The Effect of a Six-Week Mindfulness Meditation Stress Reduction Course on Sleep in Master Students at the University of Twente

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Abstract

This study aimed to examine the effects of mindfulness meditation on sleep quality among master's students. Based on Kabat-Zinn's mindfulness training, a mindfulness-based stress reduction (MBSR) course within the positive psychology and technology master track at the University of Twente was used to provide mindfulness training for six weeks. Following participation in this course, students' sleep quality and efficiency, as well as mindfulness was hypothesised to improve. A total of three sub-studies were conducted to evaluate these expectations. For the first sub-study, an online questionnaire measuring mindful awareness and sleep quality was conducted. The students in the sample were asked to fill in the questionnaire at the beginning of their MBSR course and after it. For the second sub-study, participants were asked to fill in a sleep diary every morning asking for their sleep parameters and meditation experience. Regarding the third sub-study, two participants were wearing actigraphy throughout the time of the study to assess their sleep parameters objectively. The results showed that there was no change in the mindfulness score while sleep quality scores improved during the six-week intervention. No clear correlation between meditation and sleep could be found, but sleep efficiency improved throughout the study while the total sleep time decreased. Even though this study had limitations such as a missing control group, it gives great suggestions for future research to look further into the improvement of sleep parameters in the context of meditation and the use of sleep diaries as well as actigraphy.

Keywords: Sleep, Meditation, Mindfulness-Based Stress Reduction, Sleep diary, Actigraphy

The Importance of Sleep in Students and Relations with Mindfulness

Sleep is important for all human beings as it plays a significant role in organ function, emotion regulation, memory, task performance, decision-making, and many other areas (Kahn et al., 2013; Rasch & Born, 2013; Swanson et al., 2017; Troynikov et al., 2018). Vice versa, *poor* sleep quality impairs decision-making, the speed and accuracy of task performance, and recovery after exercise (Troynikov et al., 2018). Further, sleep loss impairs recovery after physical activity, cognitive function, mood, fatigue, and vigour (Troynikov et al., 2018). Students' health and development can be affected by their sleep quality (Ding et al., 2020). Practices of mindfulness, such as mindfulness training, have been shown to alleviate sleep disorders and improve sleep quality, as well as psychological well-being (Ding et al., 2020). Meditation has a positive effect on sleep, increases the concentration and improves memory (Geethika & Priya, 2016), which are all crucial factors for academic success. In line with this, Rusch et al. (2018) found in their study that mindfulness meditation improved the sleep quality of their participants significantly compared with non-specific active controls.

Mindfulness-Based Stress Reduction and its Usage to Improve Sleep

Kabat-Zinn (1994) described mindfulness as an awareness that arises through ‘paying attention in a particular way: on purpose, in this moment, and nonjudgmentally’ (p. 4). Mindfulness means being present in the moment. It is a state of consciousness that is achieved through being mindful towards all things and situations that one would normally take for granted or would not recognise. One directs their attention in a very specific way, consciously, presently, and without judgement. The brain is trained to pay attention to internal and external events, to be present and to observe neutrally (Akhtar, 2012). Mindfulness is a systematic start to educate

oneself in an unknown area of self-determination and wisdom powered by the natural ability of relaxation, attention, and insight (Kabat-Zinn, 2011).

Already in the 1970s, Mindfulness-Based Stress Reduction (MBSR) was developed by Kabat-Zinn (2011) at the University of Massachusetts. MBSR is a short-term intervention that, in its structure and content, aims to strengthen the participants' ability to self-regulate and improve their self-confidence and sense of self-efficacy. The formal practice of the MBSR programme includes the body scan, yoga, and sitting and walking meditation within an eight-week programme. The exercises were practised together in a group and further trained at home. The experiences that the participants make with the exercises are discussed in detail in the course with other participants (Heidenreich & Michalak, 2006). MBSR has already been tested on more than 10.000 people and has shown remarkable success in treating illnesses as well as being successful outside the medical context (Akhtar, 2012).

Meditation is seen as the heart of mindfulness practise. The formal sitting or walking meditation, for which one withdraws from everyday life for a limited time, is considered a basis and preparation to be able to perform everyday actions with higher mindfulness. In meditation, it is practised not to classify situations as good or bad automatically. Because this inner evaluation results in mental chain reactions, which can feed stress and problems, such as difficulty falling asleep. But first, one must learn that they have judgmental thoughts, which can be positive or negative, and how one reacts to them emotionally. This is where mindfulness helps (Daiker & Holdau, 2017). Mindfulness can help a person become more aware of their body's and mind's boundaries as they gradually remove stress. Through relaxation and periods of silence and meditation, one can build strength and serenity for tackling upcoming tasks (Heidenreich & Michalak, 2006). Nargundkar et al. (2020) found that mindfulness meditation has positive effects

on the mental and physical well-being of students that led to an improvement in their efficiency and academic performance. In a study by Howell et al. (2010), which was based on a model of mindfulness and its relationship to self-regulation and well-being, the relations between mindfulness, a broad range of measures related to self-regulation of sleep, and a comprehensive measure of emotional, psychological, and social well-being were examined. As a result of the study, mindfulness was found to, directly and indirectly, predict well-being in 334 undergraduate students (N=334) via its association with sleep self-regulation.

Students' Hectic Lifestyle and Counteracting Interventions

When students start their academic studies and transition from adolescence into young adulthood, it usually implies a major shift in their life in several areas. This includes moving from their family to a new housing situation, financial changes, having side jobs, and social and emotional transitions. This transitional period can lead to relational challenges that some new students experience as stressful (Nedregård & Olsen, 2014). As students progress through their academic careers, this stress continues, they face numerous challenges such as time management, prioritising various assignments, health conditions, social problems, and relationships (Nargundkar et al., 2020). Due to these stressors, learning and educational demands can harm students' physical and mental health. When students are overburdened with their academic work, stress can become chronic and can lead to various sleep problems and negative consequences (Alrashed et al., 2022). Likewise, it has been found that sleep quality has a significant effect on cognitive performance (Ahrberg et al., 2012) and therefore is important to be taken into consideration.

