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Does sleep predict next-day napping or does napping influence same-day nocturnal sleep? Results of a population-based ecological momentary assessment study.

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Abstract

Study objectives. The temporal relationship between nocturnal sleep and daytime napping has only been assessed in small non-representative samples, and suggest that nocturnal sleep and napping are interdependent, although mixed results exist. We investigate the temporal relationship between nocturnal sleep and napping (and vice versa).

Methods. A population-based sample of middle-aged adults (N=683, mean age 60.7 [SD 9.5]) completed seven days of ecological momentary assessment reporting sleep and nap characteristics. Multilevel random-effects models were used to assess the temporal relationship between sleep duration and quality and nap occurrence and duration (and vice versa).

Results. 64% of the study population took at least one nap during seven days. Poor subjective sleep quality and shorter sleep duration increased the likelihood and duration of next-day napping. No effect of nap occurrence or duration was found on same-day nocturnal sleep duration and quality was found. However, when considering the timing of nap, afternoon naps, but neither morning nor evening naps, decreased same-day nocturnal sleep duration.

Conclusion. Naps seem to compensate for poor subjective sleep quality, and to some extent for short sleep duration. As only afternoon naps reduced same-day nocturnal sleep duration, timing of the daytime nap seems to matter with respect to same-day nocturnal sleep duration.

Keywords: napping; sleep quality; sleep duration; ecological momentary assessment

1. Introduction

Insufficient and excessive nocturnal sleep duration have repeatedly been linked to increased overall mortality and morbidity. Contrarily, daytime sleep (napping) has been less investigated, and positive[1] as well as negative[2,3] health consequences of napping have been reported. Although studies reported that napping is more frequent in older adults compared to younger adults[1], no differences between nappers and non-nappers were found with respect to sociodemographic characteristics[4,5]. Cross-sectional studies of non-representative samples of the general population related a higher frequency of napping with shorter nocturnal sleep, increased daytime sleepiness, and increased body mass index (BMI), while no relationship was found with sleep quality[5]. Moreover, the temporal association between nocturnal sleep and napping (and vice versa) has only been investigated in small non-representative samples of adolescents[6], middle-aged adults[5] and elderly[7], and thus, results are not generalizable. Shorter nocturnal sleep[5,6], lower sleep quality[6] and lower sleep efficiency[7] were found to increase the likelihood of next-day napping. Vice versa, napping led to lower same-day nocturnal sleep efficiency[5,6] and shorter same-day nocturnal sleep duration[6], and an increased nap duration led to shorter next-day nocturnal sleep[7]. Although the results of these studies differ in the temporal association between specific sleep measures and napping, the results suggest that nocturnal sleep influences next-day napping and napping has an effect on same-day nocturnal sleep. Experimental studies revealed mixed results regarding the effect of napping on same-day nocturnal sleep duration. Whereas some studies reported reduced same-day nocturnal sleep duration[8,9], others showed that napping had no effect on same-day nocturnal sleep duration and quality[10], and that the effect of napping did not extend beyond 6-8 hours[11].

Napping has commonly been assessed using sleep diaries[5], but these are prone to major potential bias; paper diaries can be illegible, or can be completely filled out the day the patient has to report the data[12]. Ecological momentary assessment (EMA) is a recent technology commonly used in psychology[13] and has previously been used to assess physical activity[14] and sleep[15]. EMA data pose a great opportunity to investigate sleep patterns since they tend to be more accurate than sleep diaries[12].

We aim to (1) characterize napping patterns in a middle-aged population-based sample, (2) investigate the effect of nocturnal sleep on next-day nap occurrence and duration, and (3) assess the effect of nap occurrence and duration on same-day nocturnal sleep duration and quality using EMA. We hypothesize that poor and short nocturnal sleep increases the likelihood of next-day napping, and napping decreases same-day nocturnal sleep duration.

2. Methods

2.1 Study population

The CoLaus study is a Swiss population-based observational prospective study investigating determinants of cardiovascular disease[16]. Between 2003 and 2006, 6,733 subjects (age range 35-75 years) were included from a random sample of the population of Lausanne, Switzerland. The second follow-up of the cohort was conducted between May 2014 and April 2017 (median follow-up time 10.7 years) and included 4881 subjects. Starting in 2015, participants were invited to complete EMA during one week. A total of 943 participants (19.3% of the participants of the follow-up) completed this investigation.

