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Sleep health of young adults in Western Australia and associations with physical and mental health: A population-level cross-sectional study

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Abstract

Objectives: This article aims to report on the sleep health characteristics of a population-level sample of young Australian adults and examine associations with measures of physical and mental health.

Methods: A cross-sectional study using data from the Raine Study. Data from participants (n = 1234) born into the study (Generation 2) at the 22-year follow-up were used, including data from a self-report questionnaire and polysomnography.

Results: The highest prevalence of suboptimal sleep health was seen on measures of sleep duration (30%), onset latency (18%), satisfaction (25%) and regularity (60%). Dissatisfaction with sleep (physical health: β =0.08; mental health: β =0.34) and impaired daytime alertness (physical health: β =0.09; mental health: β =0.08) were significantly associated with poorer physical and mental health and inadequate polysomnography-measured sleep duration was associated poorer mental health (β =0.07) (all *ps*<0.05).

Conclusions: Satisfaction with sleep and daytime alertness, both of which are assessed via self-report, are essential aspects of sleep health for young adults.

Implications for public health: Findings could inform public health interventions, including screening guidelines, to improve the sleep health and, in turn, the physical and mental health of young adults in Australia.

Keywords: sleep, sleep health, young adults, physical health, mental health

Introduction

Sleep disorders, such as insomnia and obstructive sleep apnoea (OSA), are highly prevalent (11% to 50% depending on country, setting and age group[1–3]) and are associated with significant physical and mental health burden.[4–6] However, there is growing evidence that the health burden associated with sleep is not limited to those with a diagnosed sleep disorder, with multiple dimensions of "poor" sleep, including insufficient or excessive duration[7-10], irregularity[11] and dissatisfaction[12], recognised as modifiable risk factors for conditions including cardiovascular diseases, diabetes and depression[9,13-15] and poorer mental and physical health more generally[10]. Such findings suggest that healthy sleep or "sleep health" is not merely the absence of a sleep disorder (similar to "health" more generally not simply being the absence of disease).[16] Sleep is essential for health and improving sleep in the population is a public

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health priority. In Australia and internationally, public health surveillance and awareness campaigns need to consider multiple dimensions of sleep health.[16]

Young adulthood (18–26 years) is a critical phase for the development of a healthy lifestyle and habits, which often continue into adulthood.[17] However, research suggests developmental trends of worsening sleep during the transition from adolescence to young adulthood,[18,19] with factors such as sleep phase delay (tendency to fall asleep and wake up later despite a regular sleep schedule) and academic and social demands likely contributing factors.[20] Young adults, therefore, may be particularly vulnerable to experiencing poor sleep that persists into adulthood and, as a result, are a priority population for primary and secondary prevention efforts to promote sleep health and reduce the risk of various chronic diseases.[21]

Despite convincing evidence that multiple dimensions of poor sleep play a causal role in reduced health outcomes, the characteristics of sleep health are not clearly articulated.[22] As a result, previous research has considered different dimensions when characterising the sleep health of a population.[23–25] Some researchers,[23] for example, have used the original sleep health framework proposed by Buysse,[16] which comprises the following sleep dimensions: regularity, satisfaction, daytime alertness, timing, efficiency and duration. Others[24] have reported on sleep health according to current sleep duration and quality guidelines and recommendations.[26,27] The United States' (US) National Sleep Foundation (NSF) sleep duration and quality recommendations comprise similar dimensions as Buysse's framework (i.e., duration and efficiency) but also include more specific measures of sleep continuity (sleep onset latency and wake after sleep onset) and sleep architecture.[26,27]

Further, to facilitate more targeted public health interventions, the Australian Institute of Health and Welfare recently highlighted that the exploration of dimensions of sleep health most strongly associated with physical and mental health conditions for specific groups is needed.[28] Such insights could, for example, inform the development of guidelines for brief proactive screening for poor sleep health in certain healthcare settings. Additionally, there is often discordance between self-report and lab-based (e.g. polysomnography [PSG]) measures of sleep dimensions[29,30] suggesting that they measure different constructs.[29] To gain a greater understanding of which dimensions of sleep health are associated with health outcomes for specific groups, research is needed exploring associations between sleep health dimensions and key health outcomes and, where possible, such analyses should consider both self-report and lab-based measures.

Population-level research characterising the sleep health of young adults is limited, particularly in Australia. One recent population-level study assessed the prevalence of clinical sleep disorders among Australian young adults (n = 1,227) and found a high prevalence of insomnia (~15%) and OSA (~21%).[3] However, this study only reported on people meeting criteria for a sleep disorder. Accordingly, it did not consider the various dimensions in the Buysse's sleep health framework and NSF recommendations, nor did it provide an indication of the prevalence of those with good sleep health, or attempt to capture the proportion of people experiencing poor sleep who may not meet criteria for a sleep disorder. Other Australian research assessing sleep health, rather than clinical sleep disorders, suggests the sleep health of young adults may be suboptimal. This research has, however, relied solely on self-report data and/or considered few sleep health dimensions.[23,25,31,32] In addition, associations between numerous dimensions of sleep health with physical and mental health have not been explored for this group.

