene relates to practicing behaviors that can negatively impact sleep [31]. Good sleep hygiene was positively correlated with sleep quality in elite international junior athletes [33]. In the current study, a large proportion of athletes utilized naps (63–74%) and the most common frequency of napping was 1–2/week. Daytime naps can be used to supplement nighttime sleep effectively in athletes [44]. Educating athletes on correct timing, practice, and duration of naps to supplement potentially shortened nighttime sleep during competition may be an effective way to enable additional physiological and psychological recovery provided by sleep [25]. Everyday electronic device (ED) use before bed was used by a large proportion of this cohort (68–74%). ED use before bed was associated with an increased risk of shorter sleep duration and longer sleep latency in a large cross-sectional study in adolescents [45]. However, a small study on eight elite athletes found no association between ED use and either sleep quality and sleep latency

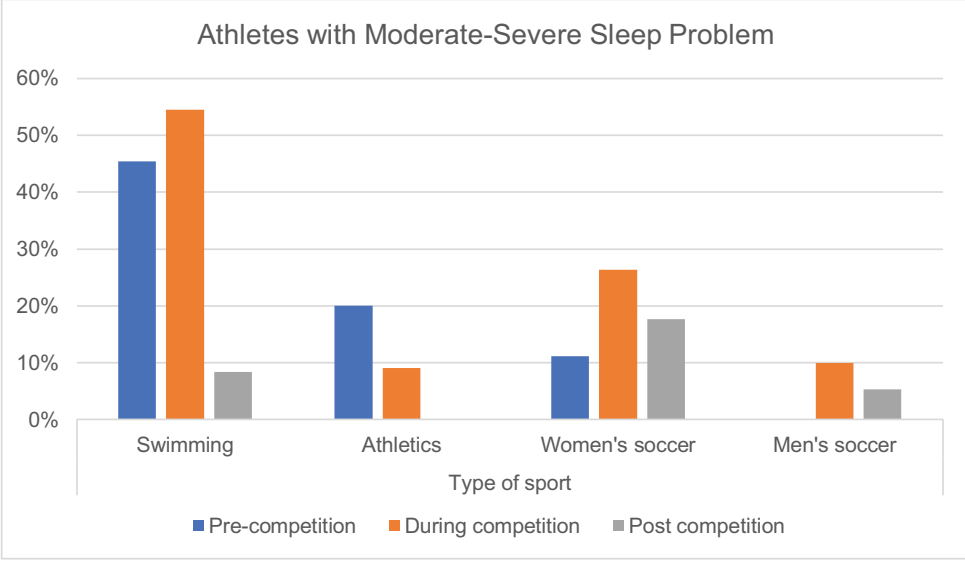

Figure 2. Percentage of athletes within each sport identified as having moderate-severe sleep problem at each time point.

Table 4. Mixed model analyses, estimated marginal means with 95% confidence intervals.

		Pre-competition	During competition	Post-ompetition	Time	Sport	Time × Sport
ASSQ	Swimming	7.1 (5.8, 8.5)	8.1 (6.5, 9.7)	4.5 (3.2, 5.8)	0.007	0.004	0.018
	Athletics	3.8 (2.4, 5.3)	4.9 (3.3, 6.5)	3.3 (1.9, 4.8)			
	Women's soccer	4.4 (3.3, 5.5)	5.4 (4.2, 6.6)	4.7 (3.6, 5.8)			
	Men's soccer	4.8 (3.7, 5.8)	4.5 (3.3, 5.7)	5 (3.9, 6)			
SHI	Swimming	33.1 (29.8, 36.3)	32.4 (29.4, 35.4)	32.3 (28.4, 36.2)	0.456	0.045	0.861
	Athletics	28.5 (25.1, 31.8)	27.7 (24.6, 30.8)	28.5 (24.2, 32.7)			
	Women's soccer	29.2 (26.6, 31.7)	29.4 (27.1, 31.7)	32.2 (29, 35.4)			
	Men's soccer	27.8 (25.4, 30.2)	27.8 (25.6, 30.1)	28.9 (25.9, 32)			
SHC	Swimming	20.1 (17.9, 22.2)	21 (18.8, 23.2)	20 (18.1, 21.9)	0.1	<0.001	0.848
	Athletics	18.4 (16.1, 20.6)	18.2 (16, 20.4)	16.1 (14, 18.1)			
	Women's soccer	17.8 (16.1, 19.5)	17.5 (15.9, 19.2)	17.4 (15.8, 19)			
	Men's soccer	16.5 (14.9, 18.1)	16.6 (15, 18.2)	15.3 (13.8, 16.8)			
sPOMS	Swimming	112.8 (101.3, 124.3)	117.6 (105.9, 129.4)	108.1 (93.9, 122.3)	0.811	0.006	0.664
	Athletics	94.8 (82.7, 106.9)	91.7 (79.9, 103.5)	85.5 (70, 101)			
	Women's soccer	93 (84, 102)	92.1 (83.2, 101.1)	97.9 (86.1, 109.7)			
	Men's soccer	93.6 (84.8, 102.3)	90.1 (81.4, 98.8)	93.5 (82.3, 104.7)			

ASSQ, Athlete Sleep Screening Questionnaire; SHI, Sleep Hygiene Index; SHC, Subjective Health Complaints; sPOMS, Sports Profile of Mood States; Time × Sport (time-by-sport interaction).

