

Sleep Duration Types

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This document describes the sleep duration types. All analyses were conducted in R version 4.0.0 (R Core Team 2020). We used the `tidyverse` (Wickham et al. 2019) for data preparation and visualization, in particular `ggplot2` (Wickham 2016), `dplyr` (Wickham et al. 2021), `tidyr` (Wickham 2021), `stringr` (Wickham 2019), and `purrr` (Henry and Wickham 2020). In addition, we used packages `readxl` (Wickham and Bryan 2019), `readr` (Wickham and Hester 2020), `glue` (Hester 2020), `patchwork` (Pedersen 2020) and `lubridate` (Grolemund and Wickham 2011). `mgcv` (Wood 2017) and `gamm4` were used for fitting generalized additive (mixed) models and `metafor` (Viechtbauer 2010) for meta analysis.

We have restricted all data to subjects who also have MRI measurements.

Data harmonization

Conversion from KSQ to PSQI

We have previously defined a conversion between the Karolinska Sleep Questionnaire (KSQ) and PSQI components (Fjell et al. 2019), but in this case we need to convert the answers to the individual questions. We defined latency (PSQI2) as the weighted average of weekday latency and weekend latency, with weights 5/7 and 2/7, respectively. See here for reference <https://www.uppdragpsyiskhalsa.se/wp-content/uploads/2018/02/KSQ.pdf>. We mapped the answers to KSQ question 9a (coded as 7a in Betula data) to the alternatives in PSQI5a, using the following table:

KSQ9	PSQI5	KSQ9_value
Never	Not during the past month	0
Occasionally (Någon gång)	Less than once a week	1
Many times per month	Once or twice a week	2
1-2 times per week	Once or twice a week	3
3-4 times per week	Three or more times a week	4
5 or more times per week	Three or more times a week	5

We also converted from KSQ9 o+p+q (involuntary sleep at work or in spare time, and struggling to stay awake) to PSQI8 using the same mapping, but this time taking the average of the numerical scores over non-missing answers to KSQ o+p+q, rounding it towards zero, and then converting. We also did the same conversion from KSQ9 b+i to PSQI5b.

The same mapping was done from KSQ9 m+n+r (sleep during work or spare time, and red during the day) to PSQI9, but here the target PSQI values were as follows:

KSQ9	PSQI9	KSQ9_value
Never	No problem at all	0
Occasionally (Någon gång)	Only a slight problem	1
Many times per month	Somewhat of a problem	2
1-2 times per week	Somewhat of a problem	3
3-4 times per week	A very big problem	4
5 or more times per week	A very big problem	5

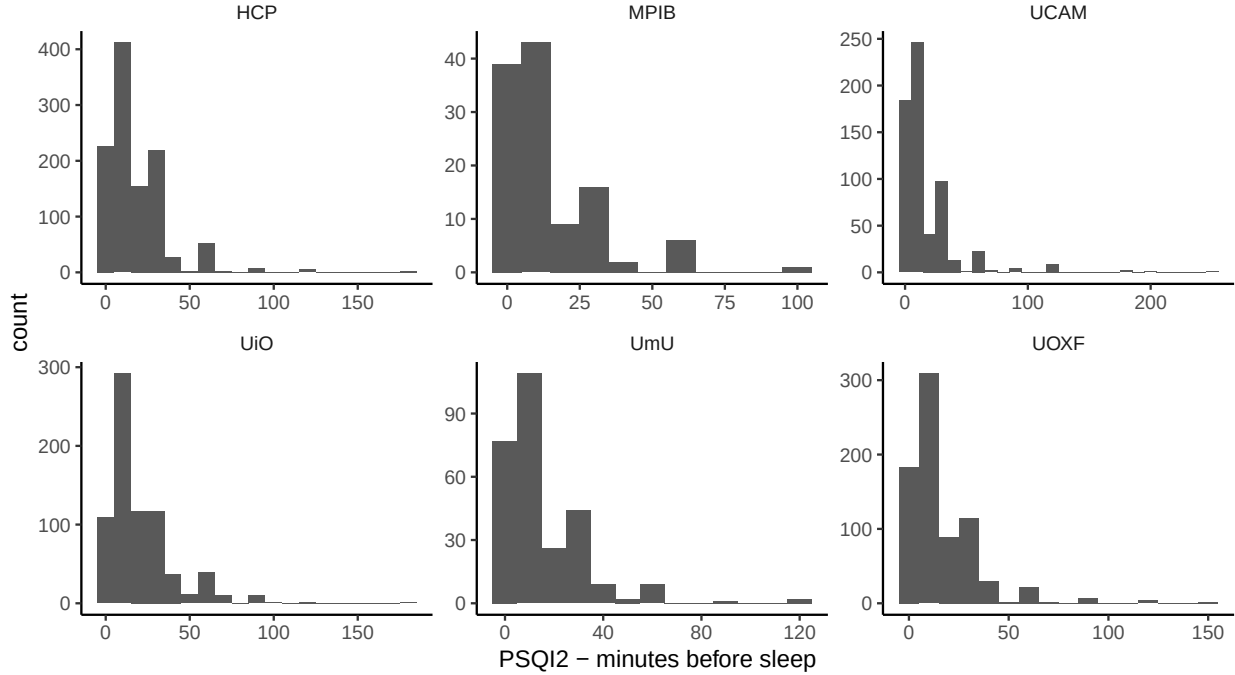
PSQI question 11d

PSQI Question 11d was only available for Cam-CAN, LCBC, and Whitehall. All answers used different scales, and we harmonized them to the Whitehall scale as follows.

Whitehall	LCBC	Cam-CAN
Not during the past month	Never	Never
Less than once a week	1-3 times the last month	Occasionally
Once or twice a week	4-7 times the last month	Often
Once or twice a week	8-14 times the last month	Often
Three or more times a week	15-21 times the last month	Most days
Three or more times a week	22-31 times the last month	Most days

Data visualization and summaries

PSQI question 2

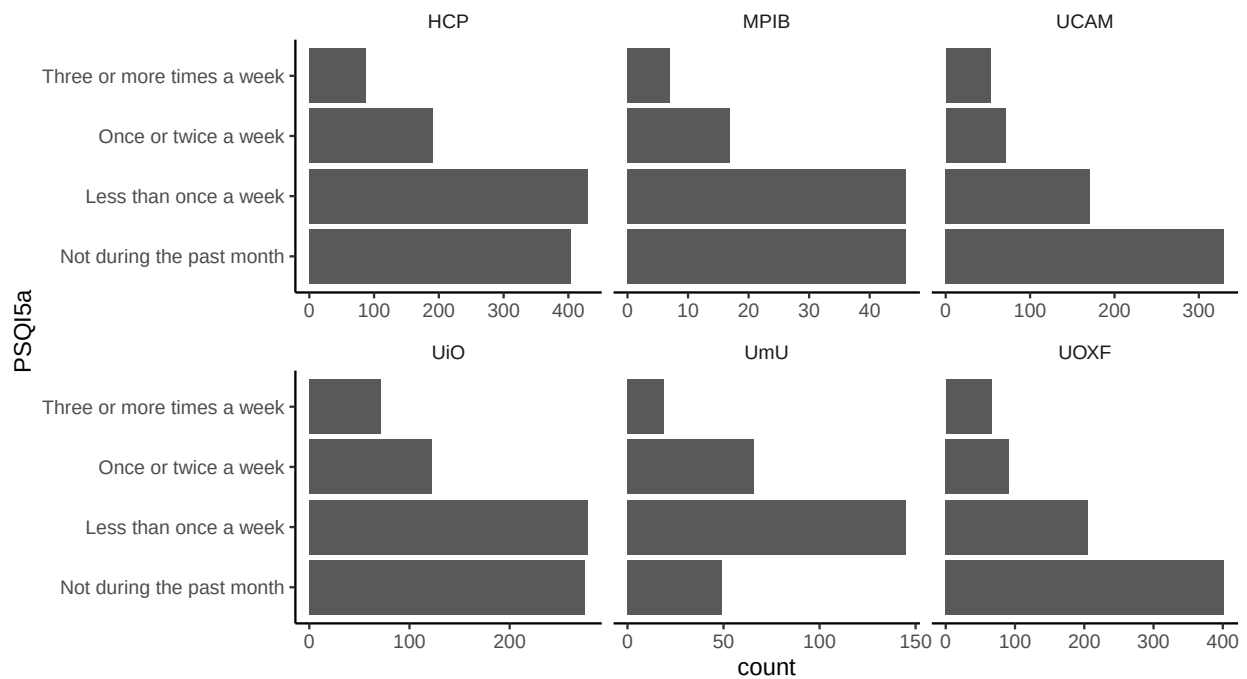


The table shows summary statistics.

study	Observations	Mean latency (SD)	Range
HCP	1112	19.888 (18.372)	0 - 180
MPIB	116	16.065 (16.399)	0 - 100
UCAM	625	18.907 (24.364)	0 - 250
UiO	746	21.975 (19.458)	0 - 180
UmU	279	17.261 (16.585)	0 - 120
UOXF	765	18.369 (17.91)	0 - 150

PSQI question 5a

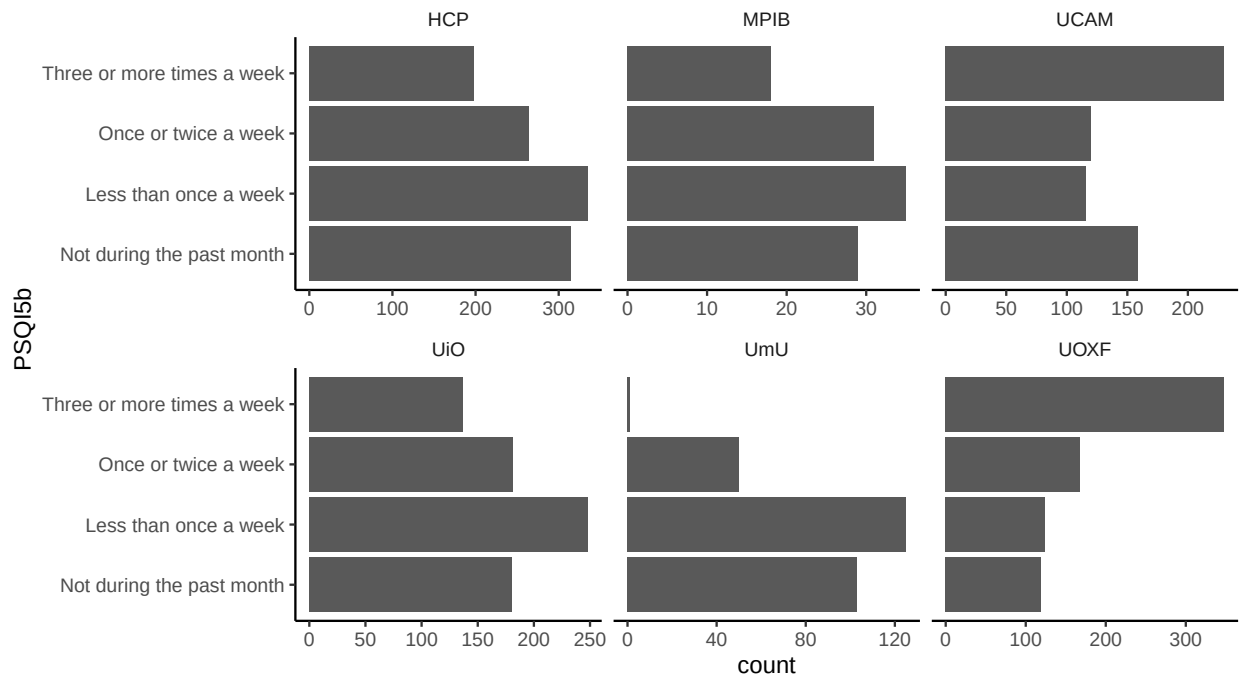
“During the past month, how often have you had trouble sleeping because you cannot get to sleep within 30 minutes?”



study	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week	Total
HCP	404	430	190	88	1112
MPIB	46	46	17	7	116
UCAM	330	171	71	53	625
UiO	275	278	122	71	746
UmU	49	145	66	19	279
UOXF	402	205	91	66	764

PSQI question 5b

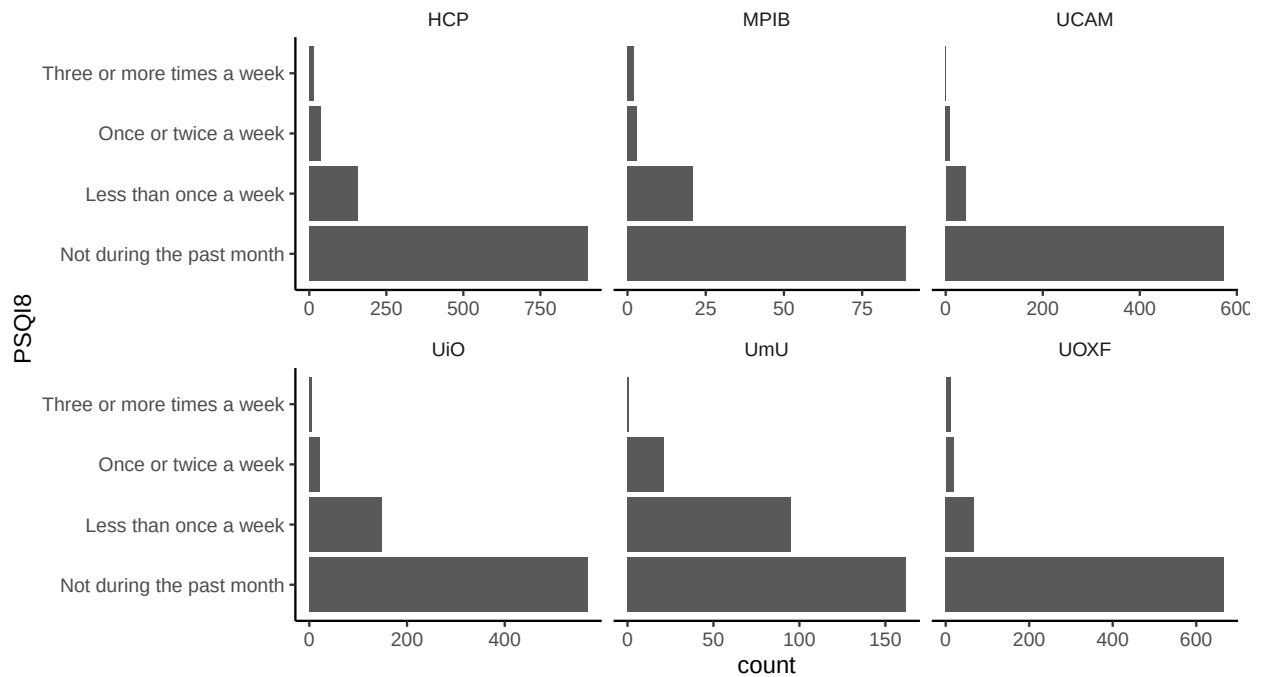
“During the past month, how often have you had trouble sleeping because you wake up in the middle of the night or early morning?”



study	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week	Total
HCP	315	335	264	198	1112
MPIB	29	35	31	18	113
UCAM	159	116	120	230	625
UiO	180	248	181	137	746
UmU	103	125	50	1	279
UOXF	119	124	168	348	759