Aims

Sleep is fundamental for health; however, there is limited research assessing the sleep health of young adults in Australia and a paucity of research exploring dimensions of sleep associated with various physical and mental health outcomes. This study addresses the current gaps in the literature by, first, providing the most comprehensive report to date on the sleep health characteristics of a population-level sample of young Australian adults. The characterisation will employ both self-report and lab-based (i.e., PSG) measures of sleep and consider dimensions included in Buysse's sleep health framework and the NSF sleep quality and duration guidelines. Second, byexamining associations between both self-report and PSG-measured dimensions of sleep health with measures of physical and mental health.

Methods

Design and participants

A cross-sectional descriptive study was undertaken using data from the Raine Study (http://www.rainestudy.org.au/): a prospective cohort study of pregnancy, childhood, adolescence and adulthood. This study uses data from participants born into the study (Generation 2) at the 22-year follow-up.[33,34] The current study evaluated sociodemographic, health and sleep-related data from a self-report questionnaire and an overnight sleep study (i.e., PSG).

A description of the sampling method of pregnant women into the study can be found here.[33] In terms of the demographic profile of the Raine Study (Generation 2) participants, previous research comparing the sample at the 22-year follow-up to the Western Australian Census data found that it is representative of the young adult population in Western Australia across key demographic variables including family structure and level of education completed.[33] However, a higher proportion (proportional differences > 10%) of participants, compared to the general young adult population, were employed in clerical/retail roles, worked more than 40 hours per week and had higher incomes.[33] There was no evidence of attrition bias across most key demographic variables.[33]

Procedures

Around the time of their 22nd birthday (2012–2014), participants still active in the cohort were contacted via telephone, had details of the 22-year follow-up explained, and were invited to participate. Interested participants were mailed an information and consent form and questionnaires to complete before attending their scheduled PSG. Consenting participants completed the questionnaires, which took approximately 2 hours.[34] The overnight sleep study was undertaken across two nights, with the first being an acclimatisation night. PSG data used in this study are from the second night. Participants arrived in the late afternoon/early evening to complete various ongoing assessments for the broader Raine Study. Later in the evening, participants were set up for PSG as close to their bedtime as practicable and encouraged to engage in their usual home-based settling behaviours. Participants woke of their own accord. Further details regarding the procedure for the PSG has been comprehensively reported elsewhere.[35]

Measures

Sociodemographic and health information

Sociodemographic information collected as part of the questionnaire included gender (male, female, other), family structure (marital status [never married, married, de facto, widowed, divorced, separated but not divorced] and number of dependants), educational attainment (< Year 10, ≥ Year 10, tertiary education), occupation (professional/managerial, clerical/retail, technical/trade/labour, unemployed/not in the labour force), hours worked per week, and income tertiles (low [≤$31,459], medium [$31,460–$56,003], high [≥$56,004]; based on Western Australian Census cut points).

The Short Form Survey 12-item (SF-12) was also administered as part of the questionnaire, and the physical and mental health component scores were calculated.[36] Scores for both composites range from 0 to 100, with higher scores indicating better physical and mental health functioning. These component scores are widely used in population-level surveys to indicate general and mental health status. None of the items pertains to any dimension of sleep health.

Dimensions of sleep health

The following dimensions of sleep health were derived from PSG data using the same methods reported elsewhere.[35]

- Sleep duration (or "total sleep time"): minutes of sleep between "lights off" and "lights on".
- Sleep onset latency: number of minutes from "lights out" to the first epoch scored as sleep.
- Wake after sleep onset: number of minutes awake between the first epoch scored as sleep and "lights on".
- Sleep efficiency: minutes of total sleep time divided by minutes available for sleep between "lights off" and "lights on", then multiplied by 100 to obtain a percentage.
- Sleep architecture:
  - o Rapid eye movement sleep (REM; per cent of total sleep time)
  - o Non-REM sleep 1 (N1; % total sleep time)
  - o Non-REM sleep 2 (N2; % total sleep time)
  - o Non-REM sleep 3 (N3; % total sleep time)

Several dimensions of sleep health were also collected as part of the self-report questionnaire. We did not the RuSATED questionnaire, a validated sleep health measure which aligns to Buysse's framework,[16] as data collection commenced prior to its development and validation. Dimensions of sleep health collected as part of the self-report questionnaire included.

