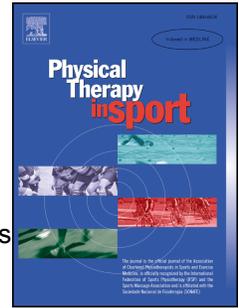


Accepted Manuscript

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PII: S1466-853X(19)30134-8

DOI: <https://doi.org/10.1016/j.ptsp.2019.07.006>

Reference: YPTSP 1082

To appear in: *Physical Therapy in Sport*

Received Date: 1 April 2019

Revised Date: 23 July 2019

Accepted Date: 23 July 2019

Please cite this article as: Biggins, M., Purtill, H., Fowler, P., Bender, A., Sullivan, K.O., Samuels, C., Cahalan, R., Sleep in elite multi-sport athletes: Implications for athlete health and wellbeing, *Physical Therapy in Sports* (2019), doi: <https://doi.org/10.1016/j.ptsp.2019.07.006>.

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Title page

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Sleep in Elite Multi-Sport Athletes: Implications for Athlete Health and Wellbeing

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Acknowledgements

The authors wish to acknowledge Student Sport Ireland and the Irish athletes at the 2017 World University Games for their time and participation in this research project.

Funding statement

This research was funded in part by the School of Allied Health, University of Limerick.

Sleep in Elite Multi-Sport Athletes: Implications for Athlete Health and Wellbeing

Objectives: To investigate the prevalence of clinically relevant sleep problems in elite multi-sport athletes and their associations with sleep hygiene, general health, mood, chronotype, and injury.

Design: Cross-sectional study.

Setting: During the competitive season in athletes' home environment.

Participants: Elite multi-sport Irish athletes (n=58) competing at the 2017 World University Games.

Main Outcome Measures: Category of clinical sleep problem (Athlete-Sleep-Screening-Questionnaire), sleep hygiene (Sleep Hygiene Index), general health (Subjective Health Complaints), mood (Sports Profile of Mood States), chronotype (Morningness-Eveningness Questionnaire), and injury (self-reported injury).

Results: 43% had no clinical sleep problem, 41% had a mild clinical sleep problem, 16% had a moderate clinical sleep problem, none had a severe clinical sleep problem. Therefore, 84% of athletes did not have a clinically significant sleep problem while 16% had a clinically significant sleep problem. One-way-ANOVA revealed significantly worse sleep hygiene ($p=0.002$), more general health complaints ($p=0.001$) and greater mood disturbance ($p=0.001$) among those with clinically significant sleep disturbances compared to those without. No association was found between having a clinically significant sleep problem and either chronotype or previous recent injury.

Conclusions: Athletes with a clinically significant sleep problem were more likely to report worse sleep hygiene, more general health complaints, and mood disturbance.

Keywords: Sleep disturbances, Injury, Mood, Chronotype, Sleep Hygiene

Introduction

Whilst the importance of sleep for athletic performance (Halson, 2008) and recovery (Kellmann et al., 2018) is frequently emphasised, many athletes obtain insufficient habitual sleep quantity (Lastella et al., 2015, Leeder et al., 2012) and quality (Gupta et al., 2017). In addition, athletes regularly face unique contextual challenges to their sleep, particularly training and competition (Nedelec et al., 2018, Sargent et al., 2014) and travel (Fowler et al., 2015). These challenges can be even greater for athletes who have a more extreme morning or evening chronotype (Facer-Childs and Brandstaetter, 2015). Insufficient sleep has been linked to negative consequences including lower general health (Alvarez and Ayas, 2004), mood disturbance (Dinges et al., 1997) and an increased risk of illness (Prather et al., 2015) and injury (Milewski et al., 2014). These findings have been reported in the general population, however the negative consequences of poor sleep for athlete general health and wellbeing is relatively unknown.