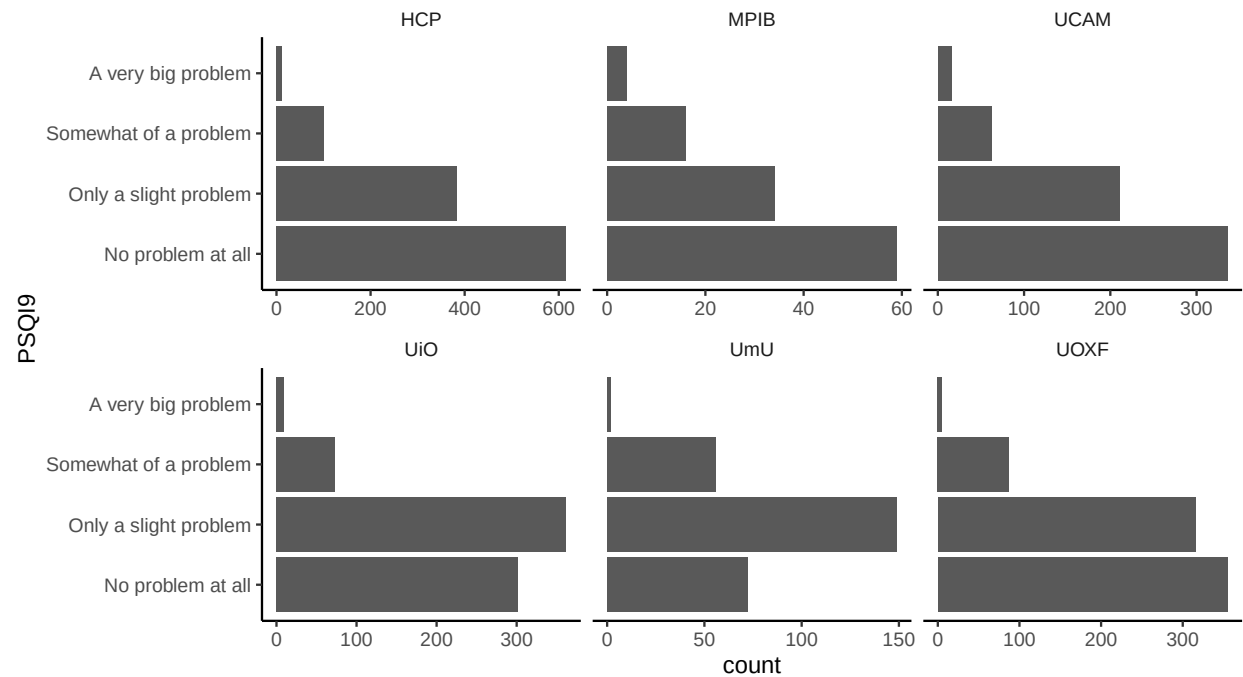
PSQI question 8

“During the past month, how often have you had trouble staying awake?”



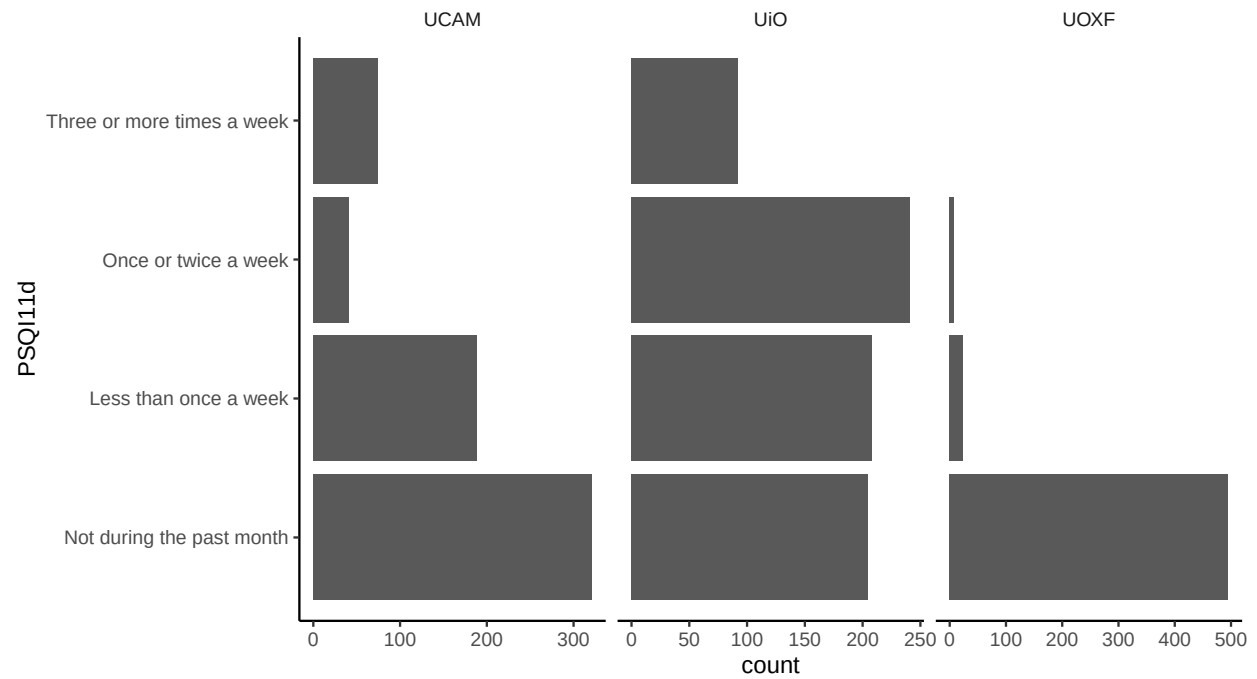
PSQI question 9

“During the last month, how hard has it been to keep enthusiasm and energy to get things done?”



PSQI question 11d

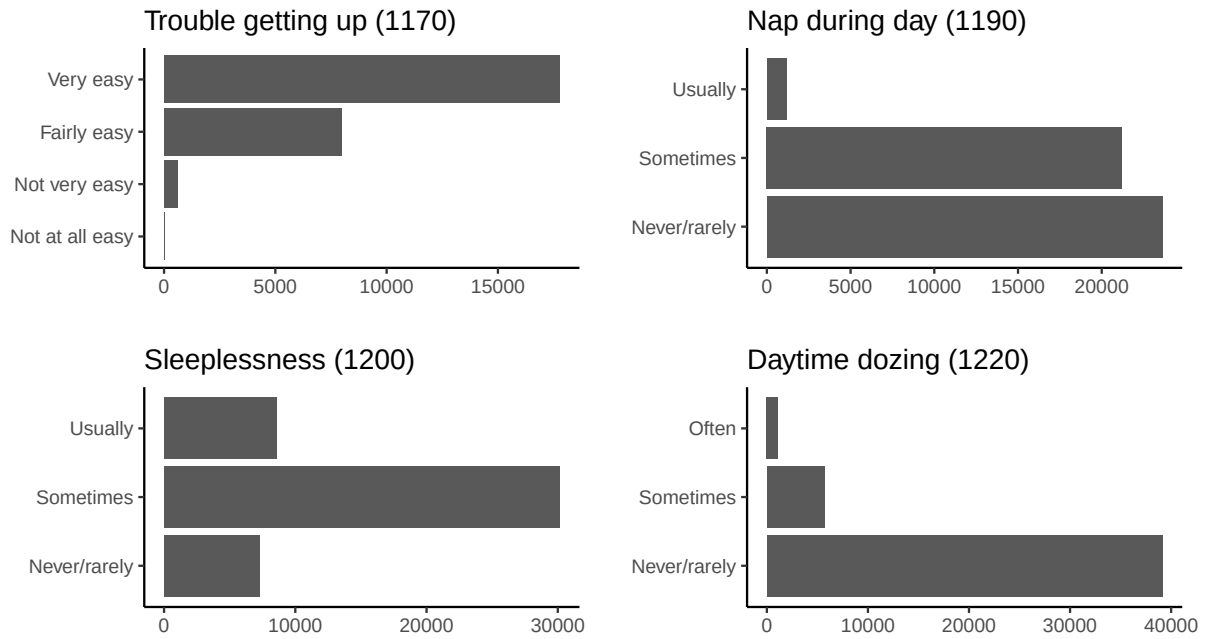
“How many times the last month did you wake up feeling tired?”



study	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week	Total
UCAM	321	189	41	74	625
UiO	205	208	241	92	746
UOXF	495	24	8	0	527

UKB sleep questions

The plot shows the responses among those who also have MRI.



The tables below show the underlying numbers.

Trouble getting up (1170)	n
Not at all easy	11
Not very easy	585
Fairly easy	7980
Very easy	17774

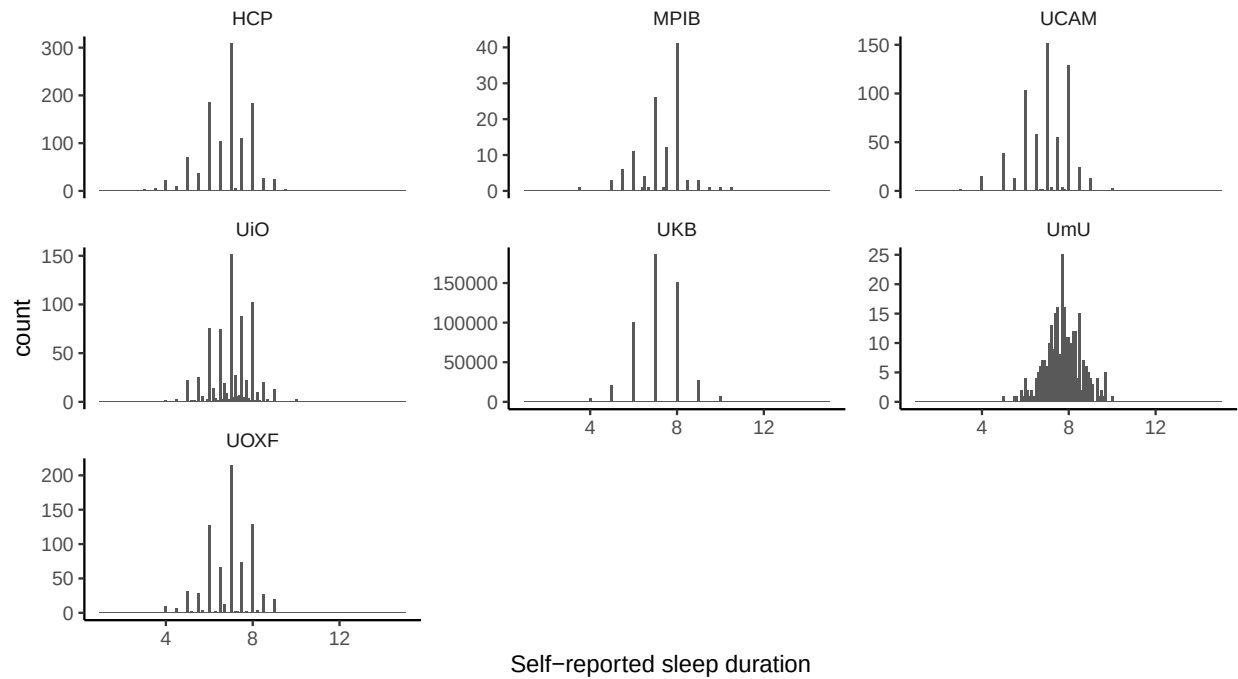
Nap during day (1190)	n
Never/rarely	23627
Sometimes	21209
Usually	1154

Sleeplessness (1200)	n
Never/rarely	7248
Sometimes	30142
Usually	8566

Daytime dozing (1220)	n
Never/rarely	39143
Sometimes	5722
Often	1105

Self-reported sleep duration

The histograms show self reported sleep duration per study.

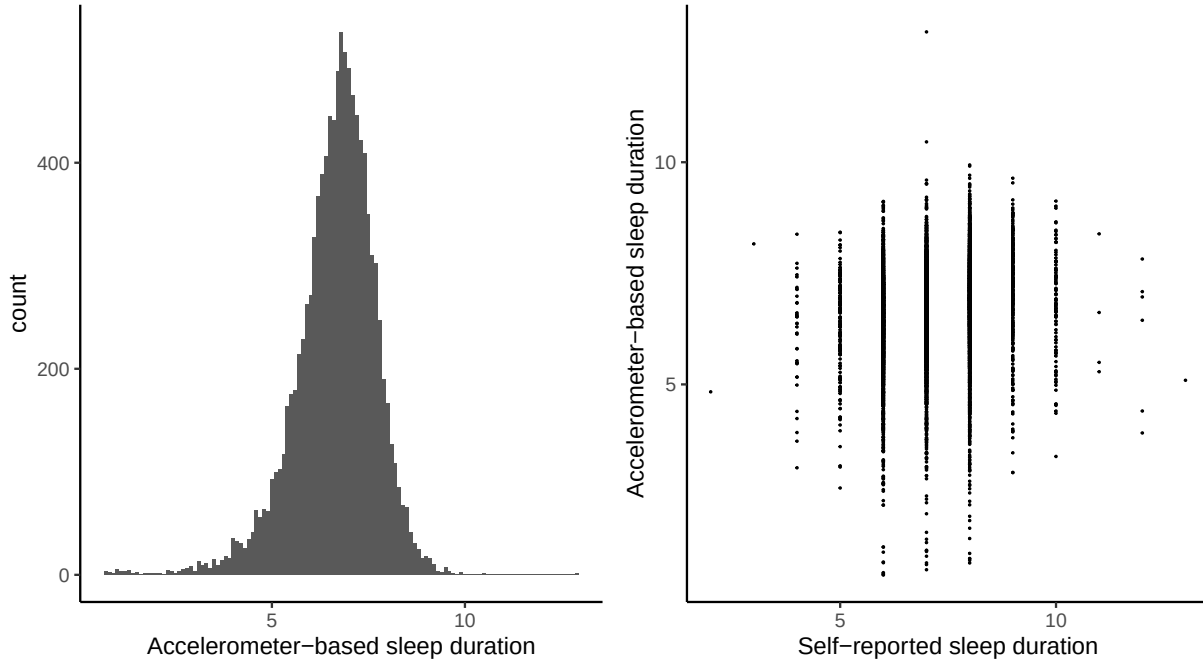


The numbers are summarized in the table below.

study	Observations	Mean sleep (SD)	Range
HCP	1112	6.82 (1.135)	2 - 12
MPIB	116	7.299 (1.064)	3 - 10
UCAM	625	6.929 (1.115)	3 - 11
UiO	746	7.03 (0.929)	3 - 10
UKB	501205	7.154 (1.103)	1 - 15
UmU	279	7.744 (0.848)	3 - 10
UOXF	765	6.908 (1.009)	3 - 9

Accelerometer-based sleep duration

Next is accelerometer based sleep duration, which is only available for UKB.



Summaries are shown below.

group	Observations	Mean sleep (SD)	Range
All	96436	6.56 (1.087)	1 - 15
Has MRI	19026	6.61 (1.033)	1 - 13

Group definitions

For studies using PSQI, the groups were defined based on the following criteria.

PSQI criteria

1. Answered ≤ 30 minutes on PSQI2.
2. Answered “Not during the past month” or “Less than once a week” on PSQI5a-b, PSQI8, and PSQI11d.
3. Answered “No problem at all” or “Only a slight problem” on PSQI9.

UKB criteria

1. Answered “Very easy” or “Fairly easy” on 1170 (trouble getting up)
2. Answered “Never/rarely” on 1190 (nap during day), 1200 (sleeplessness), and 1220 (daytime dozing).

Group 1: Less sleep need

This group had self-reported sleep ≤ 6 hours per night and either had **TRUE** on all three PSQI criteria or on both two UKB criteria.

Group 2: Lacking ability to sleep

This group had self-reported sleep ≤ 6 hours per night and either had **FALSE** on at least 50 % of the PSQI criteria or by answering “Sometimes” or “Usually” on UKB question 1190 and 1200 and “Sometimes” or “Often” on 1220.

Group 3: Sleeps sufficiently

This group had self-reported sleep between 7 and 8 hours per night and either had **TRUE** on all three PSQI criteria above or on both two UKB criteria.