- Sleep duration: a single item assessed duration: "How many total hours and minutes of actual sleep do you usually get on a typical weekday?"
- Sleep onset latency: one item assessed onset latency: "How long does it usually take you to fall asleep (minutes)?"
- Satisfaction: item 6 from the Pittsburgh Sleep Quality Index (PSQI) assessed sleep satisfaction.[37] The item reads: "During the past month, how would you rate the quality of your sleep overall?" Response options are on a 4-point Likert scale (very good, fairly good, fairly bad, very bad). This item has been used to measure the "satisfaction" dimension of sleep health in previous studies.[38]
- Daytime alertness: the Epworth Sleepiness Scale measured daytime alertness.[39] The scale comprises 8 items, with participants entering a numerical value for each using the following criteria (0 = would never doze, 1 = slight chance of dozing, 2 = moderate chance of dozing, 3 = high chance of dozing). Item scores are summed, with total scores categorised as follows:
  - o 0-5: Lower Normal Daytime Sleepiness
  - o 6-10: Higher Normal Daytime Sleepiness
  - o 11-12: Mild Excessive Daytime Sleepiness
  - o 13-15: Moderate Excessive Sleepiness
  - o 16-24: Severe Excessive Daytime Sleepiness
- Timing: items assessed usual bed and rise times: "What time (on average) have you gone to bed on weekdays" and "What time do you wake up from your usual sleep on weekdays?" The same items were also asked with reference to weekends. The RuSATED measure of sleep health asks respondents to indicate if they are typically asleep or trying to sleep between 2am and 4am.[15] Accordingly, a dichotomous "timing" variable was computed, for both weekdays and weekends, based on participants' responses to items regarding usual bed and rise time. If bed or rise times fell between 2am and 4am, they were coded as not trying to sleep within this window.
- Regularity: using the same items used to assess sleep timing, the midpoint of sleep (time fall asleep + [total sleep time/2]) for weekdays and weekends was calculated. Greater than a 1-hour difference (≥61 minutes) in the midpoint of sleep between weekdays and weekends was considered "irregular," while less than an hour (≤60 mins,) was considered regular.[38]

Variable transformation

Measures of sleep duration (minutes); sleep onset latency (minutes); wake after sleep onset (minutes); sleep efficiency (per cent); percent of total sleep time in REM, N1, N2, N3 were categorised according to NSF duration and quality guidelines (criteria for "Appropriate," "May be Appropriate" and "Inappropriate" across each parameter specified in Table 1).[26,27] These measures were further reduced to two levels for the purpose of association analyses: appropriate and suboptimal (may be appropriate/inappropriate).

The following variables were also reduced to two levels for association analyses: satisfaction (satisfied [very good/fairly good] and dissatisfied [fairly bad/very bad]) and daytime alertness (normal daytime alertness [lower normal/higher normal daytime sleepiness] and impaired daytime alertness [mild/moderate/severe excessive sleepiness]).[38]

Analyses

Aim one: descriptive statistics (numbers and percentages) were used to summarise sleep health across the various dimensions.

Aim two: associations between all dimensions of sleep health (reported on for Aim 1) and physical and mental health were explored via multivariable linear regression. Assumptions for linear regression were tested and met, except for normality. Log transformation (Lg10 [maximum value + 1 – individual score]) and removal of outliers (absolute standard score of >3.29) corrected the negative skew of both outcomes. Some measures of sleep architecture (N2, N3) could not be considered independent variables due to insufficient participant numbers across the levels of the variable. Models for the physical and mental health outcomes were built using the purposeful selection method described by Bursac and colleagues.[40] Briefly, sleep health dimensions with p-values of ≤0.25 in univariate analyses were initially entered into the models. An iterative process was then undertaken whereby entered sleep health dimensions were removed from the model if they were not significant and not a confounder. Significance was set at $\alpha = 0.1$ and confounding as a change in any remaining parameter estimate greater 20%. Next, sleep health dimensions not selected to be entered into the original models (i.e., those with p-values >0.25) were added one at a time to the model. The models were then iteratively reduced again (as per step 2), but only for the variables that were additionally added.[40] Gender, marital status and socio-economic indicators were entered and retained in models to control for their known associations with various aspects of sleep and health.

Results

Sample

Two-thousand nine hundred and sixty-eight participants initially enrolled in the Raine Study and there were 2868 live births (Figure 1). At the time of the 22-year follow-up, 565 had withdrawn and 41 had died, leaving 2262 eligible participants. 55% (n = 1234) of eligible participants consented to participate and completed the questionnaire. Seventy-seven per cent (n= 952) completed an overnight sleep study.