Identifying poor sleep in athletes is cited as a key clinical and research concern (Bonnar et al., 2018) and is considered critical in identifying athletes who may be at a greater risk of overtraining, illness and injury (Halson, 2008). Polysomnography and actigraphy are valid and reliable objective measures of sleep, however their cost, practicality and availability limit their use in sporting environments (Samuels et al., 2016). General sleep screening questionnaires including the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) are commonly used with athletes (Swinbourne et al., 2016, Halson et al., 2017, Hoshikawa et al., 2018). Whilst, the PSQI has been clinically validated in the general population, results suggest it is not valid for use in athletic populations with an overestimation of sleep disturbances reported in athletes using this measurement (Samuels et al., 2016). As a result, the Athlete Sleep Screening Questionnaire (ASSQ) - has been developed and recently validated for use in athletic populations (Bender et al., 2018). This tool enables sports medicine practitioners to screen athletes for clinically significant sleep disturbances and identify what aspects of their sleep may be most problematic, enabling appropriate targeted intervention. This is one of the first studies to utilise this newly validated questionnaire in elite athletes.

Sleep interventions in athletes have shown some success in improving sleep quality and quantity, with subsequent performance and recovery benefits (Bonnar et al., 2018). These interventions are typically focused on general sleep education and/or methods to improve sleep hygiene. Sleep hygiene can be described as practising behaviours that facilitate sleep and avoiding behaviours that interfere with sleep (Mastin et al., 2006). There is a lack of literature on the sleep hygiene behaviour of elite athletes, which may differ from the general population due to their unique lifestyles. Investigating the habitual sleep hygiene practices of elite athletes could help optimise development, and delivery, of sleep interventions among athletes (Bonnar et al., 2018).

Sleep is also related to overall general health and wellbeing (Bollinger et al., 2010, Dinges et al., 1997). Poor sleep has been associated with lower general health (Alvarez and Ayas, 2004) and increased risk of infection (Prather et al., 2015) in the general population, however studies on relationship between sleep and general health in athletes are lacking. The absence of research in this important area of athlete general health has been identified (Swinbourne et al., 2018) with a call for targeted research in this field (Walsh et al., 2011). There has been some research examining the relationship between sleep and subjective wellbeing in recreational athletes (Lastella et al., 2014) but not in elite cohorts. Research examining this relationship may provide important information for back-room medical staff in identifying potential strategies to maintain and improve athlete general health and wellbeing.

Therefore, the aims of this study were; to investigate; (1) the habitual sleep profiles and prevalence of clinically significant sleep problems in elite in-season multi-sport athletes using a validated

athlete-specific sleep screening questionnaire and (2) how sleep in this cohort of elite athletes relates to their sleep hygiene, general health, mood, chronotype, and injury.

Methods

Design

A cross-sectional observational study in elite international standard athletes, in-season and in their home environment.

Participants

Fifty-eight elite international athletes (34=male, 24=female) from four different sports (athletics n=10, swimming n= 9, diving n=2, men's soccer n=19, women's soccer n=18) participated in this study (mean \pm standard deviation (SD) age 21.8 ± 2.2 years). 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 head physiotherapist for Ireland at the World University Games. Participants provided informed consent and ethics approval was granted by the local university human research ethics committee (ethics number 2017_04_17).

Methodology

Participants completed online questionnaires, one month prior to competing at the 2017 World University Games. The questionnaires took approximately 15 minutes to complete and explored parameters of; sleep, sleep hygiene, general health, mood, chronotype, and previous recent injury.

Athlete Sleep Screening Questionnaire

Sleep was assessed using the 16-item ASSQ which is the only sleep screening questionnaire validated in an athletic population (Bender et al., 2018). 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. Five items are used to get 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 (Bender et al., 2018). In contrast, those in the moderate to severe clinical sleep problem categories are deemed to require education, monitoring, and further sleep assessment by a sleep professional (Samuels et al., 2016). Questions related to naps, caffeine use and electronic device use are also included. The ASSQ has demonstrated good agreement with an individual assessment by a sleep medicine physician specializing in sleep of elite athletes (Cohen's kappa = 0.84), having a diagnostic sensitivity of 81%, specificity of 93%, positive predictive value of 87%, and negative predictive value of 90% (Bender et al., 2018).