Group 4: Excessive sleep need

This group had self-reported sleep between 7 and 8 hours per night and either had **FALSE** on at least 50 % of the PSQI criteria or by answering “Sometimes” or “Usually” on UKB question 1190 and 1200 and “Sometimes” or “Often” on 1220.

Ungrouped

All participants not falling into any of the four groups above were defined as ungrouped.

Group descriptives

We first show the grouping among participants with self-reported sleep 6 hours or less.

Table 16: Number in each group, with self-reported sleep ≤ 6 hours.

study	Group 1: Less sleep need	Group 2: Lacking ability to sleep	Ungrouped
HCP	110 (33 %)	55 (16 %)	170 (51 %)
MPIB	3 (14 %)	3 (14 %)	15 (71 %)
UCAM	20 (12 %)	50 (29 %)	103 (60 %)
UiO	14 (10 %)	59 (41 %)	70 (49 %)
UKB	530 (5 %)	1408 (12 %)	9631 (83 %)
UmU	2 (25 %)	3 (38 %)	3 (38 %)
UOXF	22 (11 %)	41 (20 %)	146 (70 %)

Table 17: Number in each group, with self-reported sleep ≤ 6 hours.

Group 1: Less sleep need	Group 2: Lacking ability to sleep	Ungrouped
701 (6 %)	1619 (13 %)	10138 (81 %)

Next is the grouping for those who sleep 7-8 hours.

Table 18: Number in each group, with self-reported sleep 7-8 hours.

study	Group 3: Normal sleepers	Group 4: Excessive sleep need	Ungrouped
HCP	318 (52 %)	37 (6 %)	253 (42 %)
MPIB	42 (52 %)	5 (6 %)	33 (41 %)
UCAM	135 (39 %)	22 (6 %)	189 (55 %)
UiO	155 (37 %)	62 (15 %)	201 (48 %)
UKB	2907 (10 %)	2950 (10 %)	24098 (80 %)
UmU	68 (51 %)	12 (9 %)	54 (40 %)
UOXF	129 (30 %)	30 (7 %)	266 (63 %)

Table 19: Number in each group, with self-reported sleep 7-8 hours.

Group 3: Normal sleepers	Group 4: Excessive sleep need	Ungrouped
3754 (12 %)	3118 (10 %)	25094 (79 %)

Descriptives for group members. Age is taken at the first MRI measurement.

Group	Age (SD)	Sex (f/m)	Sleep duration (SD)
Group 1: Less sleep need	56.73 (14.65)	218/483	5.90 (0.36)
Group 2: Lacking ability to sleep	63.79 (11.70)	788/831	5.80 (0.52)
Group 3: Normal sleepers	58.75 (13.42)	1688/2066	7.56 (0.48)
Group 4: Excessive sleep need	66.01 (10.06)	1435/1683	7.54 (0.50)
Ungrouped	63.48 (9.54)	20351/17245	7.17 (0.99)

Accelerometer sleep

For UKB we also defined the groups based on sleep durations below 6 hours or 7-8 hours from accelerometer recordings. The group statistics are shown in the tables.

Table 21: Accelerometer based groups, ≤ 6 hours.

study	Group 1: Less sleep need	Group 2: Lacking ability to sleep	Ungrouped
UKB	312 (7 %)	691 (16 %)	3196 (76 %)

Table 22: Accelerometer based sleep, 7-8 hours.

study	Group 3: Normal sleepers	Group 4: Excessive sleep need	Ungrouped
UKB	531 (10 %)	414 (7 %)	4578 (83 %)

We also show the average accelerometer based sleep in each of these groups.

Group	Mean sleep	St. dev. sleep	IQR sleep	Max sleep	Min sleep
Group 1: Less sleep need	5.2	0.9	0.7	6	0.5
Group 2: Lacking ability to sleep	5.1	0.8	0.9	6	0.8

Group	Mean sleep	St. dev. sleep	IQR sleep	Max sleep	Min sleep
Group 3: Normal sleepers	7.4	0.3	0.5	8	7.0
Group 4: Excessive sleep need	7.4	0.3	0.4	8	7.0

Groups based both on self report and accelerometer sleep

For UKB we also defined the groups based on sleep durations below 6 hours from both self report and accelerometer recordings. The group statistics are shown in the tables.

Table 24: Accelerometer based groups, ≤ 6 hours.

study	Group 1: Less sleep need	Group 2: Lacking ability to sleep	Ungrouped
UKB	92 (6 %)	274 (17 %)	1227 (77 %)

Table 25: Accelerometer based sleep, 7-8 hours.

study	Group 3: Normal sleepers	Group 4: Excessive sleep need	Ungrouped
UKB	24 (2 %)	72 (7 %)	915 (91 %)

BMI, depression, and education differences between groups

We can also compare the groups in terms of some covariates. Note that in this case, the number of group members get reduced, because we don't have covariates for all.

BMI

Mean and standard deviations are shown below.

Group	BMI	Observations
Group 1: Less sleep need	26.84 (4.13)	377
Group 2: Lacking ability to sleep	27.27 (4.72)	946
Group 3: Normal sleepers	25.76 (3.80)	2398
Group 4: Excessive sleep need	26.73 (4.40)	2032
Ungrouped	26.35 (4.19)	24900

Here is a comparison of BMI across groups 1-4. Note, ungrouped are excluded. The reference level is Group 1.

```
mod <- lm(bmi ~ Group, data = filter(bmi_dat, Group != "Ungrouped"))
summary(mod)

##
## Call:
## lm(formula = bmi ~ Group, data = filter(bmi_dat, Group != "Ungrouped"))
##
## Residuals:
```

```
##      Min      1Q   Median      3Q      Max
## -10.0606 -2.8961 -0.5798  2.2429 26.0501
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          26.8381    0.2164 124.042 < 2e-16 ***
## GroupGroup 2: Lacking ability to sleep  0.4358    0.2559   1.703  0.0886 .
## GroupGroup 3: Normal sleepers          -1.0821    0.2328  -4.649 3.41e-06 ***
## GroupGroup 4: Excessive sleep need      -0.1108    0.2356  -0.470  0.6382
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.201 on 5749 degrees of freedom
## Multiple R-squared:  0.01938, Adjusted R-squared:  0.01886
## F-statistic: 37.86 on 3 and 5749 DF, p-value: < 2.2e-16
```

From this model we can also do an ANOVA type test of whether there are differences between any of the groups.

```
anova(mod)

## Analysis of Variance Table
##
## Response: bmi
##           Df Sum Sq Mean Sq F value    Pr(>F)
## Group       3   2005   668.25   37.864 < 2.2e-16 ***
## Residuals 5749 101461    17.65
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Depression

Mean and standard deviations are shown below.

Group	Depression	Observations
Group 1: Less sleep need	-0.27 (0.67)	367
Group 2: Lacking ability to sleep	0.47 (1.47)	923
Group 3: Normal sleepers	-0.22 (0.80)	2335
Group 4: Excessive sleep need	0.17 (1.16)	2014
Ungrouped	-0.01 (0.98)	24684

Here is a comparison of BMI across groups 1-4. Note, ungrouped are excluded. The reference level is Group 1.

```
mod <- lm(depression ~ Group, data = filter(depr_dat, Group != "Ungrouped"))
summary(mod)
```

```
##
## Call:
## lm(formula = depression ~ Group, data = filter(depr_dat, Group !=
## "Ungrouped"))
##
## Residuals:
##      Min      1Q   Median      3Q      Max
```

```
## -1.0601 -0.5541 -0.3720  0.1162  7.3668
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   -0.26933    0.05536  -4.865 1.17e-06 ***
## GroupGroup 2: Lacking ability to sleep  0.74137    0.06544  11.328 < 2e-16 ***
## GroupGroup 3: Normal sleepers           0.05322    0.05955   0.894  0.372
## GroupGroup 4: Excessive sleep need      0.44080    0.06019   7.323 2.76e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.06 on 5635 degrees of freedom
## Multiple R-squared:  0.05867,    Adjusted R-squared:  0.05817
## F-statistic: 117.1 on 3 and 5635 DF,  p-value: < 2.2e-16
```

From this model we can also do an ANOVA type test of whether there are differences between any of the groups.

```
anova(mod)

## Analysis of Variance Table
##
## Response: depression
##              Df Sum Sq Mean Sq F value    Pr(>F)
## Group          3  395.0  131.655   117.06 < 2.2e-16 ***
## Residuals 5635  6337.5    1.125
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Education

Mean and standard deviations are shown below.

Group	Education	Observations
Group 1: Less sleep need	0.09 (0.91)	369
Group 2: Lacking ability to sleep	-0.11 (1.05)	918
Group 3: Normal sleepers	0.04 (0.97)	2287
Group 4: Excessive sleep need	0.00 (1.03)	2009
Ungrouped	-0.00 (1.00)	24587

Here is a comparison of BMI across groups 1-4. Note, ungrouped are excluded. The reference level is Group 1.

```
mod <- lm(education_scaled ~ Group, data = filter(edu_dat, Group != "Ungrouped"))
summary(mod)

##
## Call:
## lm(formula = education_scaled ~ Group, data = filter(edu_dat,
##              Group != "Ungrouped"))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.6181 -0.3848  0.7056  0.7387  0.8570
```



```
##
## Coefficients:
##
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.08962    0.05205   1.722 0.085146 .
## GroupGroup 2: Lacking ability to sleep -0.20394    0.06163  -3.309 0.000941 ***
## GroupGroup 3: Normal sleepers      -0.05258    0.05609  -0.937 0.348593
## GroupGroup 4: Excessive sleep need  -0.08563    0.05663  -1.512 0.130522
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9998 on 5579 degrees of freedom
## Multiple R-squared:  0.003227, Adjusted R-squared:  0.002691
## F-statistic:  6.02 on 3 and 5579 DF, p-value: 0.0004332
```

From this model we can also do an ANOVA type test of whether there are differences between any of the groups.

```
anova(mod)

## Analysis of Variance Table
##
## Response: education_scaled
##              Df Sum Sq Mean Sq F value    Pr(>F)
## Group          3   18.1   6.0174   6.0199 0.0004332 ***
## Residuals 5579 5576.7   0.9996
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Comparison of subcortical volumes across groups

We compared subcortical volumes across the three groups. When interpreting regression coefficients, note that the reference levels were defined in the following order:

1. Group 3
2. Group 1
3. Group 2
4. Group 4

That is, when comparing group 3 to group 1, group 3 is the reference level and the regression coefficient represents how much extra subcortical volume is associated with being in group 1. When comparing group 1 to group 2, group 1 becomes the reference level, and so on.

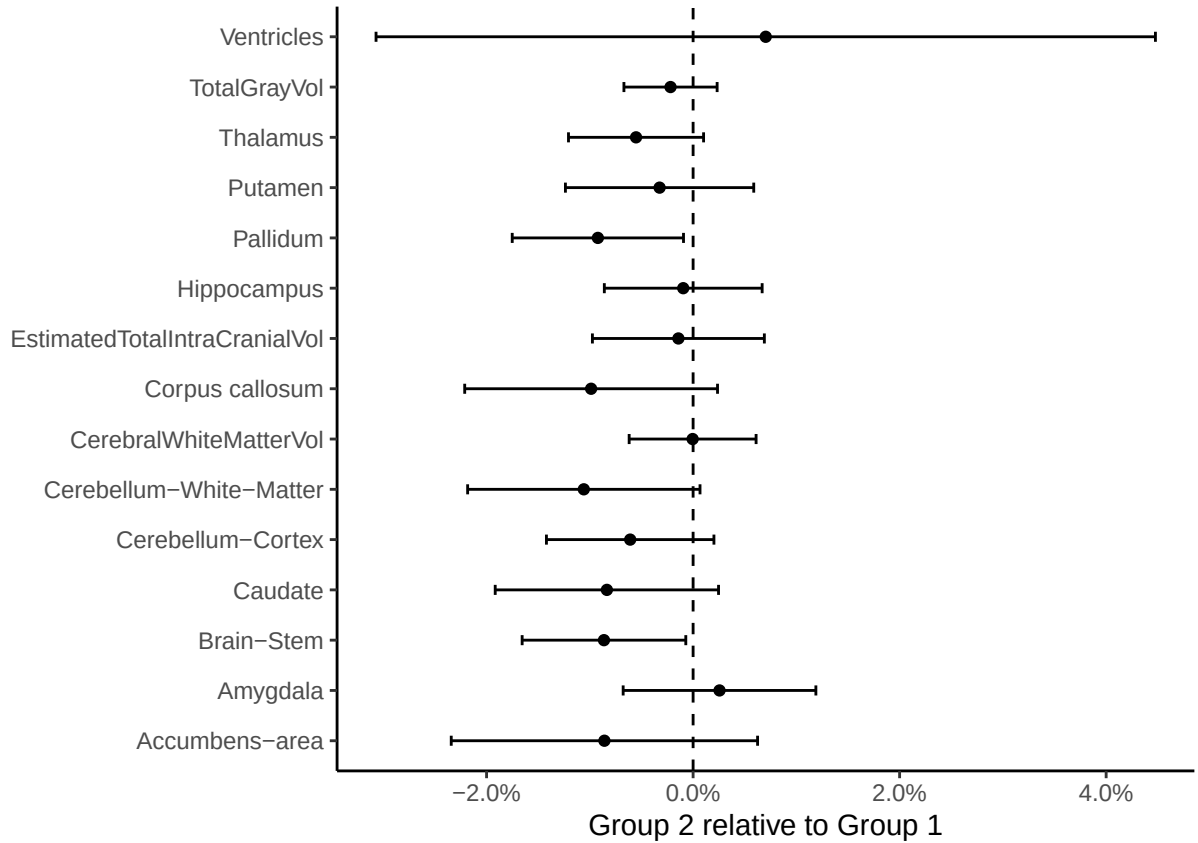
Group 2 versus Group 1

For participants sleeping less than or equal to 6 hours per night, we compared brain volumes of Group 1 and Group 2 using a model like the following. When estimated total intracranial volume was the outcome, `icv` was not included in the model. The effect of interest was the `Group` variable.