To counteract these negative consequences of stress on sleep, different interventions have been tried out to improve the sleep of students and to help them deal with the stressors. Positive

results have been demonstrated in studies examining sleep and mindfulness education programmes. In a study by Tanaka and Tamura (2016), sleep education as well as a self-help treatment were introduced to Japanese adolescence, resulting in increased sleep quality and improvements in alertness, motivation, and concentration ability. The systematic review by Dietrich et al. (2016) described that students in a college sleep hygiene programme reported improved sleep hygiene knowledge, reduced maladaptive beliefs about sleep, and decreased sleep disturbances. Dietrich et al., (2016) mentioned that it may be possible to increase the knowledge of sleep and sleep hygiene behaviour among the college population by providing formal sleep education programmes on sleep, sleep health, and sleep hygiene behaviour. Furthermore, the study by Tarrasch (2015) described an attempt to introduce mindfulness training directly into the curriculum in the form of a practicum course offered for special education and educational counselling students. It became apparent that for most of the students, there was a lack of previous experience in meditation, and they reported difficulties with the meditation as the process began. Changes in experiences emerged, sometimes following a turning point, with a change in the relationship to thoughts, accepting them more compassionately. Outcomes included a better awareness of thoughts, feelings, and behaviours, a perceived reduction in stress, and better sleep quality. In the study, mindfulness practices were found to benefit professionals' mental health and their ability to transmit meditation's benefits to their students in traditional academic settings.

It becomes obvious how important sleep is for academic success within student populations and that many approaches have been assessed within the academic curriculum as well as outside the study context. However, although counselling training programs often emphasise the importance of self-help strategies to prevent the negative effects of stress and

burnout, the demands of the academic curricula of students do not leave much room for direct instruction in such strategies (Tarrasch, 2015). It also needs to be considered that apart from the effectiveness of these programs another factor could also play a role such as whether people choose to engage in an intervention or whether it is an outside requirement. It is important to mention that if an intervention is part of a curriculum, students do not have the choice if they want to participate, and this can be a stress factor itself. Orsini et al., (2015) mentioned that Students' interest, commitment, learning, and satisfaction with education were enhanced when their motivation was internalised towards an intrinsic form. In self-determination theory (Deci & Ryan, 2012), intrinsic motivation and self-regulation are viewed as the most desirable types of motivation since they have been associated with deep learning, better performance, and well-being. Thus, it is important that the students learn about sleep and meditation within their curriculum but also have the choice to continue in their free time, leaving them a choice of the extent of their participation.

Current Study

To summarise the above, sleep is important for academic success but is often compromised due to hectic lifestyles, especially in students. MBSR can positively affect many mental health issues, among which are sleep problems. Therefore, this pilot study researched the effect of a six-week MBSR programme at the University of Twente on students' sleep in this course performed as a part of the curriculum but with optional self-help strategies. Thus, the following research question was addressed:

R1. What is the relation between mindfulness meditation and objective and subjective sleep of university students enrolled in a six-week mindfulness-based stress reduction course?

Further, three hypotheses were addressed in this study:

H1. The mindfulness scores of students following the six-week course will improve compared with the baseline measure.

H2. The sleep quality scores of students following the six-week course will improve compared with the baseline measure.

H3. Students will have a higher sleep efficiency after following the mindfulness meditation course.

Methods

Participants

All participants were enrolled in the master course ‘Personal Reflection & Development’ (PRD) in the year 2022/23 within the ‘Positive Clinical Psychology & Technology’ (PCPT) master track of the University of Twente and were invited to participate in the current study.

From the total of 67 students enrolled, 33 students participated in filling in the pre-test *(N =33),* and 22 students filled in the post-test *(N =22).* 27 participants worked with the sleep diaries *(N =27)* and two *(N =2)* individuals wore actigraphy throughout the research period. Inclusion criteria were being older than 18 years, being able to understand, write, and speak English, having internet access, and currently studying in the PCPT master track, following the PRD course. The overall sample consisted of 28 females (*N* = 28, 80%), seven males (*N* = 7, 20%), and no non-binary (*N* = 0, 0%). The age range was from 21 to 29 years (M_{age} = 23.74, *SD* = 1.77). Most participants were German (*N* = 26, 74.3%), eight (*N* = 8, 22.9%) participants were Dutch, and one participant (*N* = 1, 2.9%) was of another nationality.

The pre-test (*N* = 33) sample comprised primarily German citizens (*N* = 25, 75.76%), Dutch citizens (*N* = 7, 21.21%), and one other nationality (*N* = 1, 3.03%). Additionally, six of the respondents were male (*N* = 6, 18.18%), 27 of the respondents were female (*N* = 27, 81.81%), and zero respondents identified as non-binary (N = 0, 0%). The respondents were between 21 and 29 years old (M_{age} =23.64, *SD*=1.76). None withdrew their consent during the research, and every respondent fulfilled the inclusion criteria and filled in the pre-test questionnaire completely.

In the post-test, 62.86% (*N* = 22) of participants from the pre-test participated. German citizens constituted most of the post-test sample (*N* = 17, 77.3%), followed by Dutch citizens (*N* = 3, 13.6%), and no other nationalities (*N* = 0, 0%). Additionally, the sample consisted of 17 females (*N* = 17, 77.3%) and five males (*N* = 5, 22.7%). There were 22 to 26-year-old respondents (M_{age} =23.55, *SD*=1.41). Since none of the 22 respondents withdrew consent and they all completed the post-test questionnaire completely, the data from the remaining 22 respondents were used for the analyses with post-test data.

Design

In this research, three sub-studies adding up to one pilot study were conducted to answer the research question. The first sub-study consisted of a longitudinal pre-and post-test design in a group setting. The independent variable was '*mindfulness meditation'* and was assessed using the Mindfulness Attention Awareness Scale (MAAS) once before and once after the practise phase, as well as the dependent variable *'sleep*' measured using the Pittsburgh Sleep Quality Index (PSQI). Both were assessed via the pre-and post-test administered through Qualtrics. Every participant was invited to fill in the pre-and post-test. The second sub-study was measuring the sleep and mindfulness meditation development of every participant individually over time. This was performed with the help of a sleep diary based on the Consensus Sleep Diary (CSD). The dependent variable was *'sleep*' which was measured regarding its length and quality every morning via the sleep diary. Moreover, the diary included a question regarding the independent variable '*mindfulness meditation'* where one had to answer if and how long they had meditated the day before. Furthermore, the sleep diary gave the option of filling in comments every morning. The third sub-study researched the sleep of two individuals objectively. These participants wore actigraphy throughout the entire study when going to sleep.