2.2 Sleep and nap measurements

EMA relying on study-provided smart phones was used to obtain "on the moment" assessments of the participant's duration and quality of nocturnal sleep and daytime naps. In the morning [around 8 am], subjects provided information on sleep duration [in minutes] and sleep quality ["To which degree do you feel recovered when waking up?"]. Sleep duration was recorded in 30 min intervals and sleep quality was measured on a 7pt-Likert scale ranging from 1 "not at all recovered" to 7 "completely recovered". Three times during the day (around 12 pm, 4.30 pm and 9 pm), participants completed information on napping occurrence [yes/no] and duration [in minutes] for the time period since last answering the smart phone. We considered that napping occurred when participants reported napping either in the morning (before 12 pm), in the afternoon (between 12 pm and 4.30 pm) or in the evening (between 4.30 pm and 9 pm), and duration of morning, afternoon and evening naps were summed to construct nap duration. In order to be consistent with previous literature[6,7], subjects were considered as *nappers* when they reported at least one nap during the study period and as *non-nappers* otherwise (no nap occurrence over one week).

2.3 Covariates

Participants were invited to attend the outpatient clinic at the University Hospital of Lausanne (CHUV, Lausanne, Switzerland) in the morning after an overnight fasting for clinical assessment and questionnaires completion. Age, sex, educational attainment (low: mandatory education or apprenticeship, medium: high school diploma, high: university diploma), marital status (living alone or in couple), weekend (weekday or weekend), excessive daytime sleepiness and risk of sleep apnea were collected using questionnaires. Excessive daytime sleepiness (EDS) stemmed from the Epworth sleepiness scale[17]. EDS was considered as present with a sum score ≥11. Risk of sleep apnea stemmed from the Berlin questionnaire and was considered as high with a sum score of ≥2[18]. Sedentary behavior was assessed by the validated Physical Activity Frequency Questionnaire[19] and defined as spending more than 90% of the daily energy in activities below moderate- and high-intensity (defined as requiring at least 4 times the basal metabolic rate, BMR)[20]. BMR multiples are close to Metabolic Equivalent of Task (MET) multiples, although MET multiples do not take into account participant sex, age or height. Body weight and height were measured using a calibrated scale and a vertical stadiometer, respectively (Seca®, Hamburg, Germany). BMI was calculated as body mass in kg divided by the square of the participant's height in meters. Information on weekday/weekend was derived from the date. Depressive status was measured with the validated 20-item Center for Epidemiologic Studies – Depression Scale questionnaire, and depressive status was considered for a score ≥17 for men and 23 for women[21]. The consumption of sleeping pills (yes/no) was assessed with EMA in the morning evaluation.

2.4 Statistical analyses

All statistical analyses were performed using STATA 15.1 (Stata-Corp, College Station, TX, USA). The study sample was characterized by descriptive statistics for nappers and non-nappers. Categorical variables were summarized as the number of subjects with column percentages, and continuous variables as means with standard deviation. Pearson chi-square (for categorical variables) or ANOVA (for continuous variables) were used to evaluate differences between nappers and non-nappers. Sleep characteristics of the previous and same-day night were described according to nap occurrence and ANOVA was used to evaluate differences. Multilevel random-effects logistic regression was used to assess the temporal relationship between nocturnal sleep duration as well as sleep quality and nap occurrence. Multilevel random-effects linear regression models were used to investigate the temporal relationship between nocturnal sleep duration as well as sleep quality and next-day nap duration, and to assess the temporal association between nap occurrence as well as nap duration and same-day nocturnal sleep duration as well as quality. First-order auto-regressive error structure was specified in multilevel random-effects linear regression for the sequentially assessed sleep and napping data. First-order auto-regressive error structure could not be specified in multilevel random-effects logistic regression due to the different error structure. We adjusted for age, sex, education, living alone status and weekend.