Sociodemographic and health information

A comprehensive demographic profile of participants, including at the 22 year follow-up has been reported in a previous study.[33] Briefly, 51% of participants were male, 78% were not married and 8% had at least one child. Regarding education, 88.4% had completed at least year 10 at high school and 40% had completed tertiary studies. Most participants (54%) were employed in clerical or retail roles, 29% in technical or trade positions, and 17% in managerial or professional roles. Eighteen per cent were not currently in the labour force. Regarding work hours and income levels, 44% worked more than 40 hours per week and 23% reported high incomes.[33]

In terms of health, the average score on the physical health composite was 53.9 (standard deviation [SD]: 6.40; range 14.57 to 70.90; n = 1146). Scores of 50 or less have been suggested as indicating the presence of a physical condition.[41] Regarding mental health, the average score on the mental health composite was 46.74 (SD: 10.27; range 1 to 68.47; n = 1146). A score of 42 or less may be indicative of mental health difficulties.[41]

Dimensions of sleep health

Sleep duration

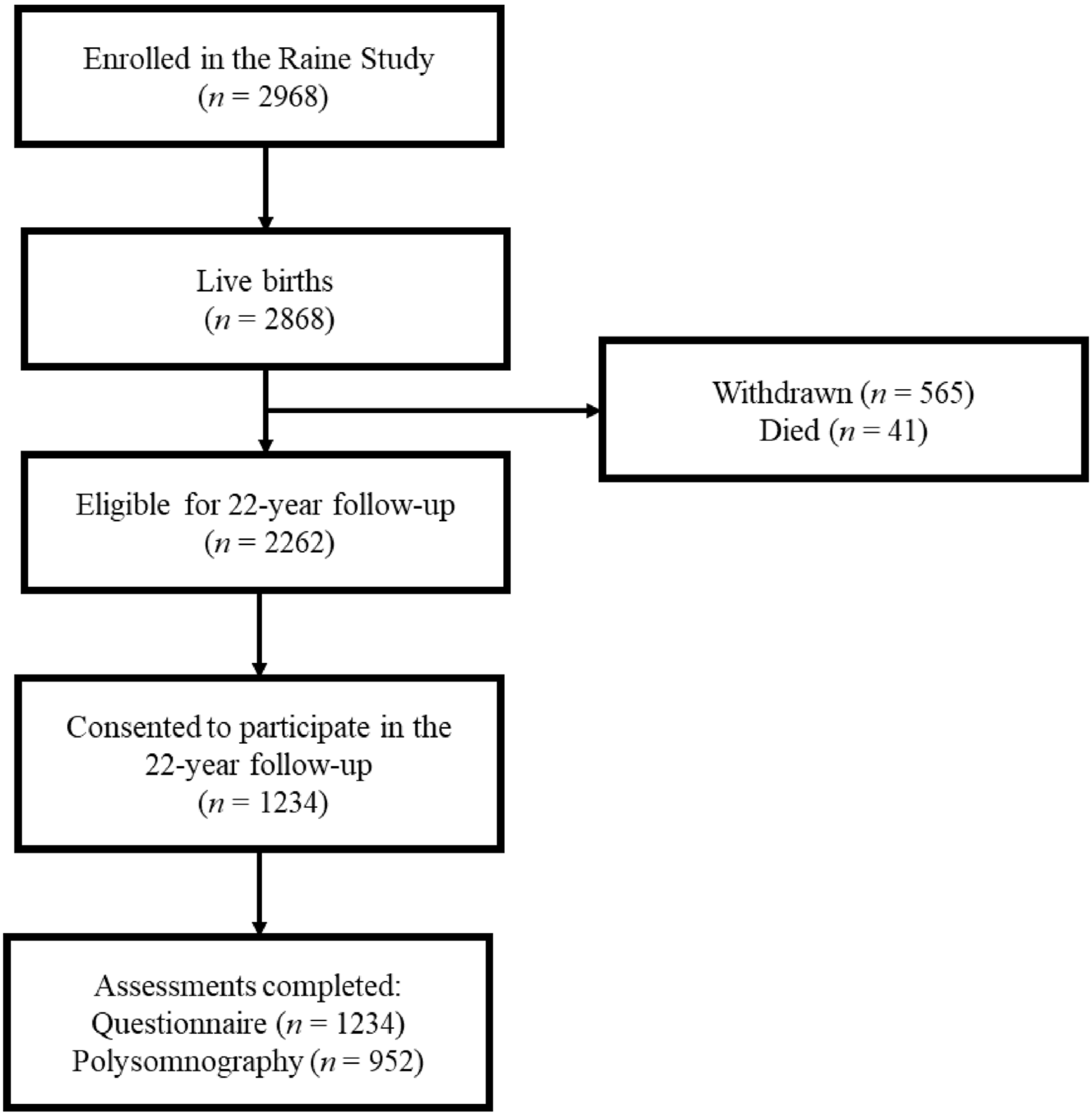
Twenty-two per cent (n = 213) of participants who completed the overnight sleep study slept for the recommended 7 to 9 hours (Table 1). Almost half (48%; n = 455) were in the "may be appropriate" range and almost 30% (n = 284) were in the "inappropriate" range. Of those who met "may be appropriate" (n = 455) and "inappropriate" (n = 284) sleep duration criteria, 100% slept

Table 1: Proportions of young adults in Western Australia meeting "appropriate," "may be appropriate" and "inappropriate" NSF criteria across multiple dimensions, based on PSG data.