Materials

Mindfulness Attention Awareness Scale

There are 15 items in the MAAS (Appendix A), which measures people's ability to be mindful regarding moment-to-moment experiences. It is a self-report instrument that measures the presence or absence of attention and awareness of the present moment. Research showed that this scale is related to well-being and how people cope with stressful life events (Brown & Ryan, 2003). Responses were scored based on how often respondents had the experience described in

each of the 15 statements using a 6-point Likert scale from one (almost always) to six (almost never). Therefore, a participant could indicate how much they identified with a statement. The higher the score, the more mindful the person was. Statements such as *'I rush throughout activities without being really attentive to them'* were used. Previous research showed a good degree of internal consistency with the MAAS, with an alpha of 0.85 for student and adult samples (respectively) ranging from .82 to .87 (Ciarrochi & Bilich, 2006). Moreover, MacKillop and Andersen (2007) conclude that the MAAS has good internal reliability ($\alpha = 0.89$). Its validity is demonstrated by the MAAS demonstrating both convergent and discriminant correlations in the expected direction compared to other measures, such as the NEO-Personality Inventory, the NEO-Five Factor Inventory, the mindfulness/compassion scale, Mindlessness Scale (MMS), Beck's Depression Inventory (BDI), Rosenberg's Self-Esteem Scale, and the State-Trait Anxiety Inventory (STAI) (Brown & Ryan, 2003).

Pittsburgh Sleep Quality Index

The PSQI is a self-assessment of sleep quality (Appendix B). Among the 19 items, seven 'components' are generated: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. One global score is derived from these seven components, where a higher score indicates worse sleep quality. An 18-month assessment of the PSQI's clinical and clinimetric properties was conducted with 'good' sleepers (healthy subjects, N = 52) and 'poor' sleepers (depressed patients, N = 54; sleep-disorder patients, N = 62) (Buysse et al., 1989).

There were acceptable measures of internal homogeneity, consistency (test-retest reliability), as well as validity. In determining good sleepers from poor sleepers, a global PSQI score > 5 yielded a diagnostic sensitivity of 89.6% and specificity of 86.5% (kappa = 0.75, p

0.001). The clinimetric and clinical properties of the PSQI suggest its utility both in psychiatric clinical practise and research activities (Buysse et al., 1989).

Qualtrics Questionnaire

The questionnaire was created with the help of the online programme Qualtrics (https://www.qualtrics.com) and administered in English. It was developed by the researcher to obtain written consent for participation and assess the demographics of the participants as well as their mindfulness attention awareness (MAAS) and their sleep quality (PSQI). The pre-test was accessible from the 8th of November to the 23rd of November 2022 and administered online. Participants had to indicate that they were consenting to participate in this study and their agreement with the registration of their answers (Appendix C). The following questions asked for the demographics of the participants. They had to indicate their age, gender, and nationality. After that, the MAAS and PSQI were presented. The questionnaire was filled out by the participants individually and online, which allowed them to choose the moment in time and place for their participation. The questionnaire was given at the end of the practice phase again but this time without informed consent (post-test). The second questionnaire consisted of the MAAS and PSQI only. It was accessible from the 15th of December to the 29th of December 2022.

The Consensus Sleep Diary Core

To assess sleep and its different components, the two most common methods of ambulatory sleep assessment are actigraphy which is an objective measurement and sleep diaries as a subjective measurement (Konjarski et al., 2018). Actigraphy is a small unit worn to measure the gross motor activity of a person. This unit looks like a wristwatch (smartwatch) and is non-invasive. The unit continually records the movement of the person using it and thus collects data about the rest/activity cycles. After the use of actigraphy for the planned time, the data can be

read to a computer and analysed offline. This will be discussed in further detail in the following section. Sleep diaries can be provided in an online/mobile form or used with pen and paper. People filling out a sleep diary must do so within the first hour after waking up and answer several questions regarding their subjective sleep experience.

The CSD was developed in collaboration with insomnia experts and its potential users in 2005 (Buysse et al., 2006), and was used in this study to measure the subjective sleep parameters of the participants. In the questionnaire, respondents were asked: (1) *when they got into bed*; (2) *when they tried falling asleep*; (3) *sleep onset latency*; (4) *the number of awakenings*; (5) *the duration of awakenings*; (6) *the time of the final awakening*; (7) *the time of the final rise*; (8) *the perceived sleep quality* (rated on a Likert scale from one to five); and (9) *an additional space for comments from the respondent* (Carney et al., 2012). With these variables, the following sleep parameters were calculated: Sleep onset latency (SOL), wakefulness after sleep onset (WASO), time in bed (TIB), total sleep time (TST), and sleep efficiency (SE).

To assess mindfulness meditation another question was added to the CSD: *'How many minutes did you meditate yesterday?'*. Students could fill in the minutes they meditated the day before. If they did not meditate, they were instructed to fill in a zero. The CSD was presented to participants via the Ethica application, which is an online platform to present research questionnaires to smartphones in an app format. Ethica is a platform that allows turning smartphones into microresearch labs via a single application. It is useful as it decreases the burden on the voluntary participants while enriching the possibilities for researchers to perform their observations. Participants can join any study anywhere as long as they carry their smartphone with them, download and install the Ethica application, and register for the study (Untiet, 2021).

Actigraphy

Actigraphy is a reasonably accurate alternative for diagnosing and managing sleep patterns (Silva & Kemp, 2023). It consists of a wristwatch-like device that participants wear on the non-dominant wrist during the night. Here, both participants wore it on their left wrist. By measuring movement, and from these data determined with the help of algorithms when a person is asleep, it provides the same sleep parameters as the CSD; SOL, WASO, TIB, TST, SE, and additionally a fragmentation index (FI) that indicates the number of movements and awakenings during the sleep period, as an indicator of restlessness during the night.

Procedure

This study was ethically approved (221179) by the ethics committee of the Faculty of Behavioural, Management, and Social Sciences of the University of Twente. The students of the PCPT master track participating in the PRD course were informed by their teacher Dr Ed de Bruin about this study. The University of Twente offers a six-week mindfulness meditation stress reduction course that is based on MBSR to their students enrolled in the positive clinical psychology and technology master track. This course is offered to prepare students for their later careers and possible upcoming stressors. Due to the limited time within the master, two units out of the MBSR are not used at the University of Twente. The mindfulness day, as well as the yoga, were not included in the mindfulness meditation stress reduction course. The programme did include the typical weekly group meetings, the homework, the walking and sitting mindfulness meditation, as well as the body scan. Furthermore, every week, students and teachers met to work on their autobiographical writing. Here, students could reflect on the course, talk about their experiences, and write about their personal development.