Sleep Hygiene

Sleep hygiene was assessed using the Sleep Hygiene Index (SHI) (Mastin et al., 2006). The SHI consists of 13 items related to inappropriate sleep behaviour, which is based on the diagnostic criteria for poor sleep hygiene proposed by the International Classification of Sleep Disorders (Thorpy, 2012). 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. SHI has been found to have good test-retest reliability ($r = 0.71$, $p < 0.01$) and is positively correlated ($p < 0.01$) with all

associated features of inadequate sleep hygiene (Mastin et al., 2006) with Cronbach's alpha = 0.61 in an athletic population (Knufinke et al., 2018).

General Health

General health was assessed using the validated Subjective Health Complaints Inventory (SHC) (Tschudi-Madsen et al., 2011). The SHC questionnaire includes common health conditions and reasons for an encounter with a general practitioner and is an indicator of overall general health (Eriksen et al., 1999). Participants were asked to report if they had experienced any of the following 12 complaints during the last 30 days: palpitations/extra heartbeats, chest pain, breathing difficulties, heart burn, stomach discomfort, diarrhoea, 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 0-36 where a higher score is indicative of lower general health (Tschudi-Madsen et al., 2011). Internal consistency of SHC has been shown to be good (Cronbach's alpha = 0.82 for women and 0.75 for men)(Eriksen et al., 1999).

Mood

Mood was assessed using the abbreviated 40-item Sports-Profile of Mood States (SportsPOMS), which has been reported to be more time-sensitive and appropriate for competitive athletes (Grove and Prapavessis, 1992). This abbreviated version of the POMS consists of 40 adjectives related to seven mood states of tension, depression, fatigue, vigour, confusion, anger and esteem-related affect. Participants are asked to score each adjective from 0-4; 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 (vigour, 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. The 40-item SportsPOMS has shown good internal consistency (Cronbach's alpha 0.66-0.95) (Grove and Prapavessis, 1992).

Chronotype

Chronotype was assessed using the Morningness-Eveningness Questionnaire (MEQ) (Horne and Östberg, 1976). The MEQ is a 19-item questionnaire used to determine the natural propensity of an individual to be active across a 24-hour period. The questions are multiple choice, with each answer scored from 1-6. The items are summed to give a final score from 16-86, where <41= "evening-type", 42-58= "intermediate" and 59 ≥ "morning-type". The MEQ has shown good internal consistency (Cronbach's alpha =0.77) with a test-retest reliability ICC of 0.90 (Lee et al., 2014).

Injury

Previous injury was assessed via the following questions from (Timpka et al., 2017) (1) "Have you had any injury complaints in the past 4 weeks?" (2) "If yes, how did this injury occur" (3) "How long did this injury last?" (4) "How much worry/anxiety has this injury caused you?"

Statistical analysis

Descriptive statistics are presented as mean (\pm SD). The distributions of all numeric variables were assessed for skewness using formal tests of normality and through visual inspection of histograms. One-way ANOVA analyses were used to compare the mean differences in continuous variables

between the ASSQ classifications, and results were reported with eta-squared effect sizes. Tukey post-hoc pairwise comparisons indicated which groups differed significantly. Chi squared tests of independence were used to compare differences in proportions across the ASSQ classifications for categorical variables and were reported with Cramer's V effect size. Eta-square effect sizes were interpreted using Cohen's classification of 0.01 as indicating a small effect, 0.06 indicating a medium effect and 0.14 indicating a large effect (Cohen, 1988). Cramer's V effect sizes were interpreted as 0.10 for a small effect, 0.30 for a medium effect and 0.50 for a large effect (Cohen, 1988). The 5% significance level was used for all statistical tests. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 23.0 IBM Corp.

Results

The descriptive characteristics of participants (n=58) by sport are presented in Table 1.

Athlete Sleep Screening Questionnaire

Sleep Difficulty Score

The ASSQ classified participants as follows: 43% (n=25) had no clinical sleep problem, 41% (n=24) had a mild clinical sleep problem, 16% (n=9) had a moderate clinical sleep problem, and no participants had a severe clinical sleep problem.

