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How are sleep, physical activity, and mental health related?

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Abstract

This thesis investigates the relationship between sleep, physical activity and mental health. Studies have found causal links between sleep and mental health and physical activity and mental health, but studies that combine both sleep and physical activity have been lacking in external validity. They use samples consisting of children or adolescents. This thesis expands on this existing literature by making use data of adults from the Netherlands and the US.

I made use of multivariate regression models with control variables to find correlations between sleep, physical activity and mental health. I found that respondents with higher sleep duration and better sleep quality were more likely to have better mental health outcomes. I also found that respondents with higher levels of physical activity were more likely to have better mental health outcomes. However, I did not find enough evidence for a significant interaction term. Therefore, I cannot conclude that the partial association between sleep and mental health is stronger when individuals also engage in physical exercise and vice versa.

I am, however, only able to interpret the results of this thesis as correlations. The conditional-independence assumption does not hold in this case. There could be other factors, not incorporated in the regression models, which may explain the links found in this thesis. Therefore, I cannot make any causal claims about the results of this thesis. Furthermore, because the data was self-reported, there may have been inaccuracies in the answers of the respondents due to social desirability bias and human error.

Therefore, I would recommend future research to investigate the relationships found in this thesis and the interaction term further through RCTs, so causal relationships may be identified. I would also recommend collecting data on the variables of interest and not using self-reported data.

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Contents

Introduction

After a bad night's sleep, we may notice ourselves getting irritable more easily, having more issues with concentration and overall, having a bad mood. After a workout, we often feel more energized, happy, and calm. People often receive recommendations like "sleep it off" or "clear your mind in the gym" in day-to-day life, when experiencing a bad mood or feeling down. However, this advice is not purely anecdotal. There is scientific research supporting these links between sleep and physical activity with mental health. Poor sleep is for example linked to higher rates of depression (Zhai, Zhang & Zhang, 2015) and anxiety (Ghrouz et al., 2019). Furthermore, a more sedentary lifestyle is associated with higher rates of depression (Carter et al. 2016) and regular exercise shows positive links with mental health and well-being (Bailey et al. 2013).

This thesis aims to deepen the knowledge of the relationship of sleep and physical activity with mental health. A major portion of people suffers from mental health issues. In 2021, the Mental Health Inventory classified 15.1% of Dutch people aged twelve and up as mentally unhealthy (Centraal Bureau voor de Statistiek, 2023). In the US about 19% of adults suffered from an anxiety disorder in the last year and about 30% of US adults experience a form of anxiety disorder in their lives (Harvard Medical School, 2017) This indicates that mental health is a very present problem in society that needs attention.

Improvements in the mental health of the population would also reap economic benefits. Bubonya, Cobb-Clark and Wooden (2017) found that poor mental health is linked to more work absence and less productivity at work. Poor mental health is also negatively associated with education (Cornaglia et al., 2015). People with poor mental health are more likely to drop out of school or choose lower educational paths. An increase in the average education level means a more skilled workforce, increasing productivity through more efficient workers.

Better sleeping patterns will also lead to more productivity on their own. Misalignment of the circadian and sleep-wake rhythms leads to neurobehavioral decrements. On top of that sleep deprivation impairs the function of the prefrontal cortex significantly (Blatter & Cajochen, 2007). The prefrontal cortex is responsible for a wide variety of executive functions in cognition. These executive functions include working memory, information processing, attention and judgement (Roberts et al., 1998). These executive functions are crucial for productivity. Improved executive functioning of the prefrontal cortex through the investment in better sleeping patterns can lead to an increase in overall productivity.

Gibson and Schrader (2018) illustrate this further by investigating the impact of sleep on earnings. They identify that the variation of sunset times in the US is correlated with sleep and earnings. Therefore, they use sunset times as an instrumental variable for sleep on earnings. By using this instrumental variable, they find that one extra hour of sleep increases earnings by 1.1% in the short run and 5% in the long run.

Additionally, higher levels of physical activity by itself lead to increased productivity. The meta-analysis of interventions regarding physical activity by Erickson et al. (2019) concludes that physical activity has a significant positive effect on cognition. Moderate to vigorous physical activity benefits cognition in the post-recovery period after exercise. Greater amounts of physical activity are even linked to reduced risks of cognitive impairment, such as Alzheimer's disease.

This is further demonstrated by Sjøgaard et al. (2016). They found that in 15 RCTs done in Denmark that one hour of weekly physical exercise leads to health enhancements. They also found that employees were more productive due to a lower body mass index and increased muscle strength compared to the control groups. Therefore, investments in the improvement of physical activity will lead to an improved overall productivity level of the population.

Studies that analyse the association of both sleep and physical activity with mental health like Ghrouz et al. (2019), Hosker et al. (2019) and Sampasa-Kanyinga et al. (2020) all find positive relationships. Ghrouz et al. (2019) used cross-sectional data from a convenience sample of 617 Indian college students. They found that physical activity levels are inversely correlated with anxiety and poor sleep quality is positively associated with anxiety and depression.