Sleep dimension	Appropriate	May be appropriate	Inappropriate	Total
Sleep duration (hours)				
NSF criteria	7-9	6, 10-11	< 6, >11	
% (n)	22.4 (213)	47.8 (455)	29.8 (284)	100.0 (952)
Sleep onset latency (minutes)				
NSF criteria	≤30	>30 ≤45	>45	
% (n)	83.6 (796)	8.8 (84)	7.6 (72)	100.0 (952)
Wake after sleep onset (minutes)				
NSF criteria	≤20	>20 ≤40	>40	
% (n)	28.2 (268)	35.0 (333)	36.9 (351)	100.0 (952)
Sleep efficiency (%)				
NSF criteria	≥85	<85 ≥65	<65	
% (n)	70.1 (667)	25.8 (246)	4.1 (39)	100.0 (952)
REM (%TST)				
NSF criteria	N/A	0-40	≥41	
% (n)		99.9 (951)	0.1 (1)	100.0 (952)
N1 (%TST)				
NSF criteria	≤5	6-20	≥21	
% (n)	20.4 (194)	77.1 (734)	2.5 (24)	100.0 (952)
N2 (%TST)				
NSF criteria	N/A	0-80	≥81	
% (n)		100.0 (952)	0.0 (0)	100.0 (952)
N3 (%TST)				
NSF criteria	N/A	≥6	≤5	
% (n)		99.6 (948)	0.4 (4)	100.0 (952)

NSF: National Sleep Foundation; PSG: Polysomnography; TST: Total Sleep Time; REM: Rapid Eye Movement Sleep; N1: Non-REM sleep 1; N2: Non-REM sleep 2; N3: Non-REM sleep 3; N/A: Not Applicable (no 'inappropriate' criteria).

Figure 1: Participant flow diagram.



for less than the recommended duration (i.e., between 6 and 7 hours and less than 6 hours, respectively).

Regarding self-reported sleep duration on a typical weekday, 77% (n = 864) reported within the recommended range and 18% (n = 204) and 5% (n = 50) reported sleep durations in the "may be appropriate" and "not appropriate" ranges, respectively (Table 2). Of those reporting sleep duration in the "inappropriate" range (n = 50), 76% (n = 38) had inadequate sleep duration, while 24% (n = 12) had excessive sleep duration.

Sleep onset latency

For most participants who completed the overnight sleep study (84%; n = 796) sleep onset occurred within the recommended timeframe (Table 1), with the remaining approximately equally distributed between the "may be appropriate" (9%; n = 84) and' inappropriate' (8%; n = 72) ranges.

In terms of self-reported sleep onset latency, 76% (n= 853) were in the recommended range and 7% (n = 73) and 18% (n = 196) were in the "may be appropriate" and "inappropriate" range, respectively (Table 2).

Wake after sleep onset

For wake after sleep onset, 28% (n = 268) of participants were in the "appropriate" range, 35% (n =333) were in the "may be appropriate" range, and 37% (n = 351) in the "inappropriate" range (Table 1).

Sleep efficiency

Sleep efficiency for the majority (70%; n = 667) of participants was in the appropriate range (Table 1). Approximately one quarter (26%; n = 246) was in the "may be appropriate" range and a minority (4%; n = 39) in the inappropriate range (Table 1).

Table 2: Sleep health characteristics of young adults in Western Australia across multiple dimensions collected via the self-report questionnaire.

Sleep dimension	% (n)
Sleep duration (hours)[a]	
NSF criteria:	7-9
Appropriate (7-9hours)	77 (864)
May be appropriate (6, 10-11 hours)	18 (204)
Inappropriate (<6, >11)	5 (50)
Sleep onset latency (minutes)[b]	
NSF Criteria:	
Appropriate (≤30)	76 (853)
May be appropriate (>30 ≤45)	7 (73)
Inappropriate (>45)	18 (196)
Satisfaction[b]	
Very good	15 (173)
Fairly good	60 (678)
Fairly bad	22 (243)
Very bad	3 (28)
Daytime alertness[c]	
Lower normal daytime sleepiness	54 (568)
Higher normal daytime sleepiness	35 (369)
Mild excessive daytime sleepiness	5 (56)
Moderate excessive daytime sleepiness	4 (44)
Severe excessive daytime sleepiness	1 (9)
Timing	
Weekdays[d]:	
Trying to sleep between 2am and 4am	95 (1073)
Not trying to sleep between 2am and 4am	5 (55)
Weekends[e]:	
Trying to sleep between 2am and 4am	91 (1016)
Not trying to sleep between 2am and 4am	9 (101)
Regularity[f]	
≤60 minutes difference in midpoint of sleep between weekdays and weekends	41 (451)
>60 minutes variability in midpoint of sleep between weekdays and weekends	60 (663)