Naps

Over half the group 52% (n=30) napped once/twice per week, 12% (n=7) napped three or four times per week, 7% (n=4) napped five to seven times per week and 29% (n=17) reported no naps.

Caffeine and Electronic Device Use

Forty-seven percent (n=27) reported consuming 1-2 caffeine products per day (mean \pm SD 1.07 \pm 0.96). Two percent consumed \geq 5 products per day, 5% consumed four per day, 19% three per day and 28% consumed less than one caffeine product per day. Seventy-four percent (n=43) of participants reported daily use of electronic devices within one hour of going to bed. Only one participant reported never using electronic devices within one hour of bed.

Table 1. Descriptive data for all participants presented as mean \pm SD or number (percentage)

Sport	n	Age	Sex (n, % female)	Years at elite level
Athletics	10 (17.2 %)	24.0 \pm 2.4	5 (50%)	4.6 \pm 2.7
Swimming & diving	11 (19.0%)	21.6 \pm 1.7	1 (9%)	3.36 \pm 1.1
Football	37 (63.8%)	21.3 \pm 1.9	18 (49%)	4 \pm 1.7
Total	58	21.8 \pm 2.2	24 (41.4 %)	3.98 \pm 1.9

Sleep Hygiene, General Health, Mood and Chronotype

Mean \pm SD sleep hygiene (SHI) scores were 29.26 \pm 5.96 with a higher score on a 0-52 scale indicative of worse sleep hygiene. General health (SHC) was 16.12 \pm 3.2 with a higher score on 0-36 scale indicating poorer general health. Total mood disturbance (SportsPOMS) was 97.47 \pm 21.19 with a higher score indicating greater mood disturbance. Chronotype classification (MEQ) across the cohort was; evening type n=4 (7%), intermediate type n=43 (74%) and morning type n=11 (19%).

Injury

Twenty-two percent (n=13) reported a recent injury that occurred in the previous four weeks. Fifty-four percent (n=7) of these injuries lasted 1-2 weeks in duration. Worry associated with injury was

reported as; none n=1, little worry n=8, moderate worry n=2, major worry n=2. Self-reported mechanism of injury was; (a) sudden onset in training or competition, without external collision n=5, (b) identifiable external trauma i.e. collision or fall n=5, (c) gradual onset n=1, and (d) other cause n=2.

Associations Between Measures

Differences between the ASSQ classification groups for; athletes' characteristics, general health, mood, sleep hygiene, chronotype and injury are presented in Table 2. Sex was significantly associated with ASSQ classification ($p = 0.039$, Cramer's $V = 0.33$), with male athletes more likely to have a mild or moderate clinical sleep problem, compared to females.

Mean SHI, SHC and SportsPOMS scores increased as ASSQ level of clinical sleep problem severity increased. There was a statistically significant difference between the ASSQ groups, for sleep hygiene, general health, and mood but not for chronotype. Compared to those in the none or mild group, there were significantly greater number of general health complaints ($p=.001$), significantly greater mood disturbance ($p=.001$) and significantly worse sleep hygiene ($p=.002$) in the "moderate" group.

Table 2 Comparison of Athletes' characteristics, general health, wellbeing, sleep hygiene and chronotype measures across the ASSQ classification groups