```
mod <- gamm4(value ~ s(age) + sex + site + sleep + Group + icv,
             random = ~ (1|id), data = dat)
```

Estimated effects of being in *Group 2: Lacking ability to sleep* compared to *Group 1: Less sleep need* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm^3 and also in percentage of mean volumes.

region	extra_covs	Mean volume	obs	comparison	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area		902.6	2492	Group 2 vs 1 (ref)	-7.75 (-21.1, 5.6)	-0.86 (-2.3, 0.6)
Amygdala		3290.4	2492	Group 2 vs 1 (ref)	8.42 (-22.3, 39.1)	0.26 (-0.7, 1.2)
Brain-Stem		21934.6	2490	Group 2 vs 1 (ref)	-189.31 (-363.1, -15.5)	-0.86 (-1.7, -0.1)
Caudate		6756.9	2490	Group 2 vs 1 (ref)	-56.41 (-129.5, 16.7)	-0.83 (-1.9, 0.2)
Corpus callosum		3558.1	2492	Group 2 vs 1 (ref)	-35.14 (-78.7, 8.4)	-0.99 (-2.2, 0.2)
Cerebellum-Cortex		111496.1	2489	Group 2 vs 1 (ref)	-679.33 (-1583.6, 225)	-0.61 (-1.4, 0.2)
Cerebellum-White-Matter		30979.0	2490	Group 2 vs 1 (ref)	-327.84 (-676.4, 20.7)	-1.06 (-2.2, 0.1)
CerebralWhiteMatterVol		475094.8	2492	Group 2 vs 1 (ref)	-21.19 (-2941.3, 2898.9)	0 (-0.6, 0.6)
EstimatedTotalIntraCranialVol		1545243.7	2492	Group 2 vs 1 (ref)	-2200.65 (-15065, 10663.7)	-0.14 (-1, 0.7)
Hippocampus		8066.9	2492	Group 2 vs 1 (ref)	-7.7 (-69.4, 54)	-0.1 (-0.9, 0.7)
Pallidum		3994.1	2492	Group 2 vs 1 (ref)	-36.84 (-70, -3.7)	-0.92 (-1.8, -0.1)
Putamen		9220.6	2489	Group 2 vs 1 (ref)	-29.92 (-114, 54.2)	-0.32 (-1.2, 0.6)
Thalamus		13717.8	2492	Group 2 vs 1 (ref)	-75.79 (-165.5, 13.9)	-0.55 (-1.2, 0.1)
TotalGrayVol		662557.2	2492	Group 2 vs 1 (ref)	-1447.53 (-4437.7, 1542.6)	-0.22 (-0.7, 0.2)
Ventricles		31887.0	2487	Group 2 vs 1 (ref)	224.29 (-979.1, 1427.7)	0.7 (-3.1, 4.5)



We perform a meta analysis across all regions. For the Ventricles, the sign of the regression coefficient was reversed, both here and in all subsequent analyses.

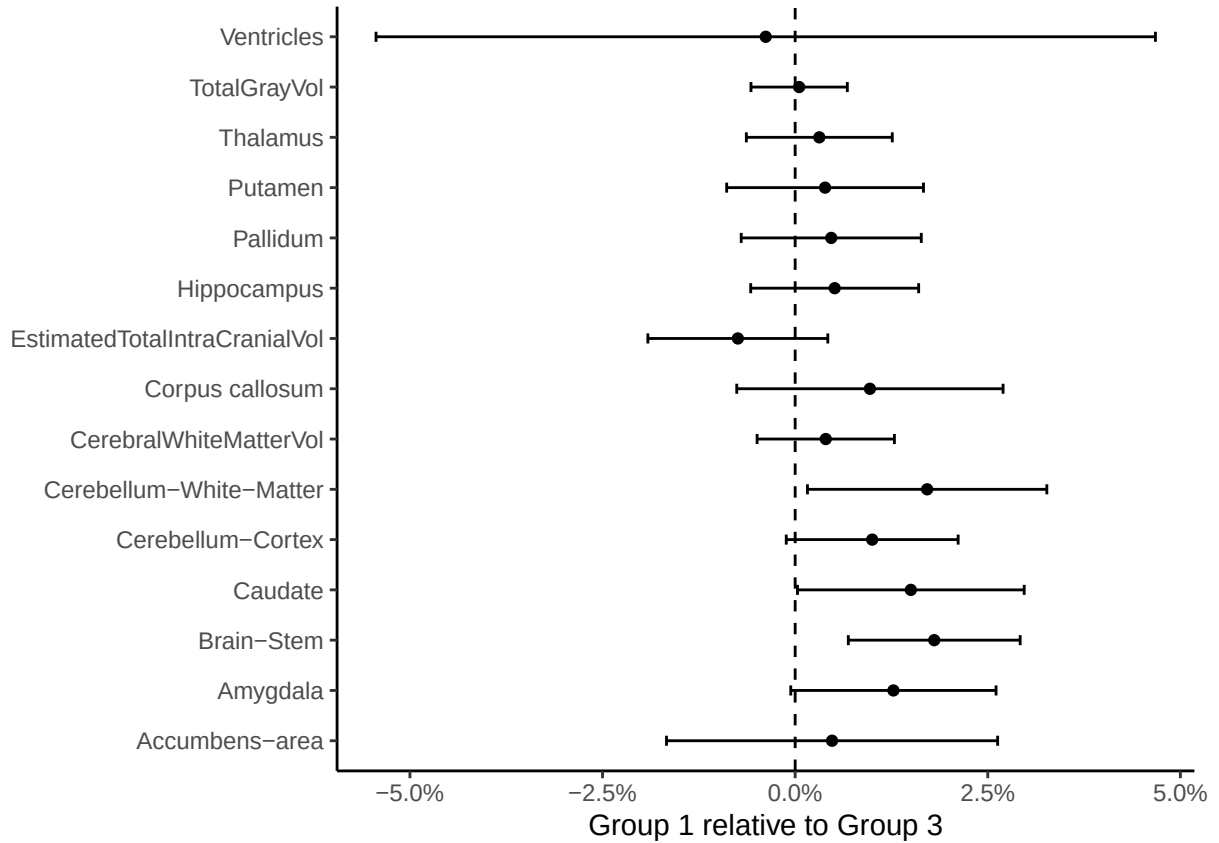
```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0 (SE = 0.0000)
## tau (square root of estimated tau^2 value): 0
## I^2 (total heterogeneity / total variability): 0.00%
## H^2 (total variability / sampling variability): 1.00
##
## Test for Heterogeneity:
## Q(df = 14) = 12.1472, p-val = 0.5945
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## -0.0040  0.0010  -3.8471  0.0001  -0.0061  -0.0020  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Group 3 versus Group 1

Estimated effects of being in *Group 1: Less sleep need* compared to *Group 3: Sleeps sufficiently* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and

confidence intervals in mm³ and also in percentage of mean volumes.

region	extra_covs	Mean volume	obs	comparison	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area		902.6	5034	Group 1 vs 3 (ref)	4.32 (-15.1, 23.7)	0.48 (-1.7, 2.6)
Amygdala		3290.4	5035	Group 1 vs 3 (ref)	41.97 (-1.9, 85.8)	1.28 (-0.1, 2.6)
Brain-Stem		21934.6	5036	Group 1 vs 3 (ref)	395.97 (151.3, 640.6)	1.81 (0.7, 2.9)
Caudate		6756.9	5036	Group 1 vs 3 (ref)	101.46 (2, 200.9)	1.5 (0, 3)
Corpus callosum		3558.1	5038	Group 1 vs 3 (ref)	34.53 (-27, 96)	0.97 (-0.8, 2.7)
Cerebellum-Cortex		111496.1	5032	Group 1 vs 3 (ref)	1114.91 (-128.9, 2358.7)	1 (-0.1, 2.1)
Cerebellum-White- Matter		30979.0	5033	Group 1 vs 3 (ref)	530.74 (49.5, 1012)	1.71 (0.2, 3.3)
CerebralWhiteMatterVol		475094.8	5034	Group 1 vs 3 (ref)	1887.03 (-2346.8, 6120.9)	0.4 (-0.5, 1.3)
EstimatedTotalIntraCranialVol		1545243.7	5036	Group 1 vs 3 (ref)	-11492.37 (-29536.6, 6551.8)	-0.74 (-1.9, 0.4)
Hippocampus		8066.9	5036	Group 1 vs 3 (ref)	41.41 (-46.5, 129.3)	0.51 (-0.6, 1.6)
Pallidum		3994.1	5036	Group 1 vs 3 (ref)	18.71 (-28, 65.4)	0.47 (-0.7, 1.6)
Putamen		9220.6	5036	Group 1 vs 3 (ref)	35.81 (-82, 153.6)	0.39 (-0.9, 1.7)
Thalamus		13717.8	5036	Group 1 vs 3 (ref)	43.02 (-86.9, 172.9)	0.31 (-0.6, 1.3)
TotalGrayVol		662557.2	5036	Group 1 vs 3 (ref)	342.69 (-3799.7, 4485.1)	0.05 (-0.6, 0.7)
Ventricles		31887.0	5030	Group 1 vs 3 (ref)	-121.78 (-1734.6, 1491.1)	-0.38 (-5.4, 4.7)



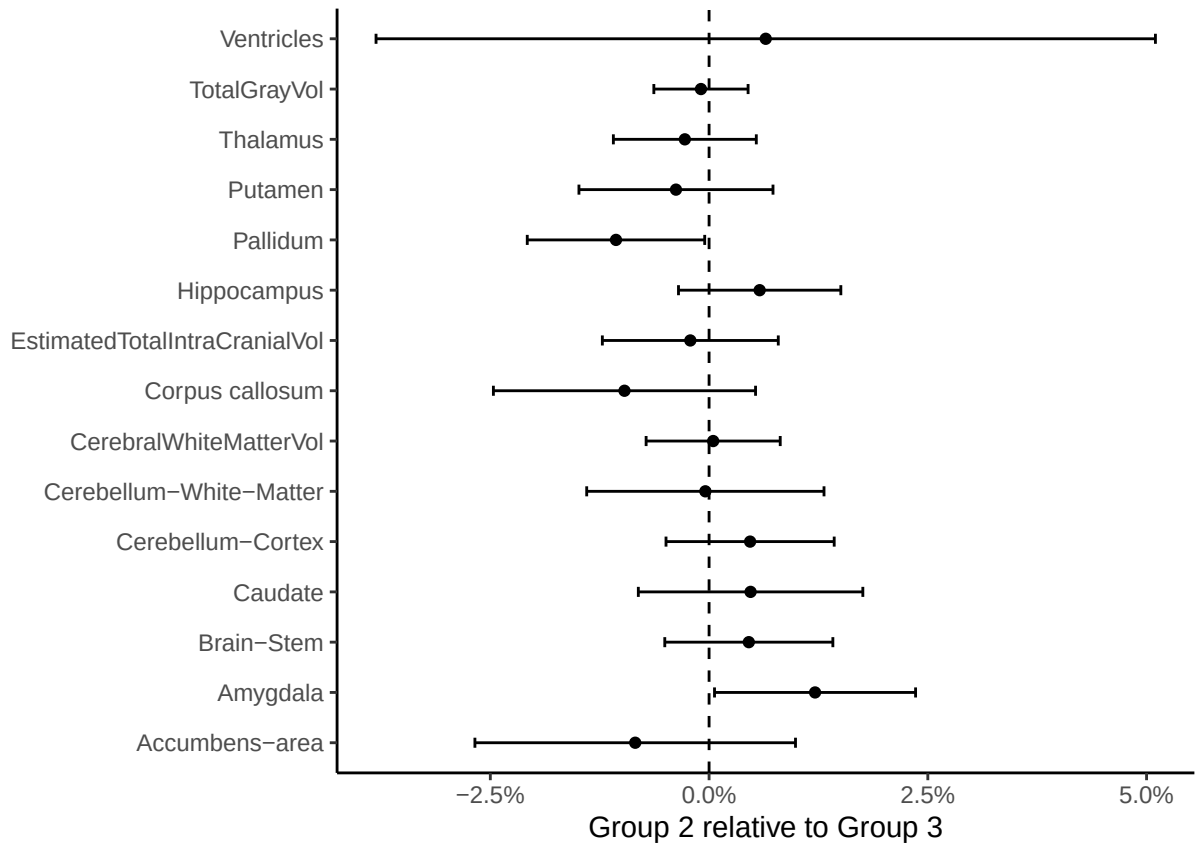
We perform a meta analysis across all regions.

```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0.0000 (SE = 0.0000)
## tau (square root of estimated tau^2 value):      0.0040
## I^2 (total heterogeneity / total variability):    32.02%
## H^2 (total variability / sampling variability):   1.47
##
## Test for Heterogeneity:
## Q(df = 14) = 18.9676, p-val = 0.1662
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## 0.0062 0.0019 3.2815 0.0010 0.0025 0.0099 **
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Group 3 versus Group 2

Estimated effects of being in *Group 2: Lacking ability to sleep* compared to *Group 3: Sleeps sufficiently* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm^3 and also in percentage of mean volumes.

region	extra_covs	Mean volume	obs	comparison	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area		902.6	6030	Group 2 vs 3 (ref)	-7.62 (-24.2, 8.9)	-0.84 (-2.7, 1)
Amygdala		3290.4	6031	Group 2 vs 3 (ref)	39.86 (2.1, 77.7)	1.21 (0.1, 2.4)
Brain-Stem		21934.6	6030	Group 2 vs 3 (ref)	99.65 (-111, 310.3)	0.45 (-0.5, 1.4)
Caudate		6756.9	6030	Group 2 vs 3 (ref)	32.05 (-54.6, 118.7)	0.47 (-0.8, 1.8)
Corpus callosum		3558.1	6034	Group 2 vs 3 (ref)	-34.4 (-87.7, 18.9)	-0.97 (-2.5, 0.5)
Cerebellum-Cortex		111496.1	6025	Group 2 vs 3 (ref)	522.84 (-548.7, 1594.4)	0.47 (-0.5, 1.4)
Cerebellum-White-Matter		30979.0	6027	Group 2 vs 3 (ref)	-13.18 (-433.3, 406.9)	-0.04 (-1.4, 1.3)
CerebralWhiteMatterVol		475094.8	6030	Group 2 vs 3 (ref)	222.09 (-3418.5, 3862.7)	0.05 (-0.7, 0.8)
EstimatedTotalIntraCranialVol		1545243.7	6032	Group 2 vs 3 (ref)	-3312.01 (-18844.6, 12220.5)	-0.21 (-1.2, 0.8)
Hippocampus		8066.9	6032	Group 2 vs 3 (ref)	46.63 (-28.2, 121.5)	0.58 (-0.3, 1.5)
Pallidum		3994.1	6032	Group 2 vs 3 (ref)	-42.49 (-83, -2)	-1.06 (-2.1, 0)
Putamen		9220.6	6029	Group 2 vs 3 (ref)	-34.89 (-137.1, 67.4)	-0.38 (-1.5, 0.7)
Thalamus		13717.8	6032	Group 2 vs 3 (ref)	-37.98 (-150, 74.1)	-0.28 (-1.1, 0.5)
TotalGrayVol		662557.2	6032	Group 2 vs 3 (ref)	-613.46 (-4182.3, 2955.4)	-0.09 (-0.6, 0.4)
Ventricles		31887.0	6027	Group 2 vs 3 (ref)	206.47 (-1213.6, 1626.6)	0.65 (-3.8, 5.1)



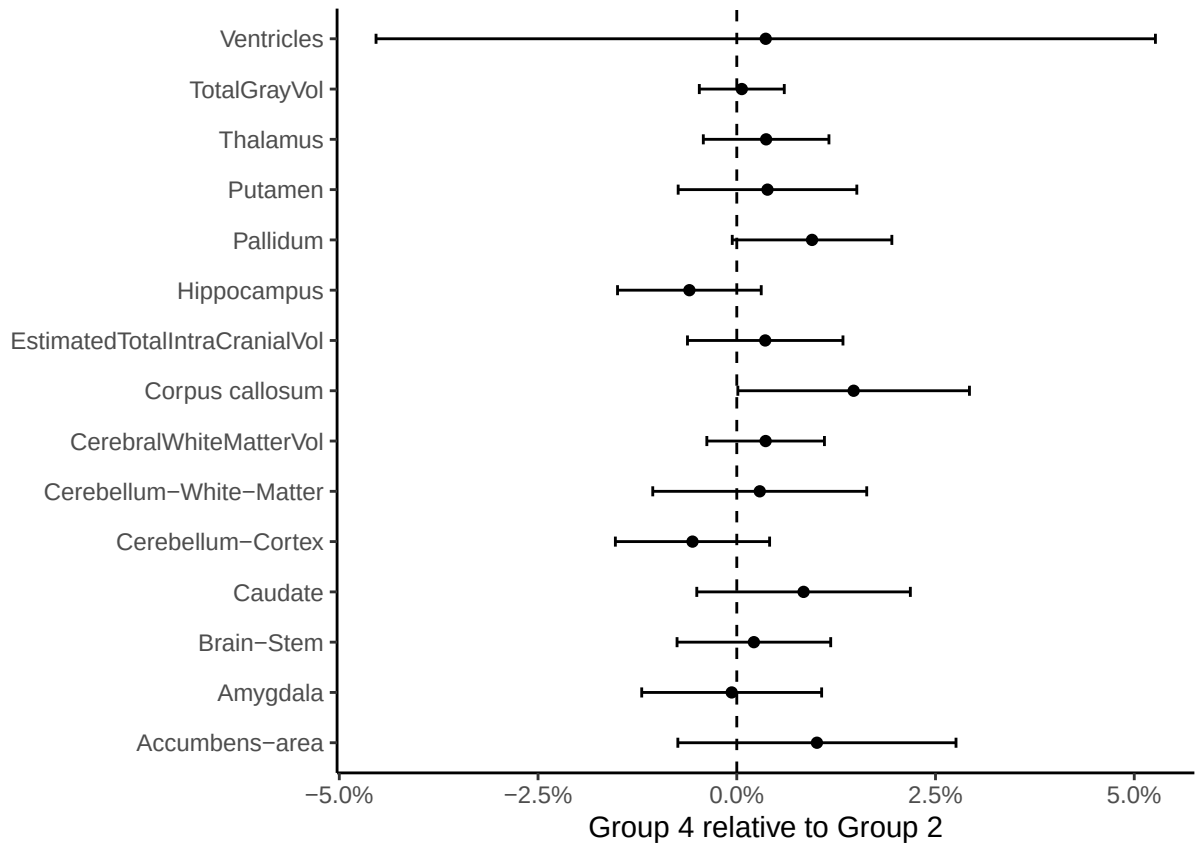
We perform a meta analysis across all regions.