Hosker et al. al (2019) is a literature review of the current research regarding the promotion of mental health of American children through sleep, nutrition, and physical activity. They found a positive effect of physical activity on depression. Higher levels of physical activity also decrease the severity of ADHD- and anxiety symptoms. Furthermore, children with higher levels of physical activity on average had lower levels of substance abuse and antipsychotics use. Lastly, they found a positive association between the quality of sleep and attention, learning, academic performance, memory, cognition, behaviour, emotion regulation, self-esteem, self-acceptance, levels of optimism, and overall quality of life.

Finally, Sampasa-Kanyinga et al. (2020) is a meta-analysis of 13 cross-sectional studies composed of 115,540 children and adolescents. They concluded that children who followed the Canadian 24-Hour Movement Guidelines for Children and Youth recommendations for sleep, sedentary time and physical activity are more likely to have better mental health outcomes than those who did not.

Additionally in current literature evidence exist that better sleep leads to better mental health outcomes. The meta-analysis of 65 sleep-based randomised controlled trials (RCT) done by Scott et al. (2021) found that the interventions on average had a significant positive effect on composite mental health and a significant negative effect on depression, and anxiety.

On top of that physical activity leads to better health outcomes. Rosenbaum et al. (2014) is a meta-analysis of RCTs with physical activity interventions in samples of adults with an official diagnosis of a mental illness

excluding people suffering from dysthymia or eating disorders. Interventions include exercise programs, exercise counselling, lifestyle interventions, tai chi, or physical yoga. In total, they analysed 29 different studies. The interventions of these RCTs on average lead to a significant decrease in the depressive symptoms of the participants.

Few studies in the current literature combine sleep and physical activity in association with mental health. The ones that do, like Ghrouz et al. (2019), Hosker et al. (2019) and Sampasa-Kanyinga et al. (2020) as mentioned above, focus on children and adolescents, or use convenience samples consisting of students. Studies analysing the relationship of either sleep with mental health or physical activity with mental health are more prominent in current literature. RCTs containing adults found causal links for both. However, interventions combining sleep and physical activity are not common in the current literature.

This thesis aims to expand the knowledge of the association of sleep and physical activity with mental health together, by implementing both sleep and physical activity variables in the models. I will be making use of samples of Dutch and United States citizens randomly sampled from the population. Using these samples improves the external validity compared to the current literature.

Based on the association analyses in Ghrouz et al. (2019), Hosker et al. (2019) and Sampasa-Kanyinga et al. (2020) and the causal links identified by Scott et al. (2021) I also expect positive associations between sleep quality and mental health outcomes. This means that I hypothesise that respondents with higher sleep duration and fewer sleeping problems are less likely to experience mental health issues.

Based on the association analyses in Ghrouz et al. (2019), Hosker et al. (2019) and Sampasa-Kanyinga et al. (2020) and the causal links identified by Rosenbaum et al. (2014) I expect positive associations between physical activity and mental health outcomes. I hypothesise that respondents with higher physical activity levels are less likely to experience mental health issues.

However, there also is a correlation between sleep and physical activity. Because of the randomisation in RCT studies sleep and physical activity will not confound each other while measuring the effect of the other. In association analyses this relationship, on the contrary, is important, because it may confound the correlations in the analyses. Higher levels of physical activity may promote better sleep and poor sleep may lead to lower levels of physical activity (Kline, 2014). This indicates that sleep and physical activity may have a positive interaction effect on mental health.

Mograss et al. (2020) further demonstrate this relationship with their findings. In their intervention, they let their participants either nap, exercise or do both before they had to take a cognitive assessment. They found significant interactions between the effects of napping and exercising on cognitive task performance. Furthermore, they found that participants who napped and exercised significantly performed better at the cognitive assessment than the participants who either just napped or exercised.

Therefore, I hypothesise that the partial association between sleep and mental health is stronger when individuals also engage in physical exercise and vice versa.

Methodology

Data

I used The Longitudinal Internet Studies for the Social Sciences (LISS) and The Behavioural Risk Factor Surveillance System (BRFSS) panel datasets in this analysis. The LISS panel consists of 5,000 households and approximately 7,500 participants in the Netherlands. This panel is randomly selected based on true random population sampling. This ensures a more representative sample of the Netherlands. The respondents fill in online questionnaires each month for which the LISS compensates them. LISS provides households that do not have the facilities to fill in the survey a computer with internet access.

The BRFSS is a randomly sampled telephone-based survey system that collects data about adult US citizens regarding their health-related risk behaviours, chronic health conditions, and use of preventive services in all 50 states. The BRFSS selects via Random Digit Dialling techniques but does not compensate the respondents monetarily.