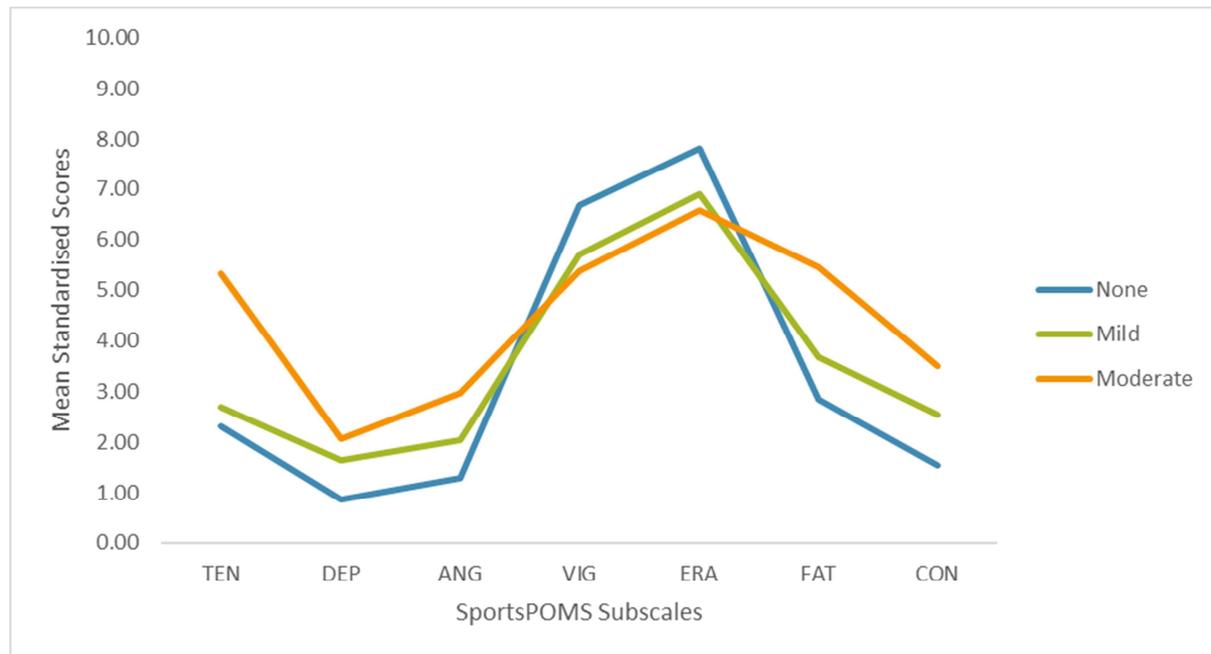
	ASSQ Classification			p-values	Effect sizes
	None (n=25)	Mild (n=24)	Moderate (n=9)		
Athlete Characteristics	Mean (sd)	Mean (sd)	Mean (sd)		
Sex (n, % female)	15 (62.5%)	6 (25%)	3 (12.5%)	0.039 ^a	0.33
Age (years)	22.04 (2.2)	21.38 (2.0)	22.33 (2.6)	0.421	0.03
Sport (n, %)					
Athletics	7 (70%)	1 (10%)	2 (20%)	n/a	
Swimming & Diving	1 (9%)	5 (45.5%)	5 (45.5%)	n/a	
Football	17 (45.9%)	18 (48.6%)	2 (5.4%)	n/a	
Health, Wellbeing, Sleep Hygiene & Chronotype Measures					
SHI	26.7 (5.4)	30.0 (5.7)	34.3 (4.5)	.002 ^b	0.20
SHC	14.8 (2.6)	16.3 (3.2)	19.3 (2.7)	.001 ^b	0.23
SportsPOMS:	87.7 (16.1)	100.3 (21.1)	117.0 (19.6)	.001 ^b	0.24
POMS Tension	5.6 (3.2)	6.5 (4.8)	12.8 (5.4)	.000 ^{bc}	
POMS Depression	2.4 (2.6)	4.6 (5.8)	5.8 (4.6)	.098	
POMS Anger	3.1 (2.9)	4.9 (4.6)	7.1 (4.9)	.034 ^b	
POMS Vigour	13.4 (2.5)	11.4 (2.9)	10.8 (2.1)	.013 ^b	
POMS Esteem-related affect	18.8 (2.6)	16.6 (2.1)	15.8 (3.7)	.004 ^b	
POMS Fatigue	5.7 (4.3)	7.3 (4.2)	10.9 (4.8)	.012 ^b	
POMS Confusion	3.1 (3.2)	5.1 (4.7)	7.0 (4.4)	.038 ^b	
MEQ	53.8 (6.9)	50.0 (7.4)	56.0 (9.6)	.077	0.09
Recent Injury	5 (8.6%)	5 (8.6%)	3 (5.1%)	n/a	

ASSQ: Athlete Sleep Screening Questionnaire, SHI: Sleep Hygiene Index, SHC: Subjective Health Complaints, SportsPOMS: Sports Profile of Mood States, MEQ: Morningness-Eveningness Questionnaire. Significant chi squared tests of independence^a. Significant Tukey post-hoc comparison: ^bnone and moderate ($p<0.05$), ^cmild and moderate ($p<0.05$) in Bonferonni controlled post hoc tests. n/a: numbers too small for Chi-square analysis.