To check for the robustness of our results, we performed several separate sensitivity analyses. First, we excluded nights where subjects claimed to sleep less than 4 hours. Second, we additionally adjusted for BMI and risk of sleep apnea. Third, we controlled for excessive daytime sleepiness. Fourth, we excluded subjects that did not have 7 valid EMA days. Fifth, we differentiated between morning naps, afternoon naps and evening naps, and assessed their effect (occurrence and duration) on same-day nocturnal sleep duration and quality, and vice versa. Last, we additionally adjusted for depression and consumption of sleeping pills.

2.5 Exclusion criteria

Participants were excluded when 1) they had less than six valid EMA days, 2) were shift-workers with night shifts, 3) had longer naps than sleep duration of the previous night at least twice over one week, or 4) had missing information on covariates.

2.6 Ethical statement

The institutional Ethics Committee of the University of Lausanne, which afterwards became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the CoLaus and HypnoLaus study and the approval was renewed for the follow-ups. The study complies with the Declaration of Helsinki and written informed consent was obtained from all participants.

3. Results

3.1 Study population and characteristics

Of the 943 participants completing EMA, 683 (72.4%) were retained for analysis. The reasons for exclusion are summarized in **Figure 1** and comparison between included and excluded participants is provided in **supplementary table 1**. Excluded participants who completed EMA were younger, male, more educated, more likely to be employed and less likely to nap than included participants (**supplementary table 1**). Excluded subjects who participated in the second follow-up but who did not complete EMA were older, more likely to live alone, more often report excessive daytime sleepiness and sedentary behavior, and more likely unemployed than included participants (**supplementary table 1**).

Figure 1 Exclusion procedure, CoLaus study, Lausanne 205-2017

Of the 683 participants retained for analysis, 438 (64.1%) were considered as nappers. **Table 1** shows the characteristics of the total study sample, and according to non-nappers and nappers. There was no difference with respect to age, gender, education, marital status, employment status and sedentary behavior between non-nappers and nappers. Nappers reported more frequently excessive daytime sleepiness and were more overweight than non-nappers.

Table 1 Total sample characteristics, and by non-nappers and nappers, CoLaus (n=683)

3.2 Sleep and nap characteristics

In total, 437 morning, 754 afternoon and 456 evening naps were observed (**supplementary table 2**) during 1089 days. 23.3% of the subjects took at least one morning, 42.5% at least one afternoon and 31.3% at least one evening nap. The average duration of morning naps was the longest (72.7 min), followed by afternoon (39.2 min) and evening naps (36.2 min) (**supplementary table 2)**. Slightly shorter sleep duration and a lower sleep quality were observed the nights preceding naps compared to nights without a next-day nap (**table 2**). However, there was no difference in sleep duration and sleep quality of the same-day night according to nap occurrence.

Table 2 Sleep characteristics of the previous and same-day nocturnal sleep according to nap occurrence

Longer sleep duration and higher sleep quality decreased the likelihood of next-day napping and decreased the nap duration (**table 3**).

Table 3 Nocturnal sleep characteristics predicting next-day nap occurrence and nap duration

Neither nap occurrence nor nap duration influenced same-day nocturnal sleep duration or sleep quality (**table 4**).

Table 4 Nap occurrence and nap duration predicting same-day night sleep duration and quality

3.3 Sensitivity analyses

Sensitivity analyses regarding the association between sleep and next day napping are reported in **supplementary table 3.** In the first sensitivity analysis excluding nights where subjects claimed to sleep less than 4h, the results remained stable. In the second and third sensitivity analyses adjusting for excessive daytime sleepiness or high risk of sleep apnea and BMI, the results remained stable, except for the effect of sleep duration on next-day nap occurrence, which became nonsignificant. In the fourth sensitivity analysis including only subjects with seven valid days of EMA data, results remained stable, except that sleep duration no longer had an effect on nap occurrence and nap duration. In the sensitivity analyses, in which the effect of sleep duration and quality was assessed on morning, afternoon and evening nap occurrence and duration, higher sleep quality lowered the probability of next-day napping in the morning and decreased next-day nap duration in the morning and afternoon.

Also, longer sleep duration decreased the morning nap duration. In the last sensitivity analysis additionally adjusting for depressive status and use of sleeping pills, the associations remained stable.