NSF: National Sleep Foundation.
[a]n= 116 missing.
[b]n= 112 missing.
[c]n = 188.
[d]n = 106 missing.
[e]n = 117.
[f]n = 120.

Sleep architecture

The proportion of total sleep time spent in N1 was in the "appropriate" range for 20% (n = 194) of participants and 77% of participants were in the "may be appropriate" range (n = 734) (Table 1). For REM, N2 and N3 most participants (99.6 to 100%) were categorised as being the in the "may be appropriate" range (there is no "appropriate" criteria for all three dimensions).

Satisfaction/perceived quality

In terms of self-reported sleep quality/satisfaction, 15% (n = 173) and 60% (n = 678) rated their sleep quality as "very good" and "fairly good," respectively. Twenty-two per cent (n = 243) reported that their sleep was "fairly bad" and 3% (n = 28) reported that their sleep was "very bad" (Table 2).

Daytime alertness

Of participants who completed the Epworth Sleepiness Scale, 89% fell in the normal daytime sleepiness range (54% [n= 568] and 35% [n = 369] were categorised as having "lower" and "higher" normal daytime sleepiness, respectively). Five per cent (n =56) met the criteria for "mild excessive daytime sleepiness" and 4% (n = 44) for "moderate excessive daytime sleepiness." Only 1% (n = 9) were categorised as having "severe excessive daytime sleepiness" (Table 2).

Timing

In terms of timing, 95% (n = 1073) reported trying to sleep between 2am and 4am, and 4.9% were not trying to sleep during this period. On weekends, 91% (n= 1016) reported usually trying to sleep between 2am and 4am, with 9% (n =101) not trying to sleep during this period (Table 2).

Regularity

Forty-one per cent (n = 451) had ≤60 minutes difference in the midpoint of sleep between weekdays and weekends, whereas 60% (n = 663) had >60 minutes variability (mean difference: 81 minutes, standard deviation 81 minutes, range 0 to 765 minutes; Table 2).

Associations between dimensions of sleep health and physical and mental health

In terms of physical health, eight sleep health dimensions met p≤0.25 criteria from the univariate analyses and were initially entered into the model (PSG-measured sleep duration, wake after sleep onset, N1 [% total sleep time], self-reported sleep onset latency, self-reported sleep duration, regularity, daytime alertness and satisfaction). The final model included satisfaction, daytime alertness, N1 (%TST) and

Table 3: Regression models exploring associations between dimensions of sleep health and physical health and mental health.

Variable	B [95%CI]	β [95%CI]*	exp(β)	sr^2	P
		Outcome: Physical Health			
Satisfaction	0.022 [-0.003, 0.048]	0.067 [-0.018, 0.081]	1.069	0.004	0.084
Daytime alertness	0.045 [0.009, 0.081]	0.094 [0.018, 0.171]	1.099	0.009	0.014
N1 (%TST)	-0.027 [-0.055, 0.000]	-0.074 [-0.148, 0.001]	0.929	0.005	0.054
		Outcome: Mental Health			
PSG-measured sleep duration (hours)	0.032 [0.003, 0.062]	0.071 [0.005, 0.133]	1.074	0.005	0.033
Satisfaction	0.151 [0.121, 0.180]	0.337 [0.264, 0.394]	1.401	0.108	<.001
Daytime alertness	0.051 [0.009, 0.093]	0.077 [0.011, 0.140]	1.083	0.006	0.017

B: Unstandardised regression coefficient; β: Standardised regression coefficient; sr^2: Semi-partial correlations; CI: confidence interval; TST: total sleep time.

sociodemographic variables, which accounted for 6% of the variability in the physical health component score ($R^2 = 0.06$, adjusted $R^2 = 0.05$, $F[7, 757] = 6.08$, $p < 0.001$; n = 765). Unstandardised and standardised regression coefficients and semi-partial correlations for each variable are reported in Table 3. Physical health component scores were 6.9% lower for those who were dissatisfied with their sleep compared to those who were satisfied. Similarly, physical health component scores were 9.4% lower among those with impaired compared to normal daytime alertness. Lastly, those with N1 (%TST) in the suboptimal range had physical component scores 7.1% higher than those in the appropriate range.