SportsPOMS subscales, standardised to be scored out of 10, are presented in a POMS "iceberg" profile plot (Prapavessis, 2000) in Figure 1. This plot illustrates the observed differences in the

SportsPOMS subscales between the ASSQ groups. Those in the moderate group had the worst mean scores across all SportsPOMS subscales. Statistically significant differences were present between the none and moderate groups for all subscales except depression (Table 2).

Figure 1. SportsPOMS “iceberg” profile by ASSQ Sleep Disorder Category



SportsPOMS: Sports Profile of Mood States, TEN (tension-subscale), DEP (depression-subscale), ANG (anger-subscale), VIG (vigour-subscale), ERA (esteem-related affect), FAT (fatigue-subscale), CON (confusion-subscale). Scores for the subscales were transformed to standardised values in the range of 0 to 10.

Discussion:

This study is the first to investigate the relationship between clinical sleep problem category and; sleep hygiene, general health, mood, chronotype, and previous injury in elite multi-sport athletes using the ASSQ. The main finding was that the majority of athletes (84%) had either no or mild clinical sleep problems with only 16% of participants experiencing clinically relevant sleep problems. Our results are slightly less concerning than those of Bender et al. (2018) who reported that 25% of Canadian National Team athletes had moderate to severe levels of clinical sleep problems using the ASSQ. Differences may be related to the comparatively younger age of the current cohort with an age range of 18-27 years compared to Bender et al. (2018) who had an age range of 18-36. Our sample also consisted of only four sports compared to 23 different sports in the study of Bender et al. (2018). A study of 107 professional ice hockey players also reported a 25% prevalence of a significant sleep problem albeit using a sleep questionnaire that has not been validated in athletes and thus doesn't allow for direct comparison (Tuomilehto et al., 2017). Other studies that used the PSQI, a non-validated questionnaire in athletes, have also reported higher rates (~50%) of poor sleep quality in athletes (Swinbourne et al., 2016, Fietze et al., 2009, Samuels, 2008). This discrepancy again suggests that the PSQI may overestimate sleep problems in athletes and emphasizes the need for; 1.) the use of a validated sleep screening questionnaire in athletes, and 2.) a consensus on assessing sleep in elite athletes to reduce the variability in measures between studies.

This is the first study to assess the associations between sleep problems and sleep hygiene in elite athletes. Our findings indicate that athletes who had a clinically relevant sleep problem were more likely to have poorer sleep hygiene practises ($p=0.002$), highlighting the association between sleep

problem and potentially modifiable sleep behaviours. Notably, when sleep hygiene scores were compared across groups, (none=26.7, mild=30.0, moderate=34.3) it is interesting to note a significant worsening of sleep hygiene with increasing levels of sleep problem. Poor sleep hygiene relates to practising behaviours that can interfere with sleep (Mastin et al., 2006). Understanding the significant relationship in athletes between clinically relevant sleep problem and poor sleep hygiene is of great importance when designing appropriate sleep interventions in this group (Bonnar et al., 2018), where we could potentially use these interventions to target poor sleep hygiene in athletes. Recent athlete sleep intervention studies focused on sleep hygiene education have reported improvements in total sleep time in elite female volleyball players (O'Donnell et al 2017), increased sleep duration and time in bed in professional rugby players (Caia et al 2018), and improvements in both objective and subjective sleep measures in elite cricket players (Driller et al 2019). It is therefore possible that athletes identified as having a clinically relevant sleep problem and associated poor sleep hygiene would respond positively to interventions focused on sleep hygiene education. Whilst the athletes in this study had similar mean sleep hygiene scores (SHI=29.26) to those previously reported in elite youth athletes, (SHI= 30.94) (Knufinke et al., 2018), causality cannot be established from our findings and it is possible that this relationship is bidirectional.