Sensitivity analyses concerning the association between napping and same-day nocturnal sleep are reported in **supplementary table 4**. The results for napping and same-day nocturnal sleep remained stable in the first four sensitivity analyses. In the sensitivity analyses, in which the effect of nap occurrence and duration on same-day nocturnal sleep was differentiated between morning, afternoon and evening, the occurrence of afternoon naps decreased same-day nocturnal sleep duration by 17 min. Morning and evening naps had no effect on sleep duration or quality. In the sensitivity analysis additionally adjusting for depressive status and use of sleeping pills, the associations remained stable.

4. Discussion

We found that a large proportion of the general population naps and that poor (and to some extent short) sleep increased the likelihood for next-day napping, with a dose-response relationship between sleep and next-day nap duration. Contrarily, neither nap occurrence nor nap duration had effects on same-day nocturnal sleep – except when timing of the nap was considered. Afternoon naps reduced same-day nocturnal sleep duration.

4.1 Prevalence of nappers

A large share of the study sample (64%) reported napping at least once over a period of a week. This prevalence is similar to other studies, which also reported no difference in age, gender, and sedentary behavior between non-nappers and nappers[4,5]. We also found that nappers reported more frequently excessive daytime sleepiness, which is in line with other studies[5,7]. The average reported length of a nap in our study (mean age: 61, mean nap duration: 52 min) was longer than in other healthy adult populations (mean age: 53.8 respectively 59.9; mean nap duration: 19.8 min respectively 34.6 min)[4,5]. However, the average length of a nap in our study was comparable to elderly populations napping on average 54 min and 55 min (mean age 73 and 77)[22,23]. We found that during the night preceding a nap, sleep duration was shorter, and sleep quality was lower. Contrarily, there was no difference in same-day nocturnal sleep duration and quality according to nap occurrence. Other studies did not take this temporal association into account but reported a difference in sleep duration between nappers and non-nappers[4,5].

4.2 Effect of sleep on naps

The first part of our hypothesis, that poor subjective and short sleep increase the likelihood of next-day napping, was supported as poor subjective sleep quality was a strong and stable predictor for next-day nap occurrence and nap duration. Further, short sleep duration was also robustly associated with increased next-day nap duration. However, the effect of sleep duration on next-day nap occurrence was explained by excessive daytime sleepiness, high risk of sleep apnea, or when participants with less than seven valid EMA days were excluded. Thus, our results suggest that people take naps to compensate for poor sleep quality or tiredness caused by short sleep and sleep-disordered breathing, and that next-day nap duration increases as a result of poor sleep quality and short sleep duration. Our findings are in line with previous studies that linked sleep quality to next-day napping[6] and sleep duration to next-day nap duration[5,6]. Similarly to these studies[5,6], we also found that sleep duration predicted next-day napping in a simple model adjusting for age, sex, educational and living alone status. However, the effect of sleep duration on next-day nap occurrence ceased when excessive daytime sleepiness and high risk of sleep apnea were included – two confounders that these studies failed to adjust for. Hence, the effect was explained by sleep disturbances in the present study.

The relationships between napping and health are complex[4]. Some studies suggested that napping is a countermeasure to the detrimental health effects of sleep deprivation, as napping can have a stress releasing effect[24]. Contrarily, other cross-sectional studies linked naps to increased BMI, central adiposity[5] and increased inflammatory markers[4]. Moreover, as napping was found to result of nocturnal sleep characteristics, the effects of naps on health should be investigated in relation with sleep duration. On the other hand, when investigating effects of sleep duration on health, it is important to take nap duration into account, as napping is common[4,5] and short sleep duration has been linked with a range of negative health outcomes[25]. Interestingly, a previous study has reported that inflammatory markers, which were elevated in nappers compared to non-nappers[4], mediate the relationship between short sleep and mortality[26].

4.3 Effect of naps on sleep

The second part of our hypothesis, namely that napping decreases same-day nocturnal sleep duration was partly supported. We found that only afternoon naps decreased same-day nocturnal sleep duration. Contrarily, morning and evening naps as well as naps in general showed no effect on same-day nocturnal sleep duration or quality. Humans have a natural propensity to nap in the afternoon[27], which may increase the quality and depth of sleep during these naps compared to morning or evening naps. A possible explanation for afternoon naps reducing same-day nocturnal sleep duration could thus be the increased sleep efficiency, shorter sleep latency and more slow wave sleep of afternoon naps compared to morning or evening naps[28]. With regards to prior experimental data, our result that afternoon naps reduce same-day nighttime sleep are in line with previous studies[8,9], but contradict other studies that revealed no effect of afternoon naps on same-day nocturnal sleep duration[10,11]. Observational studies did not take the timing of the nap during the day into account. Hence, our result that napping in general has no effect on same-day sleep duration is in line with an observational study reporting no effect[5], but contradicts those observational studies finding an effect of napping on same-day nocturnal sleep duration[6,7]. Our findings suggest that the timing of the nap during the day matters with respect to same-day nocturnal sleep duration.