This study allowed students to learn something about their sleep and mental awareness. The information regarding the upcoming study was given verbally in a presentation by the researcher and via an announcement on Canvas (a student information and course platform used by the University of Twente). The students were then sent a link via email to enrich their motivation to participate in the current study. The link led to the pre-questionnaire on Qualtrics, providing information about the study, asking for informed consent, and then asking for their demographics and providing the MAAS and the PSQI. Information on how to contact the researcher was provided as well. This questionnaire had to be completed before the start of the practise phase to be able to join the study. Two reminders were sent out to the individuals that had not participated in the study yet to reach as many participants as possible.

Students then received another email introducing the Ethica application for the CSD and how to use it. The participants followed the practise phase for six weeks where they had different sessions of mindfulness training, as well as meditation and corresponding homework. Every morning, they were asked to fill out the CDSC provided through the Ethica platform.

Two participants volunteered to additionally wear actigraphy throughout this complete period while being asleep. After the practice phase, participants were thanked for their participation via another email, and the researcher also attended many of the last sessions of the course personally to thank the participants. They were then provided with their post-test questionnaire. This questionnaire contained the MAAS and PSQI and two reminders were sent out to the individuals that had not participated in the post-test yet but did so in the pre-test, to reach as many participants as possible.

Data Analysis

Once the data were collected it was downloaded from Qualtrics and was organised using the statistical software platform SPSS (Version 28). Regarding the first sub-study measuring the independent variable '*mindfulness meditation'* and the dependent variable *'sleep*' the pre-and post-test were analysed. First, to analyse the relationship between the MAAS and the PSQI a simple linear regression analysis was done. Second, a dependent t-test was performed in order to analyse the MAAS and PSQI, controlling for the values of the pre-test measurement.

Considering the second sub-study, the data from the sleep diary were downloaded and tabulated using SPSS (Version 28). The data were manually controlled for input mistakes and corrected when necessary (e.g., changing 10h to 22h for evening times, or correcting dates). Once the data were cleaned, three new variables were generated. The first variable TST was defined to calculate the minutes slept for every diary entry (time in minutes between lights out and get up, subtracted with SOL, WASO and EMA). The second generated variable was SOL to assess the time spent in bed before falling asleep per diary entry. The third variable WASO was constructed to calculate the time spent in bed after waking up per entry. Then, the fourth variable SE was calculated by dividing TST by TIB. Once all necessary variables were calculated missing data points were filled in as blank to prepare the data set for the upcoming analyses. Then, a mixed-model analysis was done taking the random effect of the participants into account. Afterwards, four cross-correlations were performed with the participants that filled in the sleep diary at least 50% of the time (*N=5*) to check for a correlation between the variables *'mindfulness meditation'* and *'sleep'*. Here, the correlation between SOL, WASO, TST, SE and meditation were researched.

Regarding the third sub-study, the data produced by the two actigraphy were downloaded from the devices with the device software Actilife (Version 6.8.0) and analysed using IBM SPSS Statistics (Version 28) and Microsoft Excel (Version 2211). Next, the data was cleaned and prepared for analysis. The dataset was then split into before and while the intervention data. For the dataset ‘before the intervention’ and the data set ‘while the intervention’ a descriptive analysis was performed. Visual analysis was performed to show the findings.

Results

Findings of the First Sub-Study; Pre- and Post-Test

Data from the pre- or post-test that were incomplete were excluded from the analyses. Table 1 shows the results from the pre- and post-test measurements for the PSQI and MAAS considering the whole sample and the diminished t-test sample.

Table 1

Descriptive Statistics of Raw Scores and Dependent T-test

	Raw Scores				Dependent t-test		
Variable	*Full N*	*M*	*SD*	*Min-Max*	*N*	*M*	*SD*
Pre-Test							
PSQI	33	6.46	2.51	3 - 12	20	6.9	2.73
MAAS	33	3.63	.69	2.33 - 5	20	3.57	.75
Post-Test							
PSQI	22	5.50	2.26	2 - 10	20	5.7	2.27
MAAS	22	3.64	.75	2.33 - 4.93	20	3.69	.78

Note. Overall participants (*N* = 33) were on average 24 years old (SD=1.77).

Mindfulness Score Throughout the Study

Results from the test of the first hypothesis: *'The mindfulness score of a student following the six-week course will improve compared to the baseline measure.*' indicated that the PRD course did not significantly result in an improvement of mindfulness scores, $t(19) = -.96$, $p = .17$. Therefore, the null hypothesis could not be rejected, indicating no significant change in mindfulness as measured with the MAAS.

Sleep Quality Score Throughout the Study

Results from the test of the second hypothesis: *'The sleep quality score of a student following the six-week course will improve compared to the baseline measure.'* indicated a significant positive effect on the sleep quality scores, $t(19) = 2.99$, $p = .005$. This means there was a significant improvement in the sleep quality score from the PSQI between the pre-and post-test. Therefore, the null hypothesis was rejected.

Findings of the Second Sub-Study; Sleep Diary

Results from the third hypothesis: '*Students will have a higher sleep efficiency after following the mindfulness meditation course.'* Indicated that the SE deteriorated slightly with every filled-in diary entry, however, this deterioration was not significant. On average, participants filled in 14 ($M = 14.18$, $SD = 9.37$) out of 43 possible entries. Their SE was calculated ($M = 90.55\%$, $SD = 8.24\%$), and in table 2 the estimation of fixed effects can be seen. Based on these results, the null hypothesis could not be rejected.

Table 2

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept	.91	.00	79.09	98.91	<.00	.89	.92
NR	-2.93E-5	.00	346.30	-.06	.95	-.00	.00

Note. Dependent Variable Sleep Efficiency

Four cross-correlations were performed to check for a correlation between *'mindfulness meditation'* and different *'sleep'* parameters. The series length for all four analyses was 215 but as the participants (N=5) did not fill in all possible entries there were 170 valid cases in the analyses with SOL and WASO and 145 valid cases for both analyses with TST and SE 170. The cross-correlations for minutes meditated with the four variables can be seen in table 3. It appeared that correlations at lag 0 (meditating on a day is related to sleep the following night) were significant for WASO and SE. Thus, meditation was related to worse sleep as it resulted in higher values for WASO and lower values for SE. Regarding SOL, the results showed that a higher value for SOL was related to more meditation two days later. For TST no significant correlation to meditation could be found.