```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0.0000 (SE = 0.0000)
## tau (square root of estimated tau^2 value): 0.0008
## I^2 (total heterogeneity / total variability): 2.66%
## H^2 (total variability / sampling variability): 1.03
##
## Test for Heterogeneity:
## Q(df = 14) = 16.7218, p-val = 0.2713
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## -0.0001  0.0013  -0.0452  0.9639  -0.0026  0.0025
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Group 4 versus Group 2

Estimated effects of being in *Group 4: Excess sleep need* compared to *Group 2: Lacking ability to sleep* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm^3 and also in percentage of mean volumes.

region	extra_covs	Mean volume	obs	comparison	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area		902.6	5140	Group 4 vs 2 (ref)	9.1 (-6.7, 24.9)	1.01 (-0.7, 2.8)
Amygdala		3290.4	5140	Group 4 vs 2 (ref)	-2.11 (-39.3, 35.1)	-0.06 (-1.2, 1.1)
Brain-Stem		21934.6	5137	Group 4 vs 2 (ref)	47.22 (-164.8, 259.2)	0.22 (-0.8, 1.2)
Caudate		6756.9	5135	Group 4 vs 2 (ref)	56.78 (-34, 147.5)	0.84 (-0.5, 2.2)
Corpus callosum		3558.1	5140	Group 4 vs 2 (ref)	52.31 (0.5, 104.1)	1.47 (0, 2.9)
Cerebellum-Cortex		111496.1	5137	Group 4 vs 2 (ref)	-620.98 (-1702.7, 460.7)	-0.56 (-1.5, 0.4)
Cerebellum-White-Matter		30979.0	5134	Group 4 vs 2 (ref)	89.55 (-327.4, 506.5)	0.29 (-1.1, 1.6)
CerebralWhiteMatterVol		475094.8	5138	Group 4 vs 2 (ref)	1724.51 (-1789.5, 5238.5)	0.36 (-0.4, 1.1)
EstimatedTotalIntraCranialVol		1545243.7	5140	Group 4 vs 2 (ref)	5531.04 (-9582.9, 20644.9)	0.36 (-0.6, 1.3)
Hippocampus		8066.9	5140	Group 4 vs 2 (ref)	-48.09 (-121, 24.8)	-0.6 (-1.5, 0.3)
Pallidum		3994.1	5140	Group 4 vs 2 (ref)	37.82 (-2.3, 77.9)	0.95 (-0.1, 2)
Putamen		9220.6	5133	Group 4 vs 2 (ref)	35.63 (-68, 139.2)	0.39 (-0.7, 1.5)
Thalamus		13717.8	5140	Group 4 vs 2 (ref)	50.67 (-57.7, 159.1)	0.37 (-0.4, 1.2)
TotalGrayVol		662557.2	5140	Group 4 vs 2 (ref)	419.05 (-3122.2, 3960.3)	0.06 (-0.5, 0.6)
Ventricles		31887.0	5138	Group 4 vs 2 (ref)	116.14 (-1446.9, 1679.2)	0.36 (-4.5, 5.3)



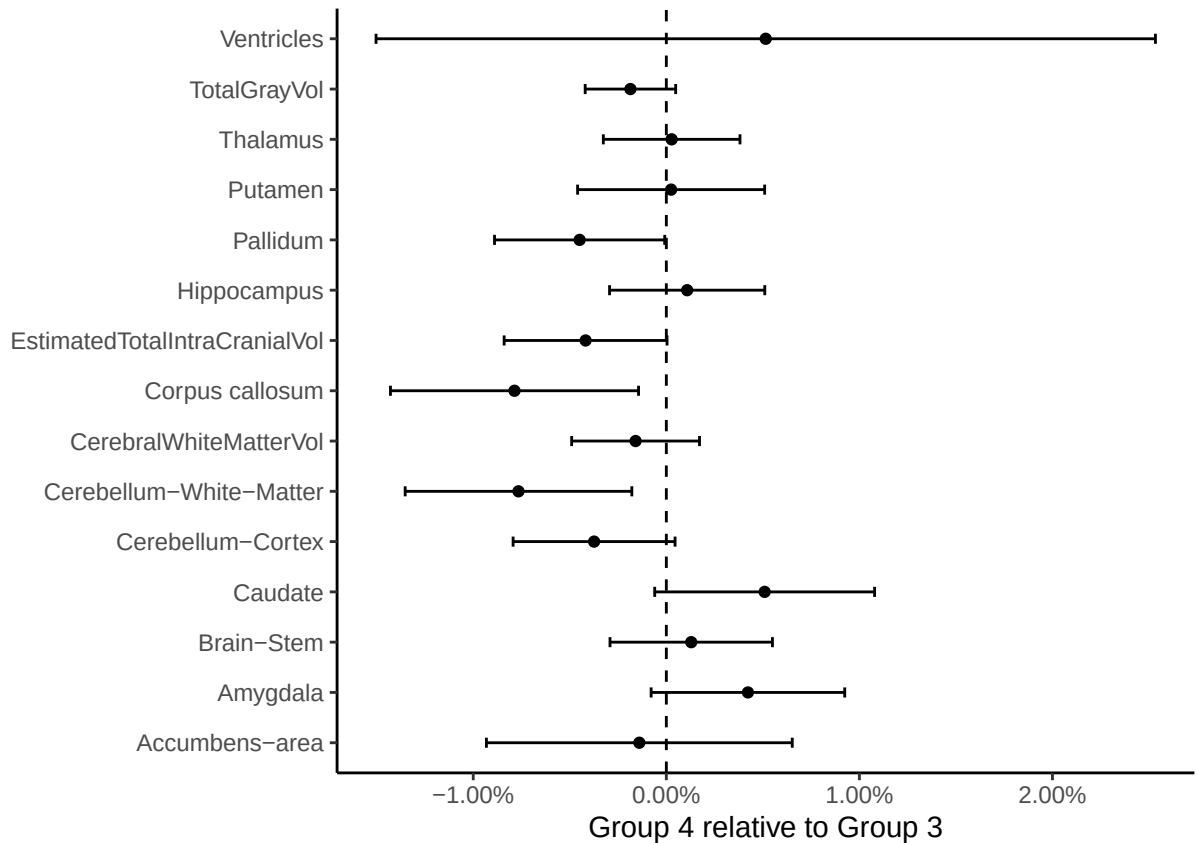
We perform a meta analysis across all regions.

```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0 (SE = 0.0000)
## tau (square root of estimated tau^2 value): 0
## I^2 (total heterogeneity / total variability): 0.00%
## H^2 (total variability / sampling variability): 1.00
##
## Test for Heterogeneity:
## Q(df = 14) = 13.6780, p-val = 0.4740
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## 0.0023 0.0013 1.7991 0.0720 -0.0002 0.0047 .
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Group 4 versus Group 3

Estimated effects of being in *Group 3: Sleeps sufficiently* compared to *Group 4: Excess sleep need* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm³ and also in percentage of mean volumes.

region	extra_covs	Mean volume	obs	comparison	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area		902.6	7682	Group 4 vs 3 (ref)	-1.26 (-8.4, 5.9)	-0.14 (-0.9, 0.7)
Amygdala		3290.4	7683	Group 4 vs 3 (ref)	13.91 (-2.6, 30.4)	0.42 (-0.1, 0.9)
Brain-Stem		21934.6	7683	Group 4 vs 3 (ref)	28.3 (-64, 120.6)	0.13 (-0.3, 0.5)
Caudate		6756.9	7681	Group 4 vs 3 (ref)	34.41 (-4.1, 72.9)	0.51 (-0.1, 1.1)
Corpus callosum		3558.1	7686	Group 4 vs 3 (ref)	-27.98 (-50.8, -5.1)	-0.79 (-1.4, -0.1)
Cerebellum-Cortex		111496.1	7680	Group 4 vs 3 (ref)	-417.14 (-884.7, 50.5)	-0.37 (-0.8, 0)
Cerebellum-White-Matter		30979.0	7677	Group 4 vs 3 (ref)	-237.19 (-419, -55.3)	-0.77 (-1.4, -0.2)
CerebralWhiteMatterVol		475094.8	7680	Group 4 vs 3 (ref)	-756.24 (-2328.9, 816.4)	-0.16 (-0.5, 0.2)
EstimatedTotalIntraCranialVol		1545243.7	7684	Group 4 vs 3 (ref)	-6460.85 (-12978.7, 57)	-0.42 (-0.8, 0)
Hippocampus		8066.9	7684	Group 4 vs 3 (ref)	8.72 (-23.7, 41.1)	0.11 (-0.3, 0.5)
Pallidum		3994.1	7684	Group 4 vs 3 (ref)	-17.93 (-35.5, -0.3)	-0.45 (-0.9, 0)
Putamen		9220.6	7680	Group 4 vs 3 (ref)	2.3 (-42.4, 47)	0.02 (-0.5, 0.5)
Thalamus		13717.8	7684	Group 4 vs 3 (ref)	3.78 (-44.8, 52.3)	0.03 (-0.3, 0.4)
TotalGrayVol		662557.2	7684	Group 4 vs 3 (ref)	-1231.51 (-2784, 320.9)	-0.19 (-0.4, 0)
Ventricles		31887.0	7681	Group 4 vs 3 (ref)	164.17 (-479.4, 807.7)	0.51 (-1.5, 2.5)



We perform a meta analysis across all regions.

```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0.0000 (SE = 0.0000)
## tau (square root of estimated tau^2 value):      0.0025
## I^2 (total heterogeneity / total variability):   56.78%
## H^2 (total variability / sampling variability):   2.31
##
## Test for Heterogeneity:
## Q(df = 14) = 29.0436, p-val = 0.0103
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## -0.0014  0.0009  -1.6297   0.1032   -0.0032   0.0003
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Subcortical volumes, controlling for additional covariates

We included education, income, BMI, and depression scores in the models. We first show some descriptive statistics.

Table 34: Observations for which we have both education and income

study	Group 1	Group 3	Group 2	Group 4
MPIB	1	5	0	0
UiO	7	72	19	24
UKB	345	2036	823	1884
UOXF	6	32	14	5

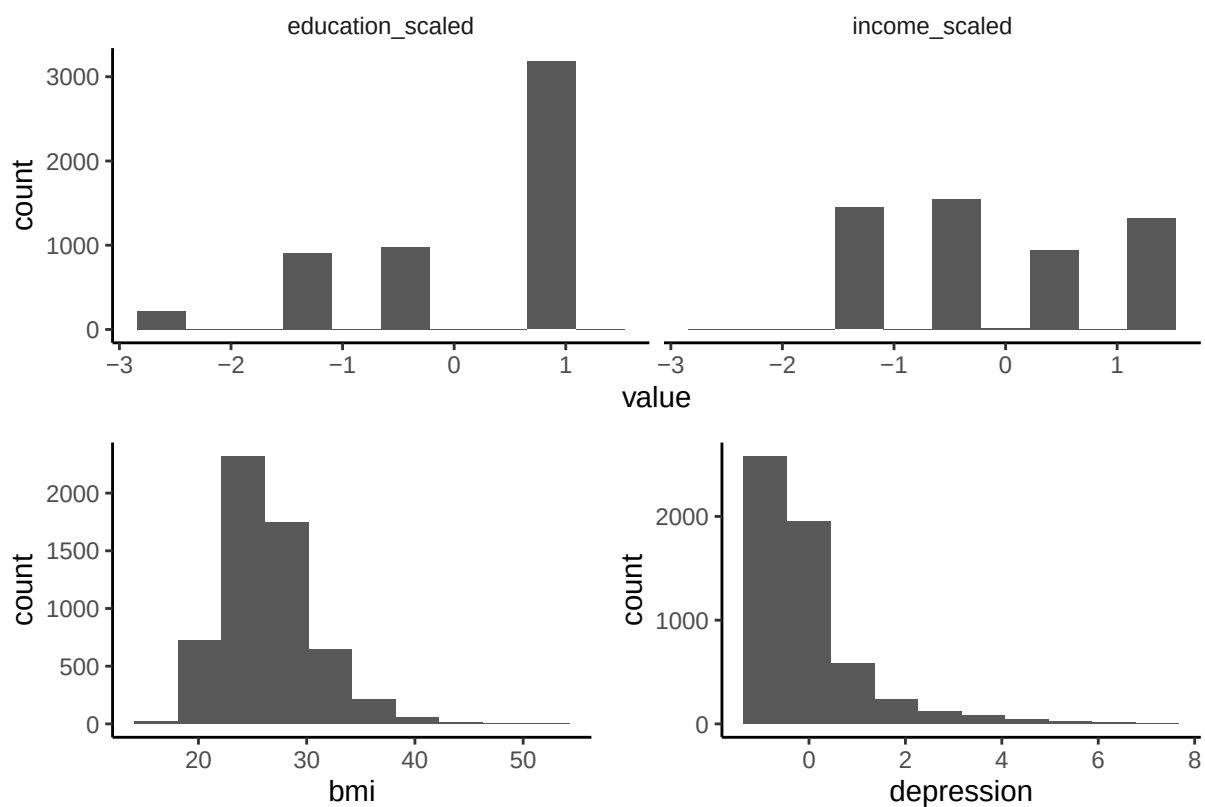
Table 35: Observations for which we have BMI

study	Group 1	Group 2	Group 3	Group 4
UCAM	18	41	117	19
UiO	10	45	111	50
UKB	349	857	2107	1952
UmU	0	3	63	11