We did not find any effect of napping on sleep quality, which is in line with the literature[6,10]. Our results suggest that napping does not have a long-term impact on sleep, and thus, napping is a good countermeasure for tiredness without affecting same-day nocturnal sleep quality.

4.4 Limitations

We acknowledge several limitations. Although EMA is more accurate than sleep diaries, results are self-reported and objective measurements of naps and sleep could yield different results. Also, sleep was measured in 30-minute segments, thus curtailing variability. Further, EMA could have influenced napping behavior. Next, it was not possible to validate EMA data with accelerometry data. Still, as accelerometry data overestimates sleep by 31 min (SD 38 min)[29], it would be difficult to validate daily naps that last on average less than an hour. Lastly, our results may not be generalizable to teenager or younger adult samples.

4.5 Conclusion

Napping is frequent the middle to older age general population. Naps seem to compensate for poor sleep quality, and to some extent for short sleep duration. Whereas afternoon napping reduced same-day nocturnal sleep duration, no effects were found for morning or evening naps as well as napping in general on same-day nocturnal sleep quality.

Thus, we conclude that sleep predicts next-day napping rather than naps influencing same-day nocturnal sleep suggesting that napping is a good countermeasure for tiredness while having no long-lasting impact on sleep.

5. Acknowledgements

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6. List of abbreviations

BMI: body mass index

CI: confidence interval

EDS: excessive daytime sleepiness

EMA: Ecological momentary assessment

SD: standard deviation

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Figure Titles and Captions

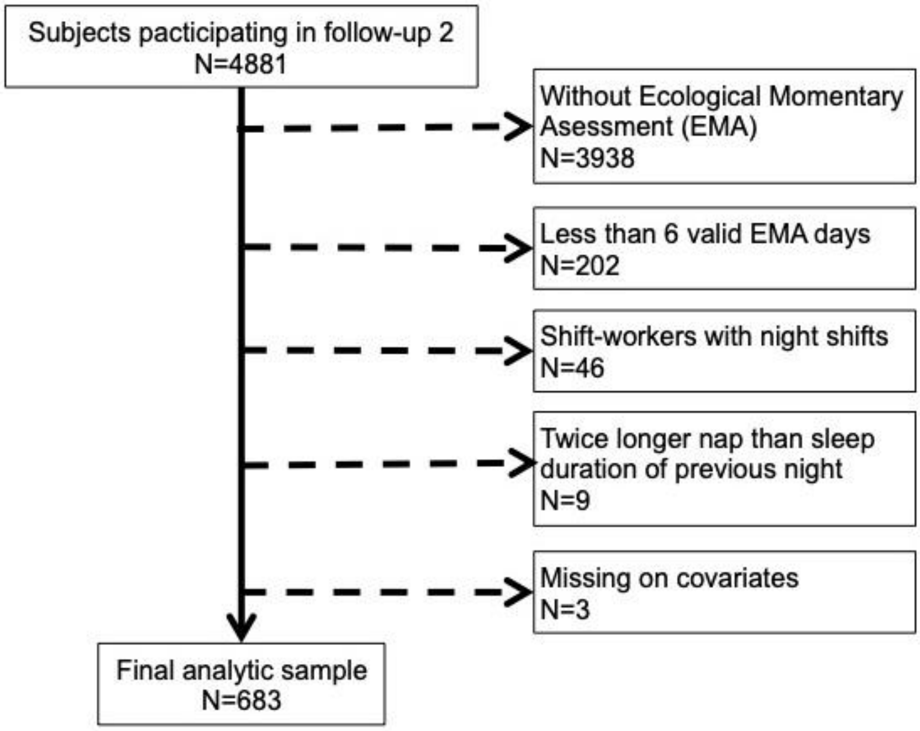

Figure 1 Exclusion procedure, CoLaus study, Lausanne 2005-2017

Tables

Table 1 Total sample characteristics, and by non-nappers and nappers, CoLaus (n=683)