I made four datasets. The first dataset contains LISS data from 2013, the second dataset contains LISS data from 2022, the third dataset contains BRFSS survey data from 2013 and the last dataset contains BRFSS survey data from 2020. I will focus on the LISS 2013 and BRFSS 2013 datasets, however, you can find the results of the LISS 2022 and the BRFSS 2020 datasets in Appendix B and Appendix D, respectively.

For all the datasets I used the same control variables. These control variables are age, gender, education, having a partner, number of children in the household and alcohol consumption. I included age and gender to make sure that the relationships are not influenced by age and gender-related factors.

People that are in romantic relationships are more likely to have improved mental health in comparison to single people (Braithwaite & Holt-Lunstad, 2017). People in relationships are also more likely to sleep better (Talero-Gutierrez et al., 2017) and being in a romantic relationship is correlated with physical activity (Karakehayova et al., 2022).

Having children might affect sleep by waking parents up during the night. Raising kids is stressful and can therefore affect mental health. Having kids means also that there might be little time left to engage in physical activities. Therefore, I added the number of children of the respondents in the models.

Lastly, alcohol use has a remarkably high comorbidity with mental health problems and causal links between alcohol use and depression exist (Jané-Llopis & Matytsina, 2006). Alcohol intake harms sleep (Ebrahim et al., 2013). Furthermore, people who drink more alcohol are also more likely to have higher levels of physical activity (Piazza-Gardner & Barry, 2012).

In the datasets I removed all observations that contained a missing value or answers like “I do not know” or “Not sure” for any of the variables that I used in the regression models. This means that the number of observations will be the same for each variable in the same dataset.

The first dataset consists of data from the “Bedtime Procrastination: An Exploration of the ‘Who’, ‘What’ and ‘Why’ Part 2”, Health Wave 7, Social Integration and Leisure Wave 6, Personality Wave 6, and December 2013 Background Variables LISS-questionnaires. I picked this data since it provides more information on the respondents sleeping habits than any other LISS survey done yet.

The sleep variables in this dataset are the average hours of sleep per night and a binary variable indicating the absence of sleeping problems. I computed average hours of sleep by taking the average of the hours slept each night from Monday to Sunday found in the sleep diary in the “Bedtime Procrastination: An Exploration of the ‘Who’, ‘What’ and ‘Why’ Part 2” data.

I measured the physical activity levels of the respondents in this dataset a continuous variable indicating how many hours the participant spends on sports per week.

I assessed the mental health of the respondents in this analysis by how anxious and depressed the respondents reported feeling during the last month. Respondents could choose between never, seldom, sometimes, often, mostly, and continuously. I coded these categories into binary variables. Respondents who answered sometimes, often, mostly, or continuously are coded as one and the respondents who answered never or seldom are coded as zero. Moreover, I included the amount of psychiatrist, psychologist and psychotherapist visits the respondents reported having. Lastly, I added a dummy variable indicating if the respondent takes medication for anxiety or depression. These variables serve as alternative outcomes on top of anxiety and depression. These last two variables are supplementary to the

anxiety and depression variables. The results of the models containing these variables can be found in Appendix A and Appendix B.

I got the data for age, gender, having a partner and number of children in the household from the background variables. Age is in years. Gender is a dummy specifying if the participant is male or female. Partner is a dummy variable specifying if the participant has a significant other. LISS defines the number of children as the number of children living in the same household.

LISS assessed the highest achieved education level of the respondents in categories determined by the Dutch Central Bureau of Statistics. These categories are primary school, VMBO, HAVO/VWO, MBO, HBO or university. I coded these categories per the Dutch education system. VMBO and HAVO/VWO are coded under High School. MBO is coded under Higher vocational education. HBO is coded as Higher professional education.

I assessed the alcohol consumption of the respondents by a categorical variable indicating how often the respondents had a drink in the last 12 months. I coded the participants that drank every day, five or six days a week, or three or four days per week as heavy alcohol consumers. I coded participants who drank once or twice a week or once or twice a month as moderate alcohol consumers. I labelled participants who drank once every two months, or once or twice a year as infrequent alcohol consumers. I classified people who did not drink as non-drinkers.

There are 2,010 respondents in the LISS 2013 dataset. This dataset consists for 53.73% of women and 46.27% of men and the mean age of the respondents is 52.53 years old (*SD=17.15*). 4.28% of the sample reports taking medication for anxiety and/or depression. On average, a respondent in this sample took 0.59 visits to a psychiatrist, psychologist, or psychotherapist per year (*SD=3.96*). 29.75% of the respondents report feeling anxious sometimes, often, mostly, or continuously in the last month. 27.91% of the

respondents report feeling depressed sometimes, often, mostly, or continuously in the last month. The respondents sleep for 7.50 hours per night on average (*SD=1.05*). 22.99% of the respondents report having sleeping problems. On average, the respondents in this sample participate for 2.06 hours in sports (*SD=3.06*). Table 1 contains the rest of the descriptive statistics of the LISS 2013 dataset.