[46]. Similarly, a study of 46 well-trained athletes found no association between ED use and sleep duration [47], although they did report an association between perceived difficulty in falling asleep and ED use [47]. Interestingly, a study that removed ED for 48 h from elite junior athletes reported no change in sleep quality or quantity, or athletic performance [48]. Regular ED use before bed is part of the embedment of technology at a societal and cultural level, and although its negative impact on sleep has been reported in adolescents, the removal of, or limitation of its use in athletes has not, as of yet, resulted in significant changes in sleep quality or quantity or athletic performance.

Athletes who were categorized as having a clinically relevant sleep problem during the competition had significantly greater number of general health complaints. There is a strong relationship between poor sleep and increased risk of infection [11] and compromised immune function [10] in the general population, with emerging research highlighting this relationship in athletes [12]. Poor sleep was associated with an increased risk of infection in overreached endurance athletes [49]. A case–control study reported that poor sleep in elite athletes was associated with a greater risk for upper respiratory tract and gastrointestinal symptoms [50]. However, this contrasts with a study of Olympic-level athletes which found no association between poor sleep and illness [39]. In the current study, athletes who were categorized as having a clinically relevant sleep disorder during competition also had significantly higher total mood disturbance. A more positive mood profile is associated with improved sports performance [51] and better athlete mental health [52] and therefore a priority for athletes, coaches, and medical staff. Keeping athletes fit and healthy enabling them to perform to the best of their ability is a key concern for every medical team [26]. The importance of maintaining and promoting sleep to preserve general health [12] and mental health [27] has been advocated in two recent consensus statements. The relationship between mood and sleep is strongly established in non-athletic populations [53,54]. The relationship between poor sleep quality and mood has been reported in amateur marathon runners [9], elite volleyball players [55], and individual and team-sport German athletes [19].

Swimmers had significantly poorer sleep profiles, as measured using the ASSQ, pre-competition and at the international competition; however, this returned to similar levels as athletics and football, post-competition. Sleep difficulties in swimmers have been reported in other research, with significant decreases in sleep duration from 8.7 h/night on rest days compared to 6.6 h/night on training days reported in elite swimmers [56]. Research comparing sleep in team-sport athletes versus individual athletes reported a longer sleep latency (time taken to fall asleep) in swimmers (40 min) compared to footballers (9 min) [3]. Early morning training sessions have been identified as barriers to sufficient nighttime sleep in elite swimmers [56,57] whereas late-night competition has been reported as a barrier to sleep in footballers [58,59]. Future research exploring the timing of competition across sports would be beneficial. Heavy training periods across a competitive season have been associated with sleep difficulties in footballers [42,58] and swimmers [60]. Increases in training load pre-competition could potentially be a factor contributing to sleep difficulties in swimmers in the current study; however, this was not measured. In the current study, swimmers had the greatest number of general health complaints, worst total mood disturbance, and poorest sleep hygiene compared to other sports and this did not change over time. Increased respiratory illnesses such as rhinitis, asthma, and airway hyper-responsiveness have been reported in elite swimmers compared with the general population [61]. Sleep quality and anxiety were positively correlated in a study of elite swimmers [62] Although direct comparisons cannot be made due to differences in outcome measures used, our findings highlight that there is a relationship between poor sleep and greater general health complaints and mood disturbance in swimmers, which is relevant to backroom medical teams tasked with keeping athletes fit, well and healthy, to train and compete at the elite level.

Strengths and limitations

This is a novel study examining an elite sport population using athlete-specific sleep measures at three important timepoints; pre-competition, during competition, and post-competition. The main strength of this paper is the novel investigation of sleep in athletes over time and the relationship between sleep and sport type, general health, mood, and sleep hygiene. It also provides an original overview of sleep profiles of elite athletes at an international multi-sport competition environment. The sample size of this study is small and further research is recommended to replicate findings. A question on sleep was removed from the SHC which may have compromised the validity of this outcome measure, though the scoring system stayed the same for all remaining items. The absence of objective sleep measures such as actigraphy is acknowledged as a limitation. This was an exploratory study and therefore no power analysis was performed. The absence of data on training load and nutrition are acknowledged as limitations of this study.

Implications

Sleep, health, and well-being are suboptimal in swimmers compared to athletics and men's and women's soccer. In order to address sports-specific problems, a tailored sleep intervention program may be necessary. In a recent study, 95% of the swimmers reported the coach as their primary source of recovery information and 100% of the coaches reported conferences and workshops as their primary source of recovery information (Shell et al. 2020). It is plausible that in order to educate and potentially improve sleep in swimmers, education of coaches via workshops & conferences on the challenges, consequences, and potential sleep hygiene strategies for swimmers would be necessary.

Athlete sleep disturbance scores were worst at the competition, and this was related to lower general health and mood disturbance. This has implications for athlete health and well-being but also potentially for athletic performance at the competition. It is likely that there are numerous contributing factors to poor sleep in the competition such as shared rooms, new environments, light and noise pollution, competition anxiety, and competition scheduling [14,63]. Addressing these issues has been identified as an important factor in designing a purpose-built athlete village at multi-sport competitions [27]. Minimizing sleep disruption for athletes at competition may require a multifactorial approach targeting logistical challenges, competition scheduling, and promoting positive sleep hygiene through education and behavioral support strategies.

Conclusion

Nearly a quarter of elite athletes in this study experienced moderate to severe sleep problems at an international competition with a higher prevalence of sleep problems (55%) in swimmers. Compared to athletics and men's and women's soccer, swimmers had the worst sleep profile pre-competition and during the competition, and this was associated with lower general health, mood disturbance, and poor sleep hygiene. Sleep problems during competition may have implications on athletic performance and achievement. Further research into sleep interventions to support athletes' sleep during international competition is warranted.

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Declaration of interest

The authors whose names are listed immediately below certify that they have no conflict of interest to declare.

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