Research in non-athletic populations reports a strong relationship between sleep and general health, with poor sleep reported as a risk factor for compromised immune function (Besedovsky et al., 2012) and increased risk of infection (Prather et al., 2015). The current study found that athletes with a clinically relevant sleep problem had significantly worse general health ($p=0.001$) compared to those without. These findings contrast with a study of Olympic-level athletes which found no association between poor sleep and illness (Drew et al., 2017). Differences in these findings may be related to their different assessment of illness, along with their use of non-athlete validated sleep questionnaires (PSQI), which tends to overestimate "poor sleep" in normal sleepers (Samuels et al., 2016), potentially indicated by the majority of athletes (73%) in the Olympic cohort reporting poor sleep (Drew et al., 2017). Nevertheless, a case-control study reported that poor sleep in elite athletes, was associated with a greater risk for upper respiratory tract and gastrointestinal symptoms (Halson et al., 2017). The importance of sleep to maintain general health in athletes has been advocated in a recent consensus statement (Walsh et al., 2011) with further research reporting the significant negative impact of poor general health on athletes' ability to perform (Raysmith and Drew, 2016).

The association between poor sleep and impaired mood has been reported in non-athletic populations (Dinges et al., 1997). To our knowledge, this is the first study to demonstrate greater mood disturbances in athletes with a clinically relevant sleep problem ($p=0.001$). A more positive mood profile is associated with better sports performance and hence this finding is likely of interest to sports medicine practitioners (Beedie et al., 2000) where improving and maintaining mood in athletes is a key priority of individuals working with athlete mental health and performance (Schinke et al., 2017). We also found that all individual mood subscales, except depression, were negatively affected in athletes with a clinically significant sleep problem. Tension-anxiety was also significantly worse in both the mild and moderate sleep problem groups compared to those without any sleep disturbance. A study of amateur marathon runners also found that greater levels of tension-anxiety were related to poor sleep quality (Lastella et al., 2014). The strong relationship between tension-anxiety and decreased sleep quality and quantity has also been reported in non-athletic age-matched populations (Wong et al., 2013). Thus, monitoring overall mood and recognising mood disturbance in athletes may also serve to identify athletes who are having difficulty with sleep.

Sex was significantly associated with the ASSQ groups ($p = 0.039$) suggesting that male athletes may be more likely to have a mild or moderate clinical sleep problem compared to females. However, this finding may be confounded by sport type. Descriptive comparisons across sport type found that (91%) of the swimming & diving athletes were classified as having a mild or moderate sleep problem, with 10 out of the 11 of these athletes being male. Previous research has reported shorter sleep duration in elite swimmers due to early-morning training sessions (Sargent et al 2012) and this may be a confounding factor in this finding. Literature on sleep in female athletes is lacking, which is reflective of the wider sex disparity in sports medicine research. However, to the author's knowledge no significant difference between male and female athletes has been reported for subjective total sleep time (Swinbourne et al), prevalence of sleep disorder (Lucidi et al 2007) or subjective pre-competition sleep disturbance (Brandt et al 2017). However, a study on French athletes reported greater difficulty falling asleep in female athletes (Schaal et al).

Regarding chronotype, this study found 19% of athletes to be morning-types, with only 7% classified as evening-types. The prevalence of morning-types in this study is somewhat lower than other studies, reporting 29% morning-types in 114 elite cricket, cycling, hockey, soccer, and triathlon athletes (Lastella et al., 2016) and 37% morning-types in 21 Bobsleigh Canadian skeletal athletes (Samuels, 2008). Our findings of morning type prevalence are more similar to that reported in the general population (14%) (Rosenthal et al., 2001). Morning-types may self-select into certain sports that align with their natural circadian rhythm, potentially improving their ability to excel in their chosen sport (Lastella et al., 2016). No relationship was found between sleep disturbance classification and chronotype classification. Greater sleep disturbance has been reported in evening-type chronotypes in the general population (Moon et al., 2018) however, a study of 114 elite athletes reported no difference in sleepiness, sleep satisfaction or sleep quality when compared across chronotype classification (Lastella et al., 2016).