Table 3

Cross-Correlation Minutes meditated with SOL, WASO, TST, and SE

Variable	SOL		WASO		TST		SE	
	CC	Std. Error	CC	Std. Error	CC	Std. Error	CC	Std. Error
Lag								
-3	15	08	17	08	10	08	-.12	08
-2	18	08	06	08	05	08	-.18	08
-1	03	08	-.07	08	05	08	-.15	08
0	10	08	23	08	04	08	-.48	08
1	-.06	08	11	08	-.01	08	-.15	08
2	-.01	08	22	08	12	08	-.18	08
3	09	08	32	08	-.05	08	-.15	08

Note. CC is the abbreviation for Cross-Correlation.

Findings of the Third Sub-Study; Actigraphy

To explore the third hypothesis: '*Students will have a higher sleep efficiency after following the mindfulness meditation course.',* in a more detailed manner another analysis was performed with the data of the third sub-study. One participant (*N*=1) wore the actigraphy before the intervention started, and both participants wore the actigraphy while the intervention took place (*N*=2). The descriptives of this can be seen in table 4.

Table 4

Descriptive Statistics of Participants One and Two

	N	Minimum	Maximum	Mean	SD
	Baseline measure (only participant 1)				
SOL_P1	5	6	35	19.20	12.11
WASO_P1	5	42	124	91.60	30.34
TIB_P1	5	542	713	652	68.85
TST_P1	5	428	609	541.20	67.32
SE_P1	5	78.97%	87.76%	82.89%	3.59%
	Intervention measures (both participants)				
SOL_P1	37	0	78	26.43	21.89
WASO_P1	37	31	216	75.19	35.76
TIB_P1	37	374	793	626.54	88.72
TST_P1	37	308	651	524.92	68.79
SE_P1	37	71.87%	93.02%	84.05%	5.41%
SOL_P2	36	3	95	23.42	19.56
WASO_P2	36	13	82	44.81	16.91
TIB_P2	36	441	766	590.72	78.46
TST_P2	36	392	715	522.5	71.84
SE_P2	36	80.48%	93.34%	88.46%	2.91%

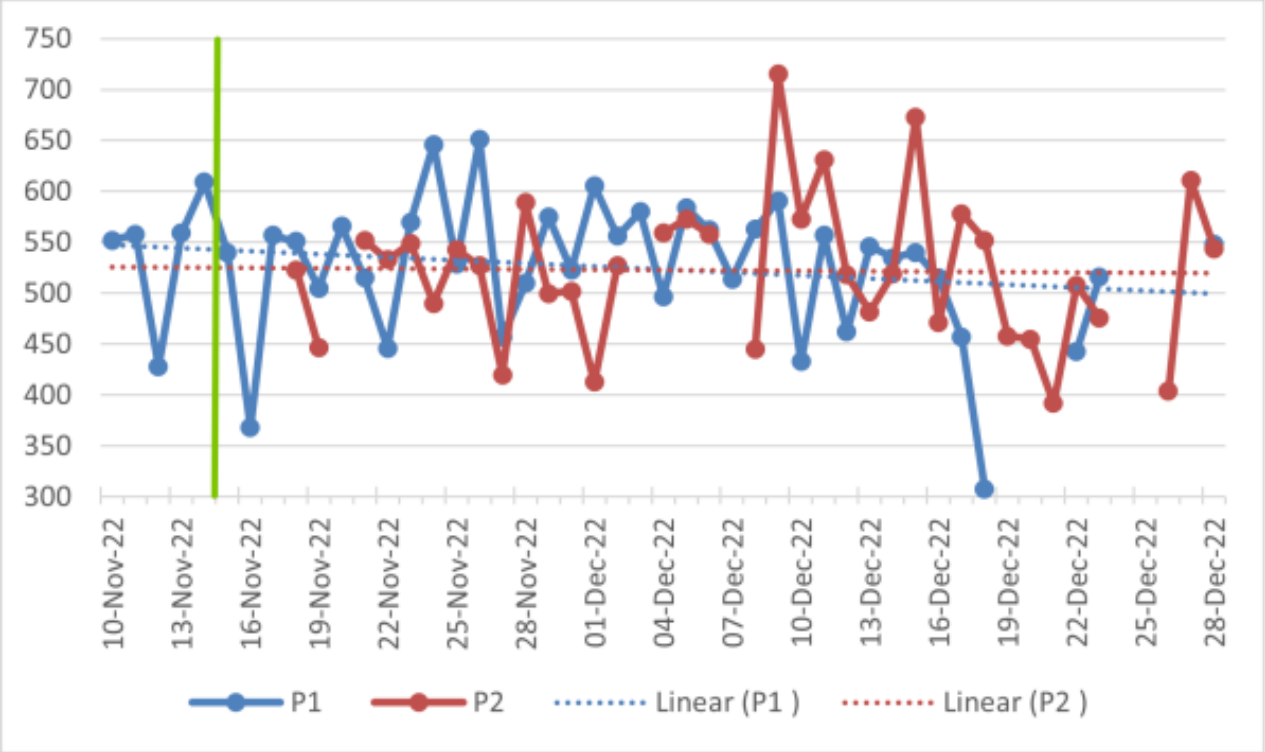
Note. P1 describes the values found for participant one that wore the actigraphy before and during the intervention. P2 describes the data for participants two that wore the actigraphy during the intervention but not before.

The visual analysis (VA) consisting of the whole dataset including the before and while intervention can be seen in figures 1 and 2. Figure 1 shows step one of the VA of TST at the Baseline measurement before the green line (condition A) and the intervention measurement after the green line (condition B). Step two of the VA gives the number of total sessions. These were A=5 and B=37 for participant one. For participant two the number of total sessions was

B=36. Regarding step three of the VA mean, median, and range were calculated for both conditions. The mean for conditions A and B can be seen in table 4. The median for condition A was Mdn= 558 with a range of 428-609 for participant one. The median for condition B was Mdn=540 with a range of 308-651 for participant one and Mdn=525 with a range of 392-715 for participant two. Step four (a) of the VA regarding the relative level change showed that for participant one the median of the first half of condition A was improving compared to the median of the second half (+7). For condition B, it showed that the median of the first half was deteriorating compared to the second half (-10.5), meaning that the TST increased very slightly until the intervention started and then decreased again. Step four (b) of the VA considering the absolute level change showed that for participant one in both conditions A and B the TST improved. Though, in condition A it improved in a stronger manner (+57) while it improved less strongly in condition B (+8).