Regarding mental health, five sleep health dimensions met $p \leq 0.25$ criteria from the univariate analyses and were initially entered into the model (PSG-measured sleep duration, self-reported sleep onset latency, self-reported sleep duration, daytime alertness and satisfaction). The final model included PSG-measured sleep duration, satisfaction, daytime alertness and sociodemographic factors, which accounted for 22% of the variability in the mental health component score ($R^2 = 0.22$, adjusted $R^2 = 0.21$, $F[7, 733] = 29.72$, $p = <0.001$; n = 741). Unstandardised and standardised regression coefficients and semi-partial correlations for each variable are reported in Table 3. Mental health component scores were 7.4% lower for those who had PSG-measured sleep duration in the suboptimal compared to the appropriate range. Next, mental health scores were 33.7% lower for those who were dissatisfied with their sleep compared to those who were satisfied. Finally, those with impaired daytime alertness had mental health component scores 7.7% lower than those with normal daytime alertness.

Discussion

This is the first Australian study to comprehensively characterise the sleep health of young adults, using both lab-based and self-report data. Across most dimensions, a minority of participants were assessed as having "inappropriate" or suboptimal sleep health. However, there were exceptions and differences based on self-report and PSG data. Impaired daytime alertness and dissatisfaction with sleep, which are assessed via self-report, were associated with poorer physical and mental health, suggesting they are essential aspects of sleep health for young adults.

In terms of the NSF guidelines, across the majority of dimensions, most young adults were assessed as being in the "appropriate" or "may be appropriate" range. Dimensions where higher proportions were assessed as having suboptimal (i.e., "inappropriate") sleep health included PSG-measured wake after sleep onset (37%) and sleep duration (30%), and self-reported sleep onset latency (18%). The finding that 18% self-reported sleep onset latency in the "inappropriate" range is less than that reported for the participants aged 18-24 in a recent population survey of Australian adults (n = 1011), where 41% reported they had "difficulty falling asleep" (25). Such differences could be due to the larger age bracket or the non-specific wording of the question (individuals' perception of difficulties can vary, whereas the current study categorised according to specific criteria regarding number of minutes). The finding that 5% of participants had "inappropriate" self-reported sleep duration is less than that reported for young people aged 15-24 in Wave 13 of the Household, Income and Labour Dynamics in Australia (HILDA) survey, where 21% were classified as having inappropriate sleep duration (18% insufficient and 3% excessive) according to NSF guidelines.[32] Such differences may again be explained by the larger age bracket in the HILDA survey, which included adolescents (15 to 24 years versus 22 years only in the current study). A lack of previous population-level studies measuring dimensions of sleep health via PSG precludes comparisons of our PSG-based findings with previous research.

With reference to the additional sleep dimensions included in Buysse's framework (satisfaction, alertness, timing and regularity), firstly, the majority of participants were satisfied with their sleep (75%), leaving 25% dissatisfied. Our finding is similar to that reported for young people aged 15-24 in the HILDA survey, where 73% reported being satisfied with their sleep using the same item adopted in the current study.[32] Secondly, regarding daytime alertness, a smaller proportion of participants in the current study met criteria for impaired daytime alertness (Epworth Sleepiness Scale ≥11; 10%) compared to participants aged 18 to 24 in a previous Australian population survey, where 27% met such criteria.[25] The inclusion of younger adults (i.e. <22 years old) in this previous study may, at least partially, explain the differences in findings, with excessive daytime sleepiness a common complaint in late teenage years.[42] Lastly, in terms of sleep timing and regularity, the majority (91-95%) were attempting to sleep between 2am and 4am, a finding consistent with that of a previous survey of Australian adults (18 to 65+; n = 2044) undertaken by Appleton and colleagues.[43] There was, however, notable variability in sleep timing between weekdays and weekends, where more than half (60%) of participants had greater than one hour difference in sleep midpoint between weekdays and weekends, reflecting high sleep irregularity. By comparison, Appleton et al. reported 25% of participants had irregular sleep.[43] Multiple interacting biological, lifestyle and environmental factors, such a tendency toward a more delayed sleep phase; competing work, study, social activities; and electronic media use may explain the irregularity of sleep between weekdays and weekends among young adults.[20] Sleep irregularity has been associated with various adverse health outcomes.[44] As a result, targeting contributing factors may be an important focus for interventions to improve the sleep health of this group.

Those with lower levels of self-reported satisfaction with sleep and impaired daytime alertness were more likely to experience poorer mental and physical health. These findings are consistent with two previous population-level studies involving adults (n = 441, mean age: 57, standard deviation: 11[45]; n = 6820, mean age: 54, standard deviation: 13[14]) from the United States. Compared to other dimensions of sleep health such as duration and efficiency there is more limited evidence supporting the inclusion of satisfaction and daytime alertness as essential aspect of sleep health. Our findings suggest that, among young adults, subjective satisfaction with sleep and daytime alertness predict physical and mental health over and above other dimensions.