Table 36: Observations for which we have depression score

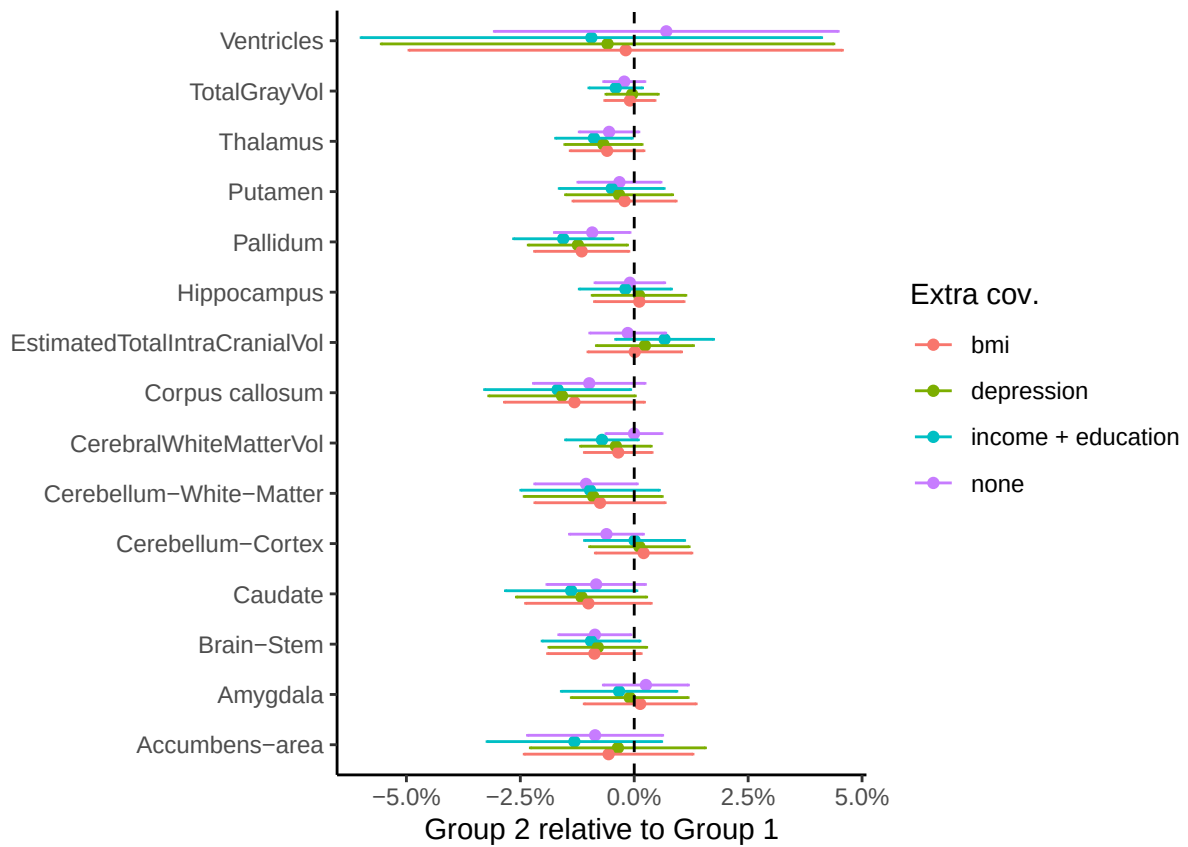
study	Group 3	Group 1	Group 2	Group 4
MPIB	2	0	0	0
UiO	47	4	14	14
UKB	2036	345	823	1884

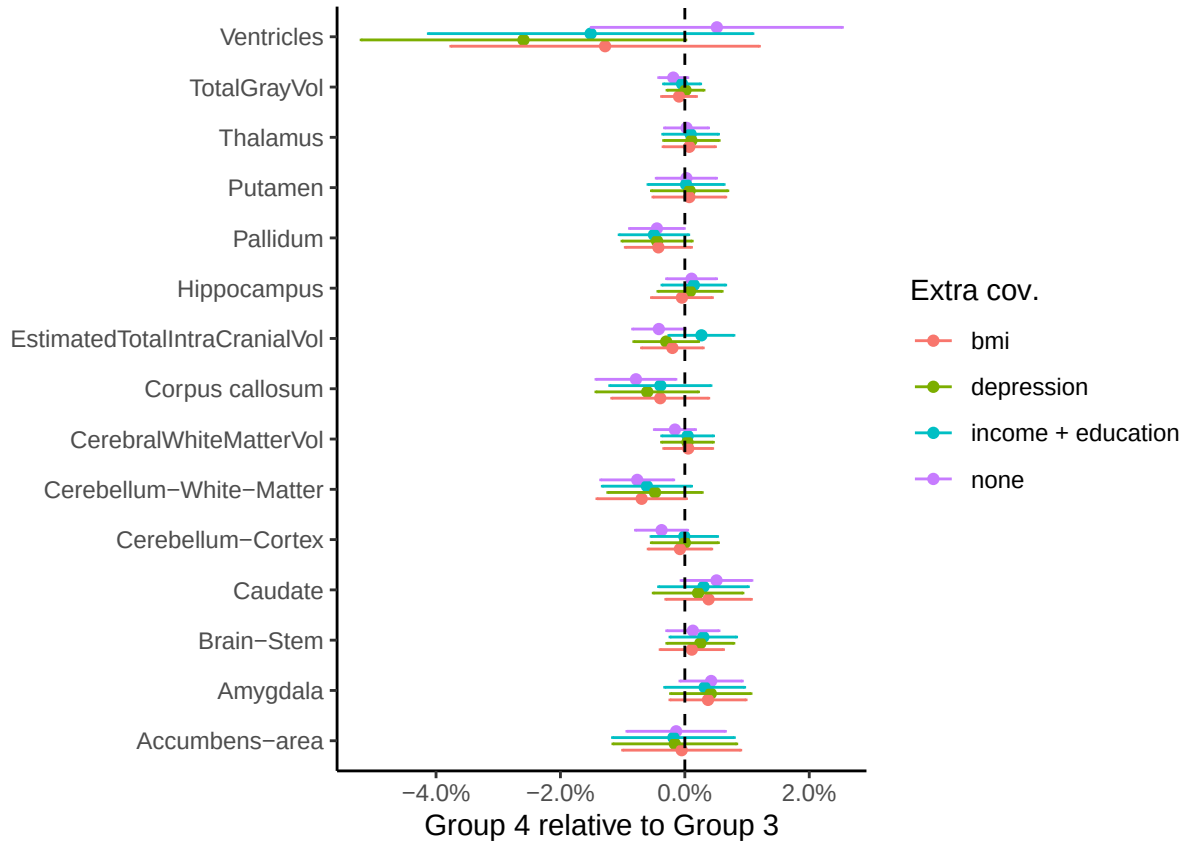
Next we show histograms of the values.



In three additional models we added `income + education`, `depression`, and `bmi`. `income`, `education`, and `depression` were Z-transformed.

The plots below show the estimated group differences after including these extra covariates. The case “none” is identical to the models shown above. First is Group 2 vs Group 1, next is Group 4 vs Group 3.





Next we test for the overall effect across regions, using meta analysis.

comparison	extra_covs	estimate	ci_lower	ci_upper	pval
Group 2 vs 1 (ref)		-0.0040	-0.0061	-0.0020	0.0001
Group 2 vs 1 (ref)	bmi	-0.0035	-0.0061	-0.0010	0.0071
Group 2 vs 1 (ref)	depression	-0.0038	-0.0064	-0.0011	0.0059
Group 2 vs 1 (ref)	income + education	-0.0061	-0.0089	-0.0032	0.0000
Group 4 vs 3 (ref)		-0.0014	-0.0032	0.0003	0.1032
Group 4 vs 3 (ref)	bmi	-0.0005	-0.0018	0.0008	0.4583
Group 4 vs 3 (ref)	depression	-0.0001	-0.0015	0.0012	0.8516
Group 4 vs 3 (ref)	income + education	0.0001	-0.0012	0.0015	0.8564

Subcortical volumes for groups based on accelerometer sleep

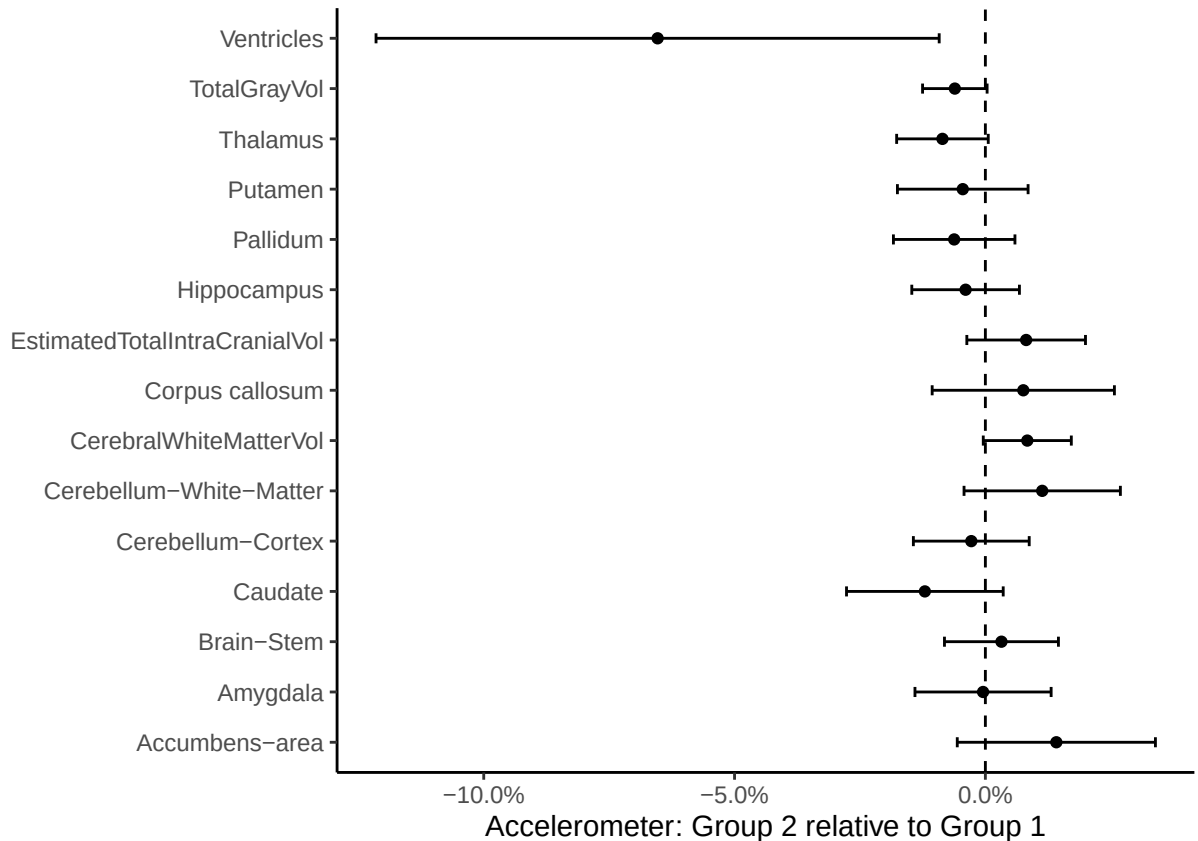
Only accelerometer based

For participants sleeping less than or equal to 6 hours per night, we compared brain volumes of Group 1 and Group 2 using a model like the following. When estimated total intracranial volume was the outcome, `icv` was not included in the model. The effect of interest was the `Group` variable. Note that the `site` term was not included here, as all accelerometer data were from the UKB.

```
mod <- gamm4(value ~ s(age) + sex + sleep + Group + icv,
             random = ~ (1|id), data = dat)
```

Estimated effects of being in *Group 2: Lacking ability to sleep* compared to *Group 1: Less sleep need* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm³ and also in percentage of mean volumes.

region	Mean volume	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area	902.6	12.77 (-5.1, 30.6)	1.41 (-0.6, 3.4)
Amygdala	3290.4	-1.52 (-46.2, 43.1)	-0.05 (-1.4, 1.3)
Brain-Stem	21934.6	70.34 (-178.8, 319.5)	0.32 (-0.8, 1.5)
Caudate	6756.9	-81.5 (-187, 24)	-1.21 (-2.8, 0.4)
Corpus callosum	3558.1	26.91 (-37.7, 91.5)	0.76 (-1.1, 2.6)
Cerebellum-Cortex	111496.1	-312.67 (-1600.1, 974.8)	-0.28 (-1.4, 0.9)
Cerebellum-White-Matter	30979.0	351.11 (-131.7, 833.9)	1.13 (-0.4, 2.7)
CerebralWhiteMatterVol	475094.8	3971.1 (-198.4, 8140.6)	0.84 (0, 1.7)
EstimatedTotalIntraCranialVol	1545243.7	12565.58 (-5709.3, 30840.4)	0.81 (-0.4, 2)
Hippocampus	8066.9	-31.78 (-118.3, 54.8)	-0.39 (-1.5, 0.7)
Pallidum	3994.1	-24.83 (-73.2, 23.6)	-0.62 (-1.8, 0.6)
Putamen	9220.6	-41.55 (-161.7, 78.6)	-0.45 (-1.8, 0.9)
Thalamus	13717.8	-117.39 (-242.6, 7.9)	-0.86 (-1.8, 0.1)
TotalGrayVol	662557.2	-4032.46 (-8295.2, 230.3)	-0.61 (-1.3, 0)
Ventricles	31887.0	-2083.42 (-3873.3, -293.5)	-6.53 (-12.1, -0.9)



Below is a meta analysis.

```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
```



```
##
## tau^2 (estimated amount of total heterogeneity): 0.0000 (SE = 0.0000)
## tau (square root of estimated tau^2 value):      0.0046
## I^2 (total heterogeneity / total variability):   37.84%
## H^2 (total variability / sampling variability):  1.61
##
## Test for Heterogeneity:
## Q(df = 14) = 22.4081, p-val = 0.0706
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## -0.0004  0.0020  -0.2208   0.8252  -0.0044   0.0035
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

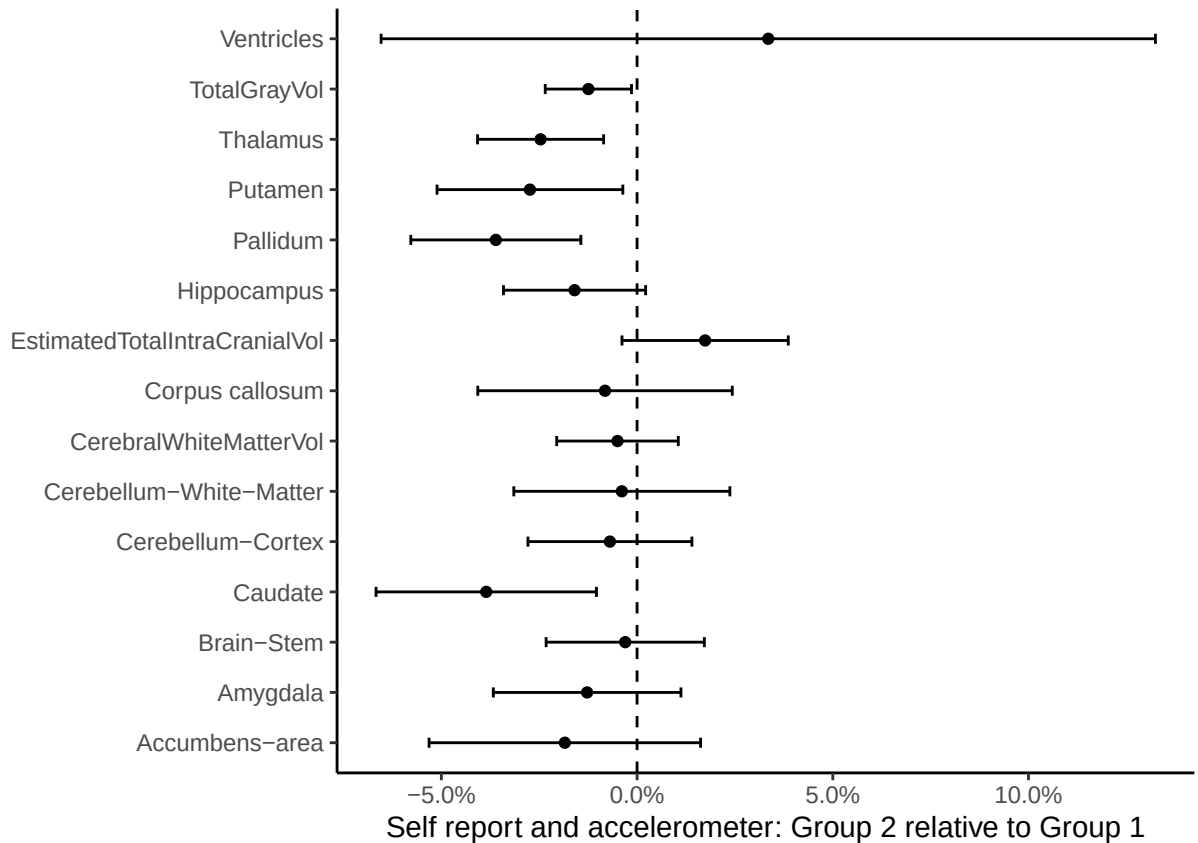
Both self report and accelerometer sleep: Group 2 versus Group 1

For participants sleeping less than or equal to 6 hours per night according to BOTH self report and accelerometer, we compared brain volumes of Group 1 and Group 2 using a model like the following. When estimated total intracranial volume was the outcome, `icv` was not included in the model. The effect of interest was the `Group` variable. Note that the `site` term was not included here, as all accelerometer data were from the UKB.