Table 1.

Descriptive statistics of the 2013 LISS dataset.

	Mean	SD	Minimum	Maximum	N
Anxiety	0.30	-	-	-	2010
Depression	0.28	-	-	-	2010
Hours of sleep per night	7.50	1.05	0.00	21.35	2010
No sleeping problems	0.77	-	-	-	2010
Hours of sports per week	2.06	3.06	0.00	40.00	2010
Female	0.54	-	-	-	2010
Age	52.53	17.15	16.00	93.00	2010
Partner	0.74	-	-	-	2010
Number of children in household	0.74	1.09	0.00	8.00	2010
Education					
Primary school	0.09	-	-	-	2010
High school	0.37	-	-	-	2010
Higher vocational education	0.23	-	-	-	2010
Higher Professional education	0.22	-	-	-	2010
University	0.09	-	-	-	2010
Alcohol consumption					
Heavy	0.34	-	-	-	2010
Moderate	0.38	-	-	-	2010
Infrequent	0.16	-	-	-	2010
Never	0.12	-	-	-	2010

Note. Anxiety, Depression, No sleeping problems and Partner are binary variables. Education and Alcohol consumption are categorical variables.

To measure the sleeping habits of the BRFSS respondents I used the average amount of hours slept per night. In the BRFSS 2013 dataset I used hours of exercise per week as physical activity variables. In the BRFSS 2020 I used a binary variable that indicates whether the participant has partaken in any physical activity or exercise in the last 30 days. On the contrary to the LISS datasets, these variables do not only include sports activities. They also include activities like walking.

To assess the mental health of the respondents I added the number of days the participant states to have experienced bad mental health in the last 30 days. Furthermore, I included a binary variable indicating if the respondent has ever been told that they have a depressive disorder. This depressive disorder variable is supplementary. The results of the models containing this variable can be found in Appendix C.

The BRFSS computes education by a categorical variable of highest completed education of the following levels: Did not graduate High school, graduated high school, attended college or technical school, graduated from college or technical school. I used marital status to compute a binary romantic partner variable. Being married or being a member of an unmarried couple means that the respondent does have a romantic partner. Being divorced, widowed, separated, or never married means that the respondent does not have a romantic partner.

The BRFSS 2013 dataset has 217,483 respondents. This dataset consists for 52.45% percent of women and for 47.55% of men. The average age of the sample is 52.34 years old (*SD=16.51*). The respondents of this sample on average had 2.93 bad mental health days per month (*SD=6.92*). 17.60% of the respondents report having been told that they have a major depressive disorder. The average amount of sleep per night for the sample is 7.04 hours (*SD=1.28*). The average amount of hours of exercise per week is 6.01 hours (*SD=9.32*). Table 2 displays the rest of the descriptive statistics of the BRFSS 2013 dataset.

Figure 2.

Descriptive statistics of the 2013 BFRSS dataset.

	Mean	SD	Minimum	Maximum	N
Bad mental health days	2.93	6.92	0.00	30.00	217483
Average amount of hours of sleep	7.04	1.28	1.00	24.00	217483
Hours of exercise a week	6.01	9.32	0.00	138.00	217483
Age	52.34	16.51	18.00	80.00	217483
Number of children in household	0.54	1.00	0.00	16.00	217483
Female	0.52	-	-	-	217483
Partner	0.60	-	-	-	217483
Education					
Attended High School	0.04	-	-	-	217483
Graduated High School	0.23	-	-	-	217483
Attended college	0.28	-	-	-	217483
Graduated college	0.45	-	-	-	217483
Average number of alcoholic drinks per month	3.23	9.35	1.00	99.00	217483

Note. Female and Partner are dummy variables. Education is a categorical variable.

Analysis

In the analysis I used Ordinary Least Squares multivariate regression models to find the correlations. I used STATA, statistical software, to process the data and run the models. The regression coefficients give the relationship between the variables of interest. The regressions equations of the models look like this:

$$Mental\ health_i = \beta_0 + \beta_1 * Sleep_i + \beta_2 * Physical\ activity_i + \beta_3 * Controls_i + \varepsilon_i$$

$$Mental\ health_i = \beta_0 + \beta_1 * Sleep_i + \beta_2 * Physical\ activity_i + \beta_3 * Sleep_i * Physical\ activity_i + \beta_4 * Controls_i + \varepsilon_i$$

In the LISS dataset the mental health variables are depression and anxiety. These are binary variables that show whether the respondent has felt anxious and depressed over the last 30 days. In the BRFSS dataset the variable for mental health is the number of bad mental health days in the last 30 days.