There was a low incidence of recent injury in this cohort, potentially related to injury precluding athletes from qualification for the upcoming competition. The number of athletes injured per sleep disturbance category were too small for formal analysis. Literature on the relationship between sleep and athletic injury is lacking, however shorter sleep duration has been reported as a risk factor for injury in adolescent athletes (Milewski et al., 2014). To date, no study has established a significant relationship between sleep and injury in elite senior athletes. Moderate to major anxiety regarding injury was reported in 31% of the recently injured athletes in this study. Athletes reporting anxiety regarding an injury are at increased risk of further injury (Short et al., 2004) and athletes reporting a pre-competition injury are at an increased risk of injury within competition (Edouard et al., 2015). Hence, these athletes should be monitored closely by sports medicine staff.

Strengths and limitations

This is a novel study examining an elite sport population, with a broad and athlete-specific range of outcomes measures. The main strength of this paper is the original investigation of the relationship of sleep to sleep hygiene, general health, mood, chronotype and injury in elite athletes. The sample size of this study is small but reflective of the smaller numbers of the general population who are elite athletes. There is a greater representation of team sport athletes (64%) in this cohort compared to individual athletes. This may be seen as a potential limitation as shorter sleep duration in athletes from individual sports has previously been reported (Lastella et al 2015b). It is also acknowledged that injury type and incidence vary considerably between sports, however this was not investigated in the current study. As a cross-sectional study, causal relationships cannot be determined. The injury definition used, and the proximity of the competition, may have influenced the low rate of injury reported. 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.

Implications

Coaches, scientists and sport medicine practitioners are interested in factors that can negatively impact general health, mood and performance. This study found a positive association between clinically relevant sleep problems and lower general health and wellbeing, reinforcing previous research in non-athletic populations associating poor sleep with worse general health (Prather et al., 2015). Combined with the findings of this study and others, greater awareness and investigation of athletes' sleep, particularly in those who have recently been sick or are frequently ill, is justifiable.

Athletes who had a clinically relevant sleep problem (16%) had significantly poorer sleep hygiene practices, emphasising the potential role of sleep education interventions to address these modifiable sleep behaviours and potentially facilitate better sleep. Nearly 60% of the athletes in this study had a mild or moderate clinical sleep disturbance and it is suggested that these athletes would benefit from sleep education and interventions, such as those advocated in a recent systematic review (Bonnar et al., 2018).

Athletes with a clinically relevant sleep disturbance had greater overall mood disturbance, highlighting the close relationship between sleep and mood. Athletic sleep interventions in Australian Rules athletes reported positive association between improved sleep and mood (Van Ryswyk et al., 2017). Sports psychologists who are working to maintain and improve mental wellbeing in athletes should be cognisant of the strong, potentially bidirectional relationship between sleep and mood. Evaluating sleep and wellbeing in athletes using sport-specific measures rather than generic questionnaires may be more meaningful to athletic populations. Future research should investigate the changes in relationship between sleep, general health, mood, wellbeing and injury in elite athletes, over-time, across a competitive season.

Conclusion

Nearly 60% of athletes in this study had a mild or moderate sleep problem. Athletes with a clinically significant sleep problem were more likely to report poorer sleep hygiene, more general health complaints, and mood disturbance. While causality cannot be established from this cross-sectional design, further research is warranted to explore these relationships.

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Highlights

Sleep screening tools identify athletes with clinically significant sleep problems.

Mood disturbance in elite athletes linked with poor sleep.

Sleep problems in elite athletes linked with greater health complaints.

Poor sleep hygiene is related to significant sleep problems in elite athletes.

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Ethical Statement

This work described in this manuscript has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Ethical approval was granted by the University of Limerick Ethics committee (ethics number 2017_04_17). Subjects who participated in this study gave informed consent.

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Conflict of interest

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

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