Figure 1

Visual Analysis TST Participants One and Two



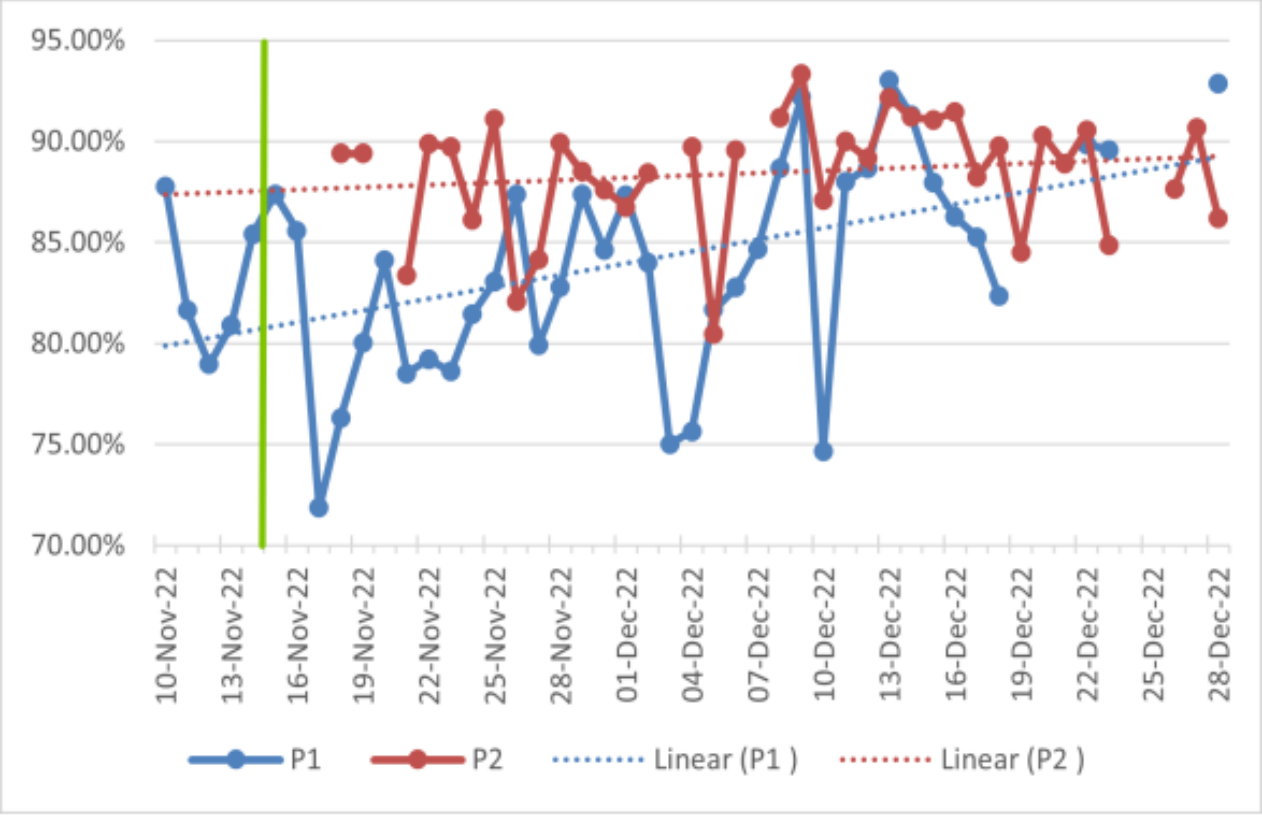
Note. The green line is marking point B.

Figure 2 shows the VA of SE for both participants. Steps one and two of the VA followed the same procedure and outcomes as described above. Regarding step three of the VA mean, median, and range were calculated for both conditions. The mean for conditions A and B can be seen in table 4. The median for condition A was Mdn=81.46% with a range of 78.97%-87.76% for participant one. The median for condition B was Mdn=84.63% with a range of 71.87%-93.02% for participant one and Mdn=89.40% with a range of 80.48%-93.34% for participant two. Step four (a) of the VA regarding the relative level change showed that for participants one, the median of the first half compared to the second half was improving in

conditions A (4.51%) and B (5.05%). Meaning that the SE increased before the intervention started and continued afterwards. Step four (b) of the VA considering the absolute level change showed that for participant one in condition A the SE was deteriorating from the first to the last value (-2.35%) and for condition B the SE improved from the first to the last value (5.5%). Considering this it can be said that the SE improved over the time of the intervention. Concluding, the null hypothesis could be rejected as SE improved during and after the mindfulness meditation course.

Figure 2

Visual Analysis SE Participants One and Two



Note. The green line is marking point B.

Discussion

The purpose of this study was to investigate the relation between mindfulness meditation and objective and subjective sleep of university students enrolled in a six-week mindfulness-based stress reduction course. This pilot study was extensive as it consisted of three sub-studies all using different ways to collect the data and analyse it. Thus, this study was able to research the relation between mindfulness meditation and objective and subjective sleep of university students enrolled in a six-week mindfulness-based stress reduction course in a very detailed manner from different points of view.

The first sub-study consisted of a longitudinal pre-and post-test in a group setting. The key findings of the first sub-study were that the mindfulness scores remained constant over time and that the sleep quality score improved after the course. Thus, these findings were not in line with H1 that the mindfulness score of a student following the six-week course would improve to the baseline measure but in line with H2: The sleep quality score of a student following the six-week course would improve compared to the baseline measure.

The findings of the second sub-study were that participants overall had a good subjective SE (90.55%) however their SE decreased not significantly over time while joining this six-week mindfulness course. This result was not in line with H3. It was expected that students would have a higher sleep efficiency after following the mindfulness meditation course. Furthermore, it appeared that meditation was related to worse sleep as it resulted in higher values for WASO and lower values for SE. Regarding SOL, the results showed that a higher value for SOL was related to more meditation two days later. For TST, no significant correlation to meditation could be found.