PSG-measured sleep dimensions associated with the two health outcomes (physical and mental health) were inconsistent: suboptimal sleep duration was associated with poor mental health, whereas suboptimal N1 (i.e., ≥21% of total sleep time; Table 1) was associated with better physical health. The inconsistency may suggest that certain dimensions of sleep health are uniquely associated with different health outcomes. Although, the finding that suboptimal N1 was associated with better physical health may reflect the lack of agreement noted within the NSF sleep quality recommendations regarding defining sleep quality using sleep architecture,[27] and suggests the need for further investigation and clearer guidelines regarding sleep architecture as measures of sleep health.[27]

Our findings have the potential to inform the development of interventions to promote sleep health among young adults. Firstly, they suggest that self-reported dimensions of sleep are most strongly associated with general health outcomes. This may offer promise for preventative public health interventions such as "health risk screening," as it could be undertaken without expensive equipment or excessive time commitments from health care providers and/or consumers. Notably, dimensions of sleep health are often interrelated, where for example, reduced alertness may be associated with suboptimal duration and/or high irregularity. Nevertheless, in healthcare settings where time pressures exist, one or two simple self-report questions may only be required to assess health risks arising from poor sleep. Secondly, sleep satisfaction could be a target of public health intervention via brief education on what constitutes "normal" sleep, with the aim of changing expectations or perceptions of sleep needs for optimal health.

The results of this study should be interpreted in the context of several methodological considerations. Firstly, this is a cross-sectional study, which limits the capacity to draw conclusions about causality or directions of effects. This might be particularly important to consider regarding the finding that people who were dissatisfied with their sleep were significantly more likely to have lower mental health scores, as people with poorer mental health may be more likely to have a general negative cognitive bias that could impact perceptions of their sleep. Such associations should be investigated longitudinally in future research. Secondly, the sample may be overrepresented in terms of those with high socio-economic status, with such factors often associated with higher levels of health and wellbeing. Next, all dimensions of sleep health referred to in the SHF quality recommendations could not be reported on due to data availability. Specifically, data for the number of awakenings per night and number of naps per day/week were unavailable. Nevertheless, relating to naps per day/week, there is a lack of a consensus regarding whether they are an indicator of sleep health.[27] Regarding the health measures, while the SF-12 is brief, it has been validated as a measure of physical and mental health in various Australian populations.[46,47] Also, the R^2 in the regression models were relatively small, which likely reflects the multitude of factors that impact physical and mental health. The larger R^2 in the model exploring associations between sleep health and mental health suggests sleep may be of particular importance to screen for in prevention and early intervention efforts for mental health difficulties, particularly as previous longitudinal research suggests sleep difficulties often precede common mental health disorders in young Australian adults.[48]

Furthermore, we note there are limitations with both self-report and PSG measures of sleep.[49] While PSG is often considered the "gold standard" approach to sleep assessment and is the only way to accurately measure sleep architecture, limitations have been reported regarding its ability to reflect typical sleep patterns.[50] For example, there has long been recognition of "the first night effect" with PSG data, where total sleep time is underestimated, alterations to sleep architecture are present, and three is reduced sleep continuity.[50] These effects have now been shown to extend beyond the first night.[51] Therefore, despite the inclusion of an acclimatisation night, the high prevalence of participants meeting "inappropriate" criteria for wake after sleep onset may be, at least partially, associated with the PSG environment. Furthermore, if the PSG environment was particularly disruptive for some participants, sleep duration and quality may have been significantly impacted during the acclimatisation night, resulting in PSG measures taken the following night potentially being impacted by rebound sleep. In terms of self-report data, while we did not use the validated RuSATED measure, our approach is similar to that adopted by other researchers in the sleep health field (e.g.38). As a final note, while we did not aim to compare descriptive statistics for self-report and PSG data, on some dimensions of sleep health there were notable differences in prevalence estimates for those meeting NSF criteria between the two measures. Such differences warrant further investigation and consideration in terms of sleep health guidelines and research more broadly.

Conclusions

The highest prevalence of suboptimal sleep health was seen on measures of sleep duration, onset latency, satisfaction and regularity. Satisfaction with sleep and daytime alertness, both of which are assessed via self-report, were associated with physical and mental health outcomes, suggesting they are essential aspects of sleep health for young adults. Findings from this study could be used to inform public health interventions, such as screening guidelines, to improve the sleep health and, in turn, the physical and mental health of young adults in Australia.

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Ethical statement

Ethics approval for the study was granted by The University of Western Australia Human Research Ethics Committee (RA/4/1/52) and the University of the Sunshine Coast (S211579).

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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