In the LISS dataset the sleep variables are average hours of sleep per night and having no sleeping problems. Average hours of sleep is a continuous variable and no sleeping problems is a binary variable depicting if the respondent has sleeping problems or not. In the BRFSS dataset the variable for sleep is also the average hours of sleep per night.

In the LISS dataset the physical activity variable is the number of hours spent on sports per week. In the BRFSS dataset the physical activity variable is the number of hours spent on exercise per week. LISS is stricter in their definition. They only consider sports, while the BRFSS also considers walking and other sorts of exercise.

The controls vector in the models consists of the control variables, I added, mentioned in the data section. (Age, gender, education, having a partner, number of children in the household and alcohol consumption) I used the model without the interaction term to find the correlations of sleep and physical activity with the mental health dimensions mentioned above in the data section.

The second model serves to find the interaction term of sleep and physical activity. This term captures the partial relationship of sleep with mental health if the respondent also partakes in physical activity and vice versa. For example, someone who does not suffer from sleeping problems might be even more likely to have better mental health outcomes the more they are physically active than someone who does suffer from sleeping problems. The coefficient can therefore be interpreted as the sign and strength of the partial relationship of sleep with mental health if the respondent also partakes in physical activity and vice versa.

Results

The regression results in Table 3 show that in the models without the interaction term, the number of hours of sleep per night is significantly correlated with depression at a 1% significance level with an estimated coefficient of -0.025. Hours of sports is also significantly correlated with depression at a 1% significance level with an estimated coefficient of -0.012 This means that one extra hour of sleep per night is significantly associated with a decrease in the chance of feeling depressed sometimes, often, mostly, or continuously of 2.5 percentage points. Furthermore, one extra hour of sport per week is significantly associated with a decrease in the chance of feeling depressed sometimes, often, mostly, or continuously of 1.2 percentage points.

I found no significant correlations between anxiety and hours of sleep or hours of sports at a 10% significance level. However, these models do provide evidence that both sleep and physical activity are positively correlated with better mental health outcomes through the significant relationship of both sleep and physical activity with depression.

In the regression models with the interaction term shown in Table 3 I found a significant partial correlation between hours of sleep and depression at a 5% significance level ($\hat{\beta} = -0.24$). I found no significant interaction terms or correlations with anxiety. However, these results still provide evidence that supports the hypothesis that both sleep and physical activity are positively correlated with better mental health outcomes.

Table 3.

Regressions results of the LISS 2013 dataset with Hours of sleep per night as sleep variable.

	Without interaction		With interaction	
	Anxiety	Depression	Anxiety	Depression
Hours of sleep	-0.007	-0.025***	-0.008	-0.024**
	(0.010)	(0.009)	(0.012)	(0.010)
Hours of sports	-0.004	-0.012***	-0.007	-0.006
	(0.003)	(0.003)	(0.028)	(0.028)
Hours of sleep # Hours of sports	-	-	0.000	-0.001
			(0.004)	(0.004)
Constant	0.692***	0.726***	0.697***	0.718***
	(0.105)	(0.097)	(0.114)	(0.103)
Observations	2,010	2,010	2,010	2,010

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption.

Table 4 shows a significant correlation between no sleeping problems and both anxiety and depression at a 1% significance level with an estimated coefficient of -0.217 and -0.271 respectively. This means that respondents that do not suffer from sleeping problems are 21.7 percentage points less likely to be feeling anxious and 27.1 percentage points less likely to be feeling depressed. Furthermore, I found a significant correlation between hours of sports and depression at a 1% significance level ($\hat{\beta} = -0.010$).

These results support the hypothesis that sleep and physical activity are positively correlated with better mental health outcomes.

The regression models with interaction term in Table 4 show a significant partial correlation between no sleeping problems and both anxiety and depression at a 1% significance level with an estimated coefficient of -0.236 and 0.299, respectively. This means that respondents that do not suffer from sleeping problems and do not partake in sports are 23.6 percentage points less likely to be feeling and 29.9 percentage points

less likely to be feeling depressed. Furthermore, I found a significant partial correlation between hours of sports and depression at a 1% significance level ($\hat{\beta} = -0.023$)

I also found a significant interaction term of no sleeping problems and hours of sports on depression at a 5% significance level with an estimated coefficient of 0.015. This means that respondents that do not suffer from sleeping problems on average are 1.5 percentage points more likely to be feeling depressed for each extra hour of sports per week, compared to respondents who do suffer from sleeping problems.

These findings support the hypothesis that both sleep and physical activity are significantly positively correlated with better mental health outcomes. However, these findings also contradict the hypothesis that sleep and physical activity interact positively in their relationship with better mental health outcomes.

Table 4.

Regressions results of the LISS 2013 dataset with No sleeping problems as sleep variable.