The findings of the third sub-study showed that the TST was higher before the intervention and lower while participating in the course. Finally, the SE improved throughout the intervention, which was in line with H3. Students had indeed a higher sleep efficiency after following the mindfulness meditation course. However, the SE showed strong variation throughout the course.

Regarding the findings of the first sub-study that mindfulness scores remained constant over time, and that sleep quality scores improved after the course it can be said that these findings might be explained by the idea that just being aware of sleep and sleep hygiene can already improve sleep quality even though mindfulness stays consistent. In the systematic review by Dietrich et al. (2016), the findings of Brown et al. (2002) were analysed and those were in line with the current results, namely, that the knowledge of sleep hygiene is already sufficient for sleep practices that are related to overall sleep quality. Thus, students tracking their sleep behaviours with the help of the sleep diaries might have affected the improved results of their sleep quality scores in the post-test. Likewise, Ding et al. (2020) and Rusch et al. (2018) found that practices of mindfulness training improved sleep quality in the people practising it. Meaning that the meditation itself might have positively influenced the sleep quality even though students did not feel more mindful necessarily.

Considering the findings of the second sub-study that participants overall had a good subjective SE (90.55%), but their SE decreased slightly over time while joining this six-week mindfulness course, one interpretation could be that students already had a good sleep efficiency on average and therefore did not improve even further, which is also known by the terms ‘ceiling effect' (Everitt & Skrondal, 2010). This means that the SE might not have improved even further as it was near the possible upper limit. Furthermore, the decrease in SE might also be explained

by more academic activities at the end of the quarter and the time just before Christmas that some people experience as stressful itself. As described in the study by Alrashed et al. (2022) the stress resulting from academic workload can lead to sleep problems and resulting negative consequences. Nagrundkar et al. (2020) mentioned in their study that academic stress consists of challenges such as time management and prioritising various assignments, as introduced in the PRD course. In account of this, it might be that the academic stress resulting from the different assignments and responsibilities led to a decrease in SE over time.

Further, the findings of the second sub-study suggested that meditation was related to worse sleep as it resulted in higher values for WASO and lower values for SE. Moreover, the results showed that a higher value for SOL was related to more meditation two days later. For TST no significant correlation to meditation could be found. Combining these results, one could speculate that students on a certain day (or a few days before) felt restless or anxious or in general too much arousal, and then decided to meditate, but this did not result in better sleep. One could also interpret these findings considering if students had a day off, they might have felt they have time to meditate the evening before, which then might have led to longer sleep which was then more fragmented resulting in more WASO. This would mean that there was a confounding effect. The common underlying factor (day off) led to more meditation, resulting in a more restless night. Finally, one could speculate that because students meditated, their night became more restless as their cognitive activities increased, or their arousal increases during meditation resulted in a more restless sleep. These findings were contrary to the expectations as Howell et al. (2010) found that practising mindfulness meditation was related to well-being and self-regulation of sleep. Next, De Bruin et al. (2015) found that adolescents in group therapy and guided internet therapy improved significantly and importantly on TST, WASO, SOL, and SE in

comparison to the waiting list control group. Tarrasch (2015) found in their study that mindfulness practice helped to reduce stress, have a higher awareness of thoughts, feelings, and behaviour, as well as better sleep quality. It was found in their study that mindfulness practices can be successfully integrated into traditional academic settings and included in preservice courses to improve professionals' mental health as well as their ability to impart meditation to students. Thus, an improvement in all four factors was expected but could not be shown in this study. This might be explained by the findings of Tarrsch (2015). In their study after meditation was introduced to the students, they had difficulties with the meditation as their training started due to a lack of previous experience.

Considering the findings of the third sub-study: TST was higher before the intervention and lower while participating in the course, and SE improved throughout the intervention, one possible explanation could be that as TST decreased SE increased because students had less opportunity to sleep meaning their sleep drive increased leading to a higher SE. This is in line with the findings of Eban-Rothschild et al. (2017) that described a person's need for sleep increased with the duration of wakefulness but subsided with sleep. Furthermore, it has been suggested that during this sleep-preparatory phase, humans' motivational states shift from wake-related goals to sleep-related goals (Eban-Rothschild et al., 2017) meaning that the lower TST can be caused by a higher motivation to stay awake. These wake-related goals could have for example been working on an assignment or fulfilling meditation exercises. Moreover, these findings are in line with the results of the first sub-study supporting the assumption of H2 that sleep parameters would improve over the time of the six-week course. However, it remains unclear what led to the raise in SE.

Concluding, it is interesting that the change in the sleep parameters could not be clearly attributed to the independent variable ‘mindfulness meditation’. Taken together with the research question: *‘What is the relation between mindfulness meditation and objective and subjective sleep of university students enrolled in a six-week mindfulness-based stress reduction course?’* could not be answered in a definite way as the results were not in line with H1, partly with H3 and only completely in line with H2.

Limitations

There are three potential limitations concerning the results of this study. The first limitation might have been that no control group was involved. First, there was no comparison to a control group, so factors like stress and workload could not be considered. Having a control group is unusual for a pilot study but still due to its absence possible underlying factors could not be considered. Therefore, it is unknown if and how they might have influenced the results of this pilot study. Second, even though several approaches were used to motivate students to participate, the response rate was low and therefore leading to few statistically significant findings. In terms of participation, 33 respondents were the highest, and 22 respondents were the lowest. This might have been due to the longitudinal character of the study. The little participation is hindering the generalisability and transferability to other samples and thus the results need to be interpreted carefully. There is a greater reliance on individual responses in a small sample size. One outlier can radically alter analyses, for instance. Thus, it can be assumed, that the results would have been of more use if there had been more participants.

A third limitation of this research might have been the somewhat unspecific inclusion criteria. Due to the option of comments in the CSD, many insights regarding the perspective of the participants were gained. However, the comments also showed that participants with

diagnosed sleep problems were present in this study. It was not mentioned at the beginning of the study that people with diagnosed sleep problems would not fit the inclusion criteria. Therefore, it remains unclear if these individuals falsified the results or if they changed them in any other interesting way.