```
mod <- gamm4(value ~ s(age) + sex + sleep + Group + icv,
             random = ~ (1|id), data = dat)
```

Estimated effects of being in *Group 2: Lacking ability to sleep* compared to *Group 1: Less sleep need* is shown in the table below, where we have included the mean volumes for all data for reference. We show estimates and confidence intervals in mm³ and also in percentage of mean volumes.

region	Mean volume	Estimate mm3 (CI)	Estimate pct (CI)
Accumbens-area	902.6	-16.66 (-48, 14.6)	-1.85 (-5.3, 1.6)
Amygdala	3290.4	-42 (-120.9, 36.9)	-1.28 (-3.7, 1.1)
Brain-Stem	21934.6	-66.31 (-509.7, 377.1)	-0.3 (-2.3, 1.7)
Caudate	6756.9	-260.39 (-450.6, -70.2)	-3.85 (-6.7, -1)
Corpus callosum	3558.1	-29.13 (-144.8, 86.5)	-0.82 (-4.1, 2.4)
Cerebellum-Cortex	111496.1	-773.69 (-3108.6, 1561.3)	-0.69 (-2.8, 1.4)
Cerebellum-White-Matter	30979.0	-120.72 (-975.8, 734.4)	-0.39 (-3.1, 2.4)
CerebralWhiteMatterVol	475094.8	-2378.69 (-9754.9, 4997.6)	-0.5 (-2.1, 1.1)
EstimatedTotalIntraCranialVol	1545243.7	26854.13 (-5963.3, 59671.6)	1.74 (-0.4, 3.9)
Hippocampus	8066.9	-128.85 (-275.3, 17.6)	-1.6 (-3.4, 0.2)
Pallidum	3994.1	-144.13 (-230.9, -57.4)	-3.61 (-5.8, -1.4)
Putamen	9220.6	-252.38 (-471.2, -33.6)	-2.74 (-5.1, -0.4)
Thalamus	13717.8	-338.22 (-559.1, -117.3)	-2.47 (-4.1, -0.9)
TotalGrayVol	662557.2	-8246 (-15548.7, -943.3)	-1.24 (-2.3, -0.1)
Ventricles	31887.0	1068.56 (-2085.2, 4222.4)	3.35 (-6.5, 13.2)



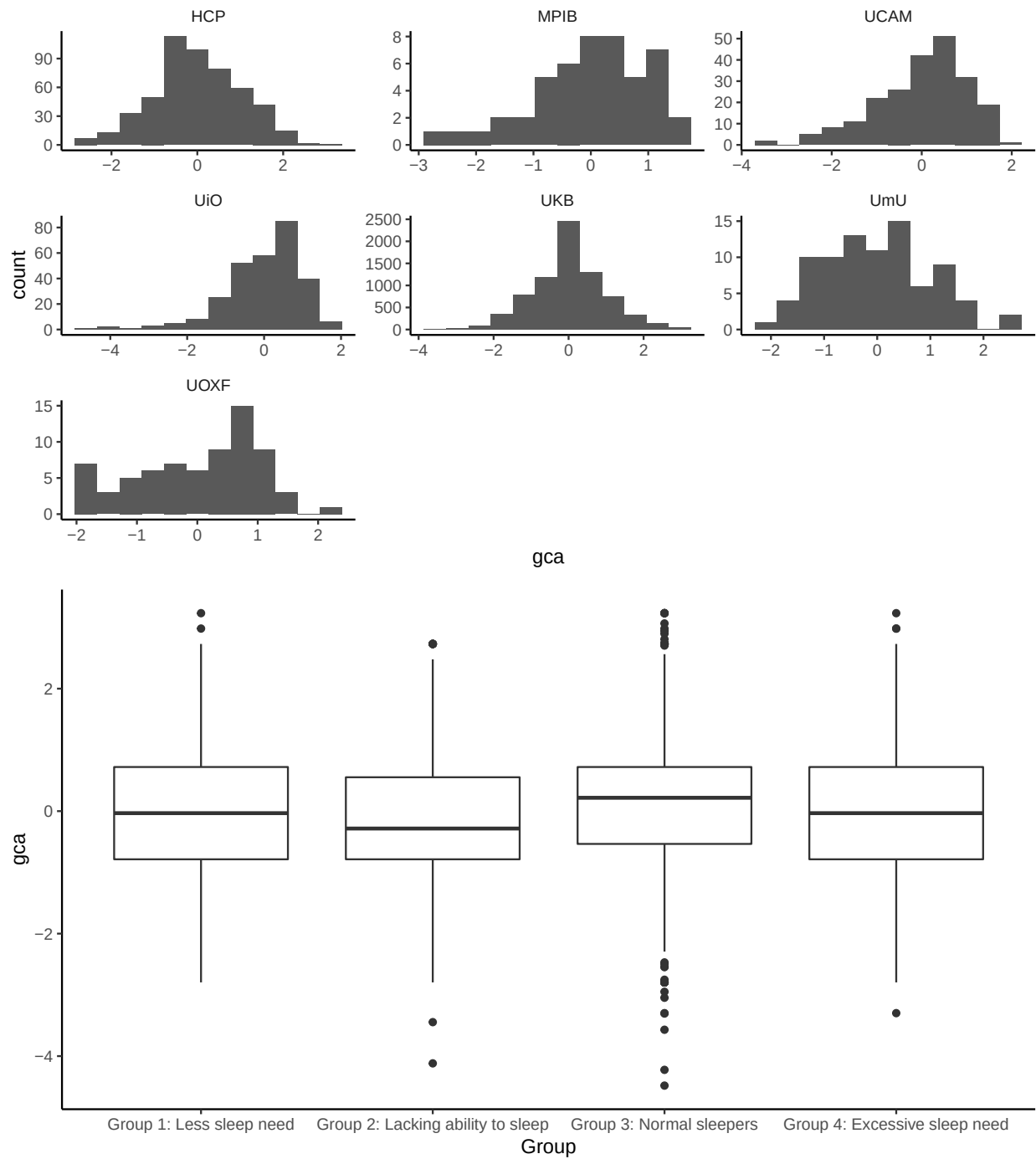
```
##
## Random-Effects Model (k = 15; tau^2 estimator: REML)
##
## tau^2 (estimated amount of total heterogeneity): 0.0001 (SE = 0.0001)
## tau (square root of estimated tau^2 value):      0.0091
## I^2 (total heterogeneity / total variability):   44.18%
## H^2 (total variability / sampling variability):  1.79
##
## Test for Heterogeneity:
## Q(df = 14) = 24.2527, p-val = 0.0427
##
## Model Results:
##
## estimate      se      zval      pval      ci.lb      ci.ub
## -0.0143  0.0037  -3.8724  0.0001  -0.0215  -0.0070  ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Comparison of general cognitive ability across groups

We here only analyze participants who also have MRI, and only those who belong to one of the groups 1,2, 3, or 4. The GCA scores were based on principal components and standardized within each group.

Table 40: Number of participants with GCA score.

study	n
HCP	513
MPIB	48
UCAM	219
UiO	286
UKB	7472
UmU	85
UOXF	71
Total	8694



Group 2 versus Group 1 (ref)

The model estimates the difference in GCA between Group 2 and Group 1.

```
##
## Family: gaussian
## Link function: identity
##
```

```

## Formula:
## gca ~ s(age) + sex + study + Group_f
##
## Parametric coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -0.75315    0.17052  -4.417 1.05e-05
## sexmale         0.09187    0.04461   2.059 0.039583
## studyMPIB       1.06690    0.43473   2.454 0.014199
## studyUCAM       0.44715    0.19415   2.303 0.021365
## studyUiO        0.41451    0.16747   2.475 0.013395
## studyUKB        0.72822    0.18718   3.891 0.000103
## studyUmU        0.20012    0.48706   0.411 0.681199
## studyUOXF       0.80656    0.27561   2.927 0.003464
## Group_fGroup 2: Lacking ability to sleep -0.07668    0.04956  -1.547 0.121987
##
## (Intercept)          ***
## sexmale               *
## studyMPIB             *
## studyUCAM             *
## studyUiO              *
## studyUKB              ***
## studyUmU
## studyUOXF            **
## Group_fGroup 2: Lacking ability to sleep
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##      edf Ref.df      F  p-value
## s(age) 3.067  3.903 4.898 0.000828 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.0133  Deviance explained = 1.83%
## -REML = 3106.7  Scale est. = 1.0115    n = 2173

```

Group 1 versus Group 3 (ref)

```

##
## Family: gaussian
## Link function: identity
##
## Formula:
## gca ~ s(age) + sex + study + Group_f
##
## Parametric coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -0.47952    0.10600  -4.524 6.23e-06 ***
## sexmale         0.16718    0.03080   5.428 6.00e-08 ***
## studyMPIB       0.32489    0.18331   1.772 0.076414 .
## studyUCAM       0.46137    0.12166   3.792 0.000151 ***
## studyUiO        0.24760    0.10519   2.354 0.018632 *
## studyUKB        0.56001    0.11855   4.724 2.39e-06 ***

```

```
## studyUmU                0.45576    0.16116    2.828 0.004707 **
## studyUOXF                0.53924    0.18467    2.920 0.003518 **
## Group_fGroup 1: Less sleep need -0.15802    0.04164   -3.795 0.000150 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##      edf Ref.df      F p-value
## s(age) 4.465  5.531 18.64  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.0305   Deviance explained = 3.34%
## -REML = 5953.6   Scale est. = 0.95742    n = 4248
```

Group 2 versus Group 3 (ref)

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## gca ~ s(age) + sex + study + Group_f
##
## Parametric coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -0.49712    0.10327  -4.814 1.52e-06
## sexmale         0.13481    0.02801   4.812 1.54e-06
## studyMPIB       0.29019    0.18176   1.597 0.110418
## studyUCAM       0.39646    0.11421   3.471 0.000522
## studyUiO        0.21675    0.09835   2.204 0.027587
## studyUKB        0.57533    0.11317   5.084 3.84e-07
## studyUmU        0.47345    0.15770   3.002 0.002694
## studyUOXF       0.61758    0.17282   3.574 0.000355
## Group_fGroup 2: Lacking ability to sleep -0.18518    0.03115  -5.944 2.97e-09
##
## (Intercept)          ***
## sexmale              ***
## studyMPIB
## studyUCAM           ***
## studyUiO            *
## studyUKB            ***
## studyUmU            **
## studyUOXF           ***
## Group_fGroup 2: Lacking ability to sleep ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##      edf Ref.df      F p-value
## s(age) 4.872  5.991 15.63  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## R-sq.(adj) = 0.0311   Deviance explained = 3.36%
## -REML = 7144.8   Scale est. = 0.97044   n = 5075
```

Group 4 versus Group 2 (ref)

The model estimates the difference in GCA between Group 4 and Group 2.

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## gca ~ s(age) + sex + study + Group_f
##
## Parametric coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -0.84870    0.17096  -4.964 7.16e-07 ***
## sexmale         0.15343    0.03020   5.080 3.92e-07 ***
## studyMPIB       0.93445    0.39356   2.374 0.017624 *
## studyUCAM       0.41357    0.18725   2.209 0.027248 *
## studyUiO        0.41948    0.14799   2.835 0.004610 **
## studyUKB        0.66578    0.17716   3.758 0.000173 ***
## studyUmU        0.57646    0.29628   1.946 0.051761 .
## studyUOXF       0.70560    0.27184   2.596 0.009473 **
## Group_fGroup 4: Excessive sleep need 0.08114    0.03197   2.538 0.011177 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(age) 4.795    5.9 9.681  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.0187   Deviance explained = 2.15%
## -REML = 6283.8   Scale est. = 0.9818   n = 4446
```

Group 4 versus Group 3 (ref)

The model estimates the difference in GCA between Group 4 and Group 3.

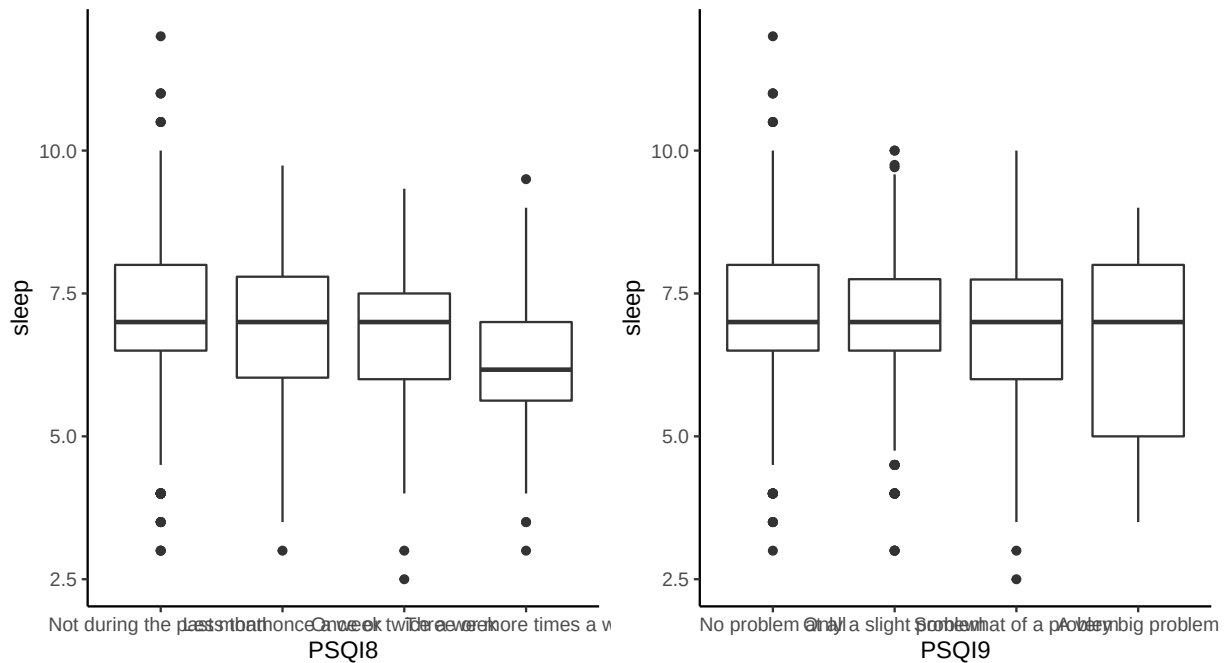
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## gca ~ s(age) + sex + study + Group_f
##
## Parametric coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -0.47658    0.10305  -4.625 3.82e-06 ***
## sexmale         0.18521    0.02463   7.519 6.27e-14 ***
```