	Without interaction		With interaction	
	Anxiety	Depression	Anxiety	Depression
No sleeping problems	-0.217***	-0.271***	-0.235***	-0.299***
	(0.026)	(0.026)	(0.030)	(0.030)
Hours of sports	-0.003	-0.010***	-0.011	-0.023***
	(0.003)	(0.003)	(0.008)	(0.007)
No sleeping problems # Hours of sports	-	-	0.010	0.015**
			(0.008)	(0.008)
Constant	0.817***	0.761***	0.832***	0.784***
	(0.067)	(0.066)	(0.069)	(0.067)
Observations	2,010	2,010	2,010	2,010

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption.

On top of these results, I also found significant correlations between sleep or physical activity and being on medication for anxiety and/or depression or therapy visits. Respondents with higher average sleep time per night and respondents who did not suffer from sleeping problems were significantly less likely to be taking anxiety and/or depression medication. They also had significantly fewer therapy visits. Furthermore, respondents with higher physical activity levels were significantly less likely to be taking medication for anxiety and/or depression. The regression results for these findings are in Appendix A.

There are no notable differences between the regression results between the LISS 2013 and the LISS 2022 datasets. The only difference between the datasets is that I did not find a significant correlation between anxiety and depression and physical activity in the LISS 2022 dataset. Appendix B contains the regression results for the LISS 2022 dataset.

The regression results without interaction term of the BRFSS 2013 dataset as shown in Table 5 display a significant correlation of hours of sleep ($\hat{\beta} = -0.594$) and hours of exercise ($\hat{\beta} = -0.015$) at a 1% significance level with bad mental health days. This means one extra hour of sleep per night is significantly correlated with a decrease in the number of bad mental health days per month of 0.594. Furthermore, one extra hour of exercise per week is significantly correlated with a decrease in the number of bad mental health days per month of 0.015.

These findings support the hypothesis that sleep is correlated with better mental health outcomes and the hypothesis that physical activity is correlated with better mental health outcomes.

The regression results with interaction term in Table 5 show a significant partial correlation of hours of sleep per night with bad mental health days at a 1% significance level with an estimated coefficient of -0.586. This means that one extra hour of sleep per night for respondents who do not partake in exercise is significantly associated with a 0.586 decrease in the number of bad mental health days per month.

I found no significant partial relationship between hours of exercise and bad mental health days at a 10% significance level. Moreover, I found no significant interaction term.

These findings support the hypothesis that sleep is correlated with better mental health outcomes. However, this model does not provide evidence for the hypothesis that physical activity is correlated with better mental health outcomes. This model also does not provide evidence that sleep and physical activity interact positively in their relationship with better mental health.

Table 5.

Regression results of the BRFSS 2013 dataset.

	Without interaction	With interaction
	Bad mental health days	Bad mental health days
Hours of sleep per night	-0.594***	-0.586***
	(0.017)	(0.021)
Hours of exercise per week	-0.015***	-0.006
	(0.002)	(0.013)
Hours of sleep per night # Hours of exercise per week	-	-0.001
		(0.002)
Constant	11.641***	11.588***
	(0.164)	(0.185)
Observations	217,483	217,483

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption.

On top of that, I found significant associations of sleep and physical activity in the BRFSS 2013 dataset. Longer sleep duration per night is correlated with a lower chance of being told that you have a depressive disorder. Furthermore, a higher frequency of exercise is associated with a lower chance of being told that you have a depressive disorder. Appendix C contains these results.

There are no notable differences between the regression results between the BRFSS 2013 and the BRFSS 2020 datasets. The only notable difference between the datasets is that I found a significant interaction term in the BRFSS 2020 dataset. Respondents in the BRFSS 2020 that exercised were even more likely to have fewer bad mental health days per month for every extra hour of sleep per night, compared to respondents that did not exercise.

There are no notable differences between the regression results of the LISS 2013 and the BRFSS 2013 datasets. Both datasets show significant positive correlations of sleep and physical activity with better mental health outcomes.

Conclusion

This thesis aimed to identify the relationship between sleep, physical activity, and mental health by using multivariate regression models using LISS and BRFSS data. Studies have found causal links between sleep and mental health and physical activity and mental health, but studies that combine both sleep and physical activity have been lacking in external validity. They use samples consisting of children or adolescents. This thesis expands on this existing literature by making use data of adults from the Netherlands and the US.

I expected sleep to be significantly positively correlated with better mental health outcomes. The same goes for physical activity. Higher levels of physical activity would be significantly positively correlated with better mental health outcomes. I also expected that the partial association between sleep and mental health is stronger when individuals also engage in physical exercise and vice versa.

I found significant positive correlations between sleep and better mental health outcomes in both the American and Dutch datasets. Anxiety and depression levels were significantly lower for respondents who had higher sleep duration and better sleep quality. Furthermore, I found significant positive correlations between physical activity and better mental health outcomes. Respondents with higher physical activity levels had significantly fewer bad mental health days and significantly lower anxiety and depression levels. However, I did not find convincing evidence that suggests that sleep is even more correlated with better mental health outcomes in combination with physical activity and vice versa.