Implications

Despite the limitations, this study investigated an important part of everyone's life: sleep. Sleep disturbances are a rising societal problem and have many negative impacts on everyone suffering from it. Troynikov et al. (2018) found that poor sleep quality impairs decision-making, the speed and accuracy of task performance, and recovery after exercise. A recent study (Ding et al., 2020) found that students' health and development can be affected by their sleep quality. Moreover, especially in the population of students at the university, disturbances in sleep have become more common (Wang & Bíró, 2021, Lund et al., 2010). Thus, a practical implication of this study is the trendsetting insight to help students sleep well. As the University of Twente is planning on doing more studies regarding sleep tracking this pilot study was of great insight on how such a study could be performed. This study is direction giving for more extensive follow-up studies and can be used as a refinement of the hypotheses.

Future Research

Much work remains to be done before a full understanding of the extent of mindfulness meditation and its effect on sleep is established. Still, the conclusions drawn in this study could serve as a good starting point for further research into mindfulness meditation and the effects it has on sleep quality. In the future, a larger sample and a control group could be used to reach statistically significant findings. Further, the usage of actigraphy for more than two participants might lead to richer objective data. Next, it is also important to consider the in- and exclusion

criteria carefully before conducting the study to be sure to measure the expected population and to see how students with diagnosed sleep problems might react differently to mediation and the program in general.

Conclusion

Although the generality of the current results must be established by future research, the present pilot study has provided some support for the positive effect a six-week mindfulness meditation course can have on sleep parameters in master students. The question remains how the improvement in sleep was related to meditation. The present research contributes to some extent to the growing body of evidence suggesting that the inclusion of an MBSR course within an academic setting is useful to enhance students' sleep and decrease their risk for stress and burnout. In the future, it is important to include programmes teaching self-help strategies such as mindfulness meditation to prevent the negative effects of stress, poor sleep or even burnout due to the high demands of students in an academic setting.

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Appendices

Appendix A

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1 Almost Always	2 Very Frequently	3 Somewhat Frequently	4 Somewhat Infrequently	5 Very Infrequently	6 Almost Never

I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6

Revised date (4 October 2006)

I drive places on 'automatic pilot' and then wonder why I went there.	1	2	3	4	5	6
I find myself preoccupied with the future or the past.	1	2	3	4	5	6
I find myself doing things without paying attention.	1	2	3	4	5	6
I snack without being aware that I'm eating.	1	2	3	4	5	6

Appendix B

Appendix. Pittsburgh Sleep Quality Index (PSQI)

Name _____ ID # _____ Date _____ Age _____

Instructions:

The following questions relate to your usual sleep habits during the past month *only*. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?
   USUAL BED TIME _____
2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?
   NUMBER OF MINUTES _____
3. During the past month, when have you usually gotten up in the morning?
   USUAL GETTING UP TIME _____
4. During the past month, how many hours of *actual sleep* did you get at night? (This may be different than the number of hours you spend in bed.)
   HOURS OF SLEEP PER NIGHT _____

For each of the remaining questions, check the one best response. Please answer *all* questions.

5. During the past month, how often have you had trouble sleeping because you...

(a) Cannot get to sleep within 30 minutes

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(b) Wake up in the middle of the night or early morning

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(c) Have to get up to use the bathroom

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(d) Cannot breathe comfortably

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(e) Cough or snore loudly

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(f) Feel too cold

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(g) Feel too hot

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(h) Had bad dreams

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(i) Have pain

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(j) Other reason(s), please describe _____

_____

How often during the past month have you had trouble sleeping because of this?

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

6. During the past month, how would you rate your sleep quality overall?

Very good	_____
Fairly good	_____
Fairly bad	_____
Very bad	_____

7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	_____
Only a very slight problem	_____
Somewhat of a problem	_____
A very big problem	_____

10. Do you have a bed partner or roommate?

No bed partner or roommate	_____
Partner/roommate in other room	_____
Partner in same room, but not same bed	_____
Partner in same bed	_____

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

(a) Loud snoring

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(b) Long pauses between breaths while asleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(c) Legs twitching or jerking while you sleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(d) Episodes of disorientation or confusion during sleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(e) Other restlessness while you sleep; please describe _____

_____

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

Appendix C

Start of Block: Informed Consent

Informed Consent
Consent Form for Participation
The influence of mobile phone usage and mindfulness meditation on sleep in master students
Thank you for agreeing to be part of the above-mentioned research project. This consent form is necessary for us to ensure that you understand the purpose of your involvement and that you agree to the conditions of your participation. Please select the according button to certify that you approve the following:
We are investigating the influence of mobile phone usage and mindfulness meditation on sleep in master students. This study is a mixed-method research project. The study consists of a pre-test that takes approximately 10 minutes to answer. Afterwards, the six-week meditation training will be accompanied by a daily sleep diary that takes about 5 minutes to fill in. Lastly, a post-test needs to be filled in, which will take around 10 minutes.
We don't anticipate that there are any risks associated with your participation, but you have the right to stop or withdraw from the research at any time without stating your reasons.
The questionnaire will be saved by the program Qualtrics and transmitted to the researchers, further information will be stored via the mobile phone application Ethica. Access to the information gained in the questionnaires will be limited to the researchers and supervisors of this project. The answers to the questionnaires will be analysed and used in a bachelor's and master's thesis. Any content that is made available through academic publications or other academic outlets will be anonymised so that you cannot be identified, and care will be taken to ensure that the information is handled confidentially. I am voluntarily taking part in this research. I understand that I do not have to take part, and I can stop the research at any time. I do not expect to receive any benefit or payment for my participation. I understand that I am free to contact the researcher with any questions I may have in the future. In order to participate in this study, you need to agree to this informed consent. If you agree to these statements, please indicate so by selecting the according button.
If you have any further questions or concerns about this study, please contact:
Lisa Grassmann +4915786149164 l.m.grassmann@student.utwente.nl
Berta Kravcenko +4917634566720 b.kravcenko@student.utwente.nl

Regarding this study:
- I consent to participate. (1)
- I do not consent to participate. (2)

Skip To: End of Survey If Regarding this study: = I do not consent to participate.

End of Block: Informed Consent

Start of Block: Demographics

What is your sex?
- Male (1)
- Female (2)
- Non-binary / third gender (3)
- Prefer not to say (4)

What is your age?

18 22 26 31 35 39 43 47 52 56 60

Age in years ()	

What is your nationality?
- Dutch (1)
- German (2)
- Other (3) _____

Where did you do your bachelor?
- University of Twente (1)
- Other (2) _____

End of Block: Demographics