```
## studyMPIB          0.23323    0.17634    1.323    0.18602
## studyUCAM          0.38122    0.11656    3.270    0.00108 **
## studyUiO           0.19891    0.09461    2.102    0.03555 *
## studyUKB           0.48519    0.11093    4.374    1.24e-05 ***
## studyUmU           0.39580    0.14828    2.669    0.00762 **
## studyUOXF          0.39909    0.18180    2.195    0.02818 *
## Group_fGroup 4: Excessive sleep need -0.07764    0.02617    -2.966    0.00303 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##      edf Ref.df      F p-value
## s(age) 4.749  5.844 22.85  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.0299   Deviance explained = 3.18%
## -REML = 9129.8   Scale est. = 0.95702   n = 6521
```

Sleep duration and tiredness

PSQI

We compare the sleep duration based on answers to PSQI questions 8 and 9. This applies to HCP and Lifebrain. The underlying numbers are shown in the tables below.

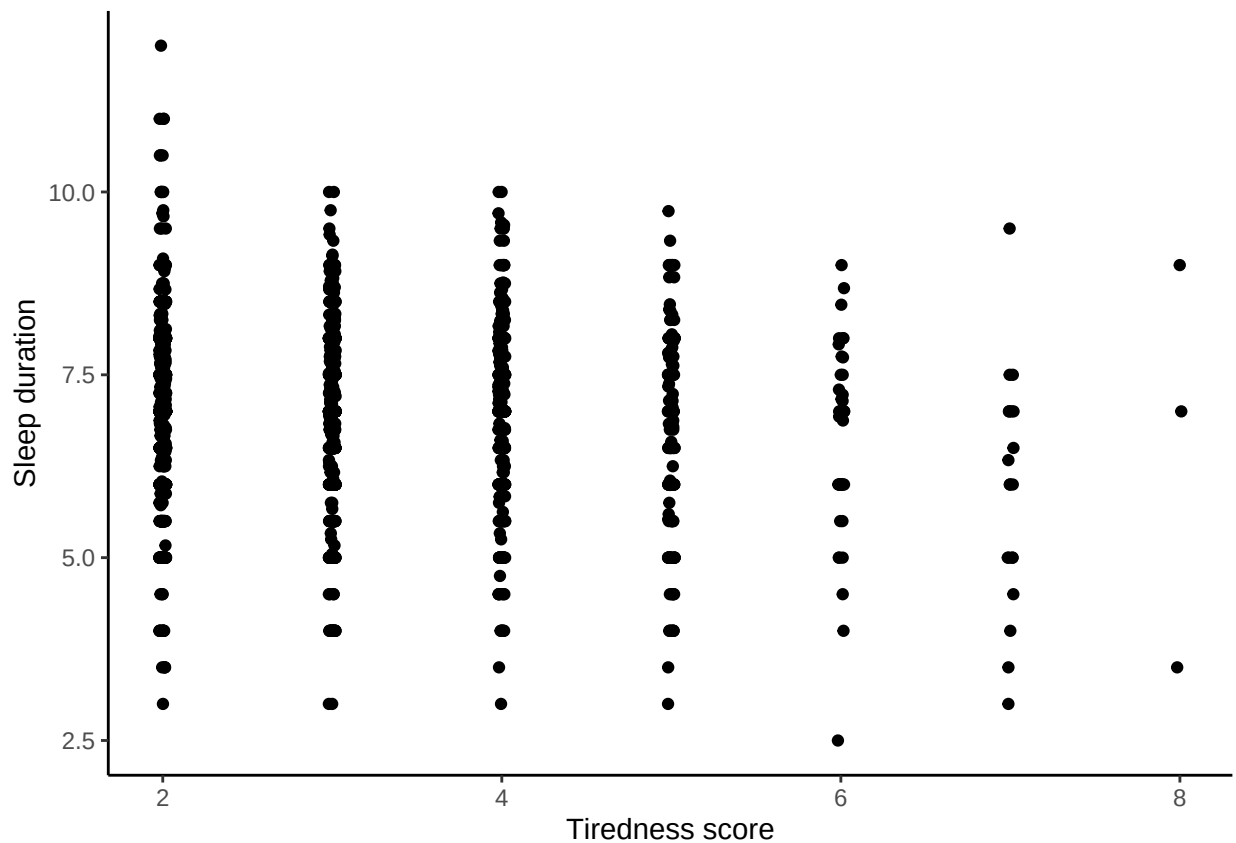


PSQI8	Mean sleep	St. dev sleep
Not during the past month	7.01	1.05
Less than once a week	6.96	1.08

PSQI8	Mean sleep	St. dev sleep
Once or twice a week	6.67	1.26
Three or more times a week	6.25	1.45

PSQI9	Mean sleep	St. dev sleep
No problem at all	7.06	1.03
Only a slight problem	6.97	1.02
Somewhat of a problem	6.77	1.25
A very big problem	6.50	1.67

Next we compute a tiredness score by assigning a 1-4 value for each of the ordinal scores in PSQI8 and PSQI9, and then summing. Some noise has been added to the plot below for visualization purposes.



Below is the estimated correlation between tiredness score and sleep duration.

```
cor.test(psqi_tiredness$tiredness_score, psqi_tiredness$sleep)

##
## Pearson's product-moment correlation
##
## data: psqi_tiredness$tiredness_score and psqi_tiredness$sleep
## t = -6.5255, df = 3636, p-value = 7.713e-11
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
```

```
## -0.13959980 -0.07535742
## sample estimates:
##      cor
## -0.1075909
```

We also show the numbers:

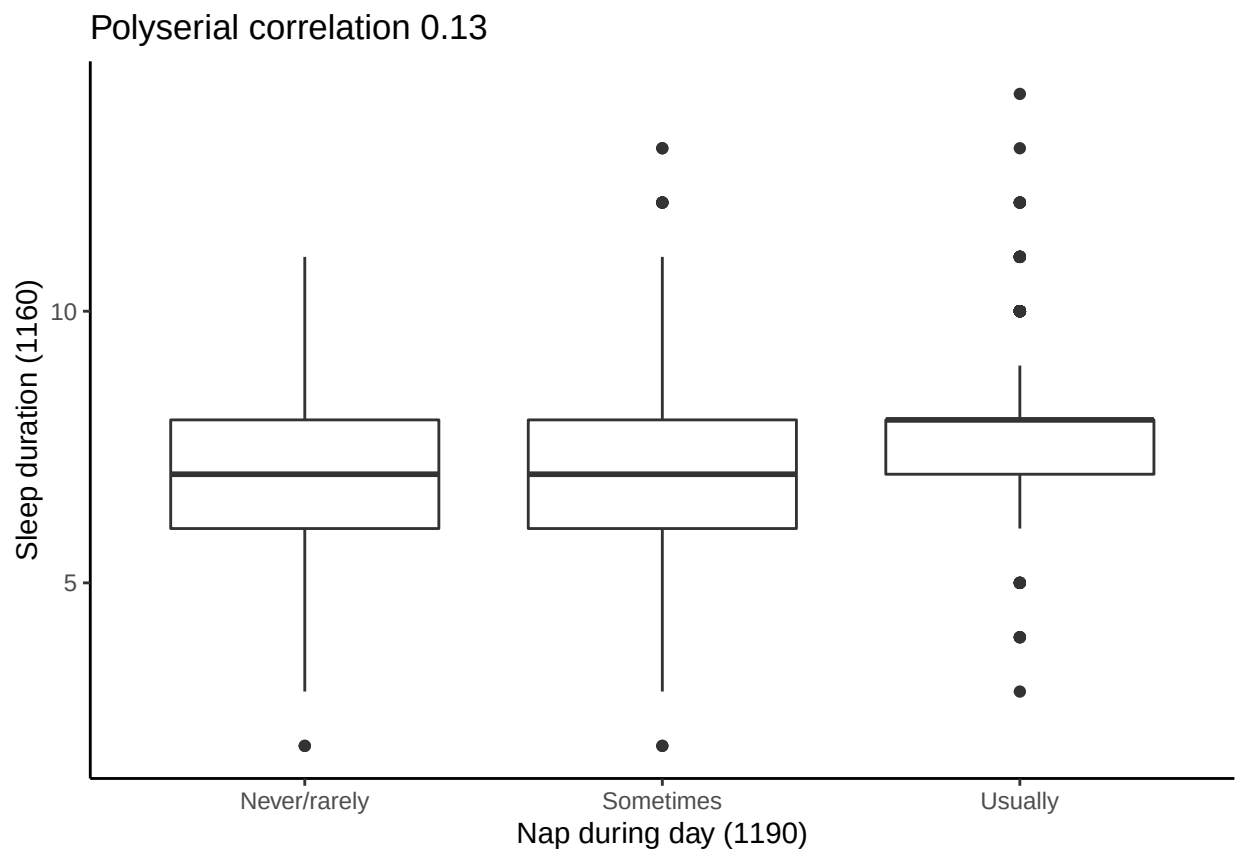
Tiredness score	Mean sleep	St. dev. sleep	Participants
2	7.09	1.03	1561
3	6.95	1.02	1254
4	6.93	1.09	573
5	6.75	1.36	184
6	6.61	1.29	43
7	5.92	1.56	20
8	6.50	2.78	3

UKB

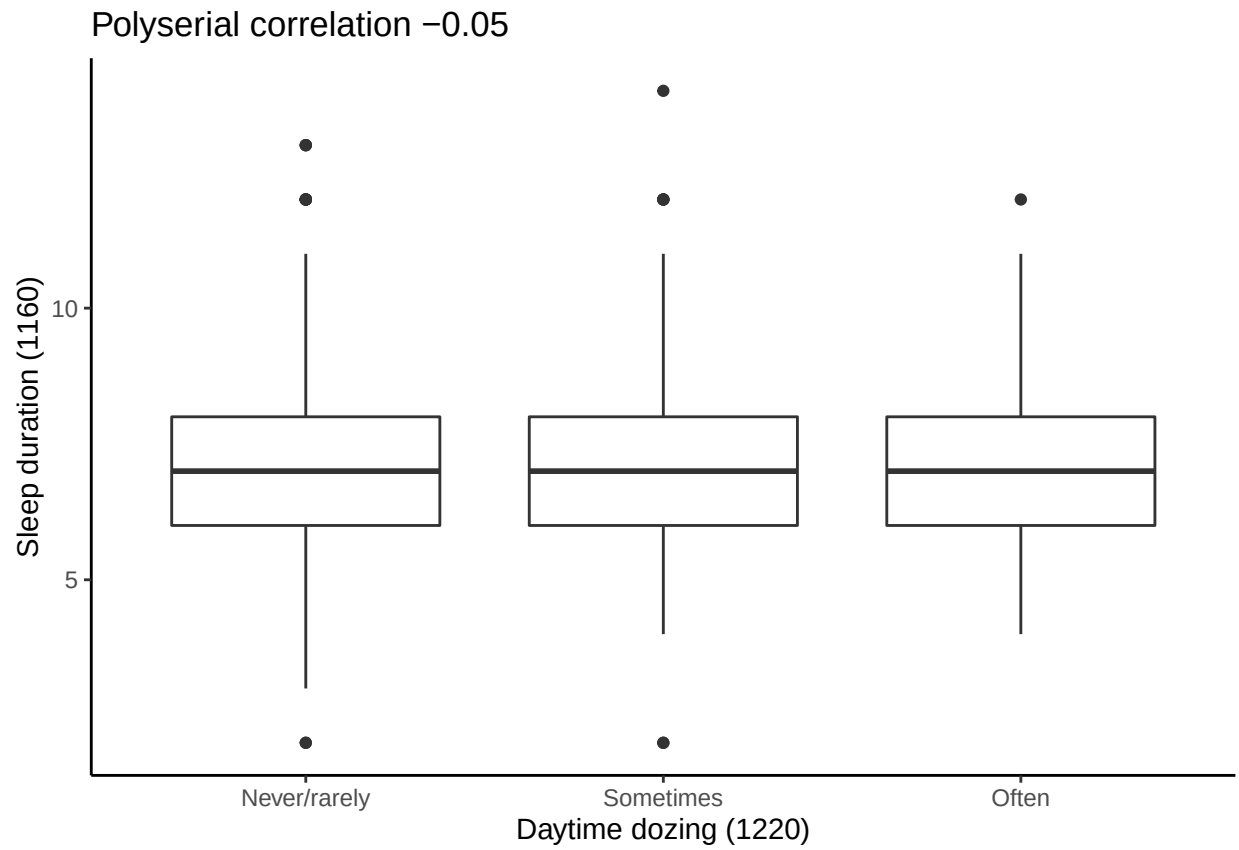
UKB has different sleep questions, and is hence shown separately.

Shown on top of each boxplot is the polyserial correlation computed with the `polycor` package (Fox 2019).

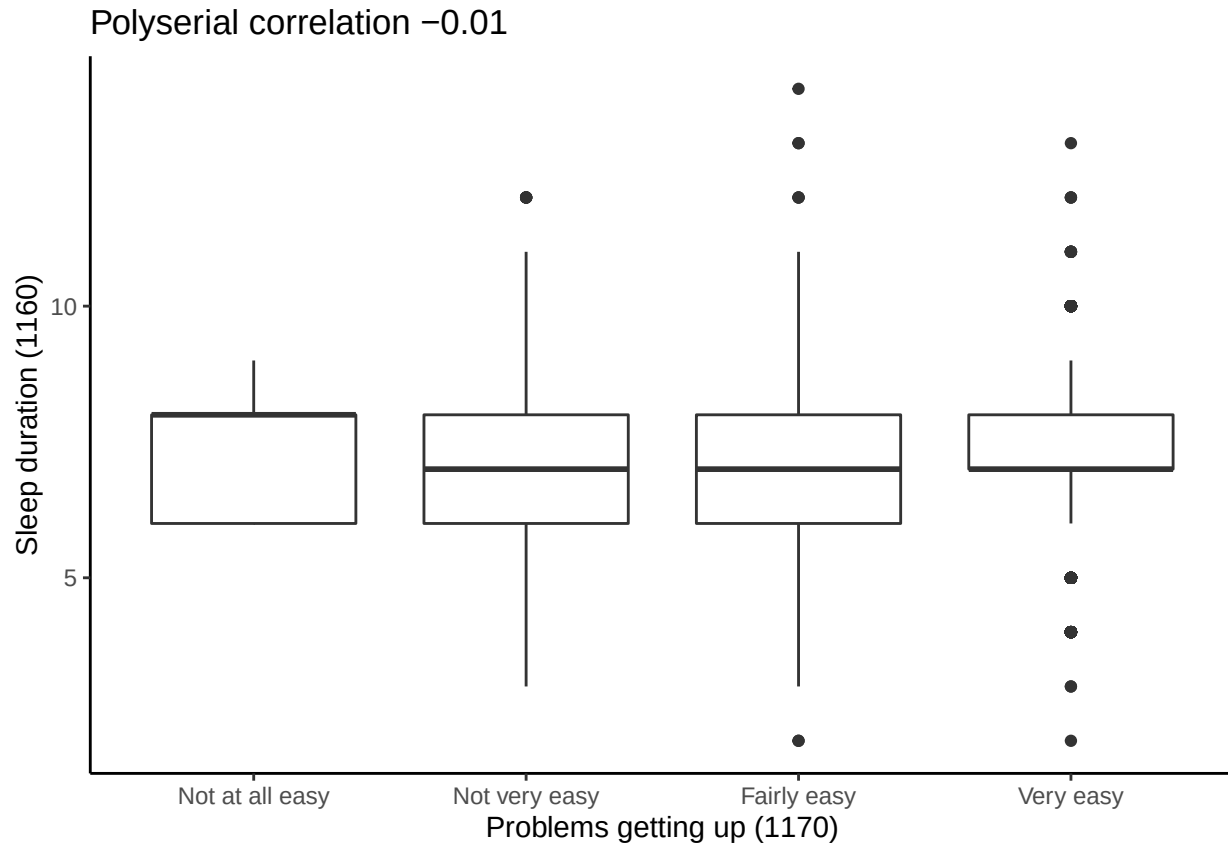
Nap during day



Daytime dozing



Problems getting up



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