The findings in this thesis show that there is indeed a positive relationship between sleep and better mental health outcomes and a positive relationship between physical activity and better mental health outcomes. These results show the potential that policies that improve the population's sleep and/or physical activity levels may lead to less prevalence of anxiety and depression symptoms. This can lead to higher economic output due to increased productivity. This is achieved through the productivity improvements that better sleep and higher levels of physical activity offer on their own (Gibson & Schrader, 2018; Erickson et al., 2019), but mentally healthy people are also more productive than people that suffer from mental health issues (Bubonya, Cobb-Clark & Wooden, 2017).

Nonetheless, I can only interpret the results of the analysis in this thesis as correlations, because there is a chance that the multivariate regressions may not have been controlled for every possible other explanation. This means that I cannot make any causal inferences about the relationships I have found. This implies that these results indicate a relationship, but a direct effect cannot be expected regarding policies based on my results.

Furthermore, the reliability of the surveys that were used for the data in this thesis can be higher. The answers to the surveys were self-reported. This means that they may not be 100% accurate. Professional

psychologists would be better to take measures of the state of the mental health of the respondents for example. Respondents may also have had a hard time recalling sleep duration and physical activity levels.

The respondents may also have experienced social desirability bias. They may have answered questions untruthfully to make themselves look better because they felt like their genuine answer would not be socially acceptable. This may especially be prevalent in sensitive topics like mental health.

For future research, I recommend that researchers use mental health interventions that include both sleep and physical activity to find the effect of sleep and physical activity on mental health. These interventions may include changes in sleep and physical activity patterns. This way identification of causal links is possible due to the nature of RCTS.

I would also recommend taking a better look into the interaction sleep and physical activity have regarding mental health. In my thesis I did not find evidence for an interaction, however, research has found that sleep and physical activity are indeed correlated with each other (Kline, 2014) and that sleep and physical activity have an interaction effect on brain function (Mograss et al. 2020). Therefore, an interaction effect may exist, although I did not find evidence for it.

Based on the limitations of the survey data mentioned above, I recommend future researchers to monitor the data for sleep and physical activity themselves instead of relying on self-reported data. Psychologists may be the best choice to assess mental health.

Lastly, the LISS datasets had considerably less observations than the BRFSS datasets. Therefore, the BRFSS results have a higher internal validity compared to the LISS datasets. To get a better understanding of the relationships in the Dutch population I recommend a bigger sample size.

Appendices

Appendix A

Table A1.

Regressions results of the LISS 2013 dataset with Medication and Therapy as dependent variables and Hours of sleep as sleep variable.

	Without interaction		With interaction	
	Medication	Therapy	Medication	Therapy
Hours of sleep	-0.062***	-0.931***	-0.078***	-1.108***
	(0.015)	(0.297)	(0.018)	(0.400)
Hours of sports	-0.003**	-0.036**	-0.010***	-0.117
	(0.001)	(0.018)	(0.003)	(0.073)
Hours of sleep # Hours of sports	-	-	0.009***	0.098
			(0.003)	(0.073)
Constant	0.105***	3.547***	0.119***	3.692***
	(0.028)	(0.802)	(0.030)	(0.862)
Observations	2,010	2,010	2,010	2,010

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption. 4.2 % of the sample reported taking medication for anxiety and/or depression and the average amount of therapy visits per year was 0.59 (*SD = 3.96*).

Table A2.

Regressions results of the LISS 2013 dataset with Medication and Therapy as dependent variables and No sleeping problems as sleep variable.

	Without interaction		With interaction	
	Medication	Therapy	Medication	Therapy
No sleeping problems	0.010**	0.043	0.011**	0.049
	(0.004)	(0.084)	(0.005)	(0.089)
Hours of sports	-0.003**	-0.041**	0.003	-0.008
	(0.001)	(0.019)	(0.009)	(0.161)
No sleeping problems # Hours of sports	-	-	-0.001	-0.004
			(0.001)	(0.022)
Constant	-0.023	2.419***	-0.032	2.373***
	(0.039)	(0.659)	(0.043)	(0.760)
Observations	2,010	2,010	2,010	2,010

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption. 4.2 % of the sample reported taking medication for anxiety and/or depression and the average amount of therapy visits per year was 0.59 (*SD = 3.96*).

Appendix B

The LISS 2022 dataset consists of the Health Wave 15, the Social Integration and Leisure Wave 15, the Personality Wave 14, and the December 2022 Background Variables questionnaires. I picked this data, since this is the latest data on sleep, physical activity, and mental health available at the time of writing this thesis.

Table B1.

Descriptive statistics of the 2022 LISS dataset.