	All subjects (n=683)	**Non-nappers (n=245)**	**Nappers (n=438)**	**p-value**
Age (years)	60.7 ± 9.5	59.9 ± 9.0	61.1 ± 9.7	0.094
Men	286 (41.6)	96 (39.2)	188 (42.9)	0.342
Education				0.796
High	155 (22.7)	59 (24.1)	96 (21.9)	
Medium	176 (25.8)	61 (24.9)	115 (26.3)	
Low	352 (51.5)	125 (51.0)	227 (51.8)	
Marital status (living alone)	283 (41.4)	103 (42.0)	180 (41.1)	0.810
Unemployed[1]	274 (41.0)	92 (38.0)	182 (42.7)	0.235
Excessive daytime sleepiness[2]	65 (12.2)	11 (5.5)	54 (16.3)	<0.001
Sedentary status[3]	257 (48.4)	93 (47.5)	164 (49.0)	0.738
BMI categories[4]				0.046
Normal	285 (41.9)	117 (47.8)	168 (38.5)	
Overweight	259 (38.0)	80 (32.6)	179 (41.1)	
Obese	137 (20.1)	48 (19.6)	89 (20.4)	
Depressed[5]	60 (10.2)	21 (9.7)	39 (10.5)	0.777
Sleeping pills*	71 (10.4)	20 (8.2)	51 (11.6)	0.153

BMI, body mass index. Results are expressed as number of participants (column percentage) or as mean ± standard deviation (SD). Between-group comparisons performed using chi-square for categorical variables and student's t-test for continuous variables.

***** taking sleeping pills at least once during EMA

[1] n=668, [2] n=534, [3] n=531, [4] n=681, [5] n=589

Table 2 Sleep characteristics of the previous and same-day nocturnal sleep according to nap occurrence

	No nap	**Nap**	**p-value**
Previous night			
Sleep duration	402.0 ± 85.2	395.8 ± 90.7	0.041
Sleep quality	5.1 ± 1.6	4.9 ± 1.7	<0.001
Same-day night			
Sleep duration	402.7 ± 84.3	397.8 ± 92.5	0.135
Sleep quality	5.0 ± 1.7	5.0 ± 1.7	0.675

Results are expressed as means ± standard deviation in minutes (sleep duration) and on a seven-point Likert scale (sleep quality). Between-group comparisons were performed using ANOVA.

Table 3 Nocturnal sleep characteristics predicting next-day nap occurrence and nap duration

	Nap occurrence		Nap duration	
	Coefficient (95% CI)	**p-value**	**Coefficient (95% CI)**	**p-value**
Sleep duration	-0.039 (-0.074, -0.005)	0.023	-0.394 (-0.696, -0.093)	0.010
Sleep quality	-0.153 (-0.215, -0.091)	<0.001	-2.062 (-2.598, -1.526)	<0.001

Results are expressed as unstandardized regression coefficients and 95% confidence interval (CI).

Table 4 Nap occurrence and nap duration predicting same-day night sleep duration and quality.

	Sleep duration		Sleep quality	
	Coefficient (95% CI)	**p-value**	**Coefficient (95% CI)**	**p-value**
Nap occurrence	-7.920 (-19.408, 3.568)	0.177	0.025 (-0.084, 0.134)	0.653
Nap duration	-0.015 (-0.176, 0.147)	0.860	0.000 (-0.001, 0.002)	0.795

Results are expressed as unstandardized regression coefficients and 95% confidence interval (CI).

Contents of supplementary files

Supplementary table 1: Characteristics of included and 1) excluded subjects who completed EMA and 2) excluded subjects who participated in the follow-up but who did not complete EMA.

Supplementary table 2: Characteristics of morning, afternoon and evening naps.

Supplementary table 3: Sensitivity analyses for nocturnal sleep characteristics predicting next-day nap occurrence and nap duration.

Supplementary table 4: Sensitivity analyses for nap occurrence and nap duration predicting same night sleep duration and sleep quality.