	Mean	SD	Minimum	Maximum	N
Anxiety	0.32	-	-	-	5499
Depression	0.30	-	-	-	5499
Medication	0.05	-	-	-	5499
Therapy	1.34	23.83	0.00	999.00	5499
No sleeping problems	0.78	-	-	-	5499
Hours of sports per week	2.39	3.59	0.00	90.00	5499
Female	0.53	-	-	-	5499
Age	54.68	18.24	16.00	96.00	5499
Partner	0.69	-	-	-	5499
Number of children in household	0.64	1.05	0.00	6.00	5499
Education					
Primary school	0.06	-	-	-	5499
High school	0.28	-	-	-	5499
Higher vocational education	0.24	-	-	-	5499
Higher professional education	0.27	-	-	-	5499
University	0.14	-	-	-	5499
Alcohol consumption					
Heavy	0.27	-	-	-	5499
Moderate	0.38	-	-	-	5499
Infrequent	0.18	-	-	-	5499
Never	0.17	-	-	-	5499

Note. Anxiety, Depression, No sleeping problems and Partner are binary variables. Education and Alcohol consumption are categorical variables.

Table B2.

Regressions results of the LISS 2022 dataset with No sleeping problems as sleep variable.

	Without interaction		With interaction	
	Anxiety	Depression	Anxiety	Depression
No sleeping problems	-0.236***	-0.249***	-0.227***	-0.247***
	(0.016)	(0.016)	(0.018)	(0.019)
Hours of sports	-0.001	-0.002	0.003	-0.002
	(0.002)	(0.002)	(0.004)	(0.004)
No sleeping problems # Hours of sports	-	-	-0.004	-0.001
			(0.005)	(0.005)
Constant	0.902***	0.902***	0.895***	0.839***
	(0.040)	(0.040)	(0.041)	(0.041)
Observations	5,499	5,499	5,499	5,499

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption. 5.2% of the sample reported taking medication for anxiety and/or depression and the average number of therapy visits per year is 1.34 (*SD = 23.83*).

Table B3.

Regressions results of the LISS 2022 dataset with Medication and Therapy as dependent variables and No sleeping problems as sleep variable.

	Without interaction		With interaction	
	Medication	Therapy	Medication	Therapy
No sleeping problems	-0.091***	-3.675***	-0.102***	-4.064**
	(0.010)	(1.377)	(0.012)	(1.720)
Hours of sports	-0.002***	-0.044	-0.007***	-0.197
	(0.001)	(0.063)	(0.002)	(0.285)
No sleeping problems # Hours of sports	-	-	0.006**	0.186
			(0.002)	(0.274)
Constant	-0.023	2.419***	0.158***	9.785***
	(0.039)	(0.659)	(0.020)	(3.263)
Observations	5,499	5,499	5,499	5,499

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption. 5.2% of the sample reported taking medication for anxiety and/or depression and the average number of therapy visits per year is 1.34 (*SD = 23.83*).

Appendix C

Table C1.

Regression results of the BRFSS 2013 dataset with Depression as dependent variable.

	Without interaction	With interaction
	Depression	Depression
Hours of sleep per night	-0.010***	-0.009***
	(0.001)	(0.001)
Hours of exercise per week	-0.001***	0.000
	(0.000)	(0.001)
Hours of sleep per night # Hours of exercise per week		-0.000***
		(0.000)
Constant	0.343***	0.334***
	(0.007)	(0.008)
Observations	217,483	217,483

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption. 17.6% of the sample reported having been told that they have a depressive disorder.

Appendix D

Figure D1.

Descriptive statistics of the 2020 BFRSS dataset.

	Mean	SD	Minimum	Maximum	N
Bad mental health days	3.86	7.71	0.00	30.00	184236
Average amount of hours of sleep	7.08	1.32	1.00	24.00	184236
Exercise	0.83	-	-	-	184236
Age	52.37	17.25	18.00	80.00	184236
Number of children in household	0.54	1.05	0.00	82.00	184236
Female	0.49	-	-	-	184236
Partner	0.61	-	-	-	184236
Education					
Attended High School	0.07	-	-	-	184236
Graduated High School	0.22	-	-	-	184236
Attended college	0.27	-	-	-	184236
Graduated college	0.47	-	-	-	184236
Average number of alcoholic drinks per month	3.92	11.86	1.00	99.00	184236

Note. Exercise, Female and Partner are dummy variables. Education is a categorical variable.

Table D2.

Regression results of the BRFSS 2020 dataset.

	With interaction	Without interaction
	Bad mental health days	Bad mental health days
Hours of sleep per night	-0.611***	-0.677***
	(0.019)	(0.043)
Exercise	-1.580***	-2.213***
	(0.055)	(0.344)
Exercise # Hours of exercise per week	-	0.090*
		(0.047)
Constant	14.688***	15.155***
	(0.193)	(0.337)
Observations	184,236	184,236

Note. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.01. I controlled for age, gender, income, education, having a partner, number of children in the household and alcohol consumption.

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