

Supplementary Material

Bidirectional associations between sleep and physical activity investigated using large-scale objective monitoring data

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Tables

Table S1 | Descriptive statistics for trimmed versus raw (untrimmed) data

Variable	Trimmed		Raw	
	Median	IQR	Median	IQR
Daily step count	5521	[3,090, 8,751]	4963	[2744, 8036]
Sleep duration (hours)	7.17	[6.25, 8.05]	7.13	[6.13, 8.07]
Sleep efficiency, %	89.7	[83.6, 93.8]	89.4	[82.8, 93.7]
Sleep onset latency (minutes)	24	[15, 38]	23	[15, 38]

Table S2: Demographic information by included versus excluded participants

Variable	Participants		<i>p</i>
	Included (n = 70,963)	Excluded (n = 248,872)	
Age in years (SD)	48.5 (12.0)	51.7 (15.4)	<0.00001
Sex			
Female	12,437	76,961	
Male	58,526	171,911	
BMI (kg/m ²) (SD)	27.75 (4.93)	26.94 (5.53)	<0.00001

Note. Presented *p*-values are derived from a two-sided *t*-test. No adjustment for multiple comparisons was made.

Table S3: Top 20 countries with the highest number of included participants and their demographic information.

Country Name	Sample size	Age	Female	Male	BMI
United States	18102	47.2	3787	14315	28.6
Germany	13453	51.4	2320	11133	28.2
France	10421	49.4	2031	8390	26.9
United Kingdom	4647	48.0	748	3899	28.0
Japan	2896	46.6	245	2651	25.1
Switzerland	2851	49.4	470	2381	27.3
Australia	1793	45.7	307	1486	28.8
Netherlands	1759	48.2	307	1452	26.9
Canada	1632	47.7	310	1322	28.3
Italy	1223	50.1	134	1089	26.7
Sweden	1140	47.9	175	965	27.3
Belgium	1029	48.8	166	863	27.3
Finland	1018	48.0	147	871	28.3
Spain	991	49.9	146	845	27.1
Austria	872	49.4	121	751	27.9
Denmark	723	48.4	95	628	27.7
Norway	640	46.8	94	546	27.4
Poland	564	45.7	76	488	27.4
Portugal	412	49.8	76	336	26.3
Czech Republic	305	44.2	38	267	27.7

Table S4: Model comparison: with and without interaction terms for ‘TST by demographic variables’

Interaction	df	AIC
Without interaction model	73.4	545116757
TST by age	84.8	545105385
TST by bmi	84.6	545115014
TST by sex	81.3	545122800

Table S5: Model comparison: with and without interaction terms for ‘Step count by demographic variables’

Interaction	df	AIC
Without interaction model	65.8	87526528
Step count by age	69.8	87553849
Step count by BMI	70.0	87528643
Step count by sex	73.7	87553119

Figures

Figure S1 | Visual confirmation of no interaction between sleep duration (TST) and BMI on step count. Left: exposure-response curve follows a similar trend across different BMI values. Right: exposure-response curves for 'sleep duration → step count' effect, split by participants with BMI ≥ 24 vs BMI ≤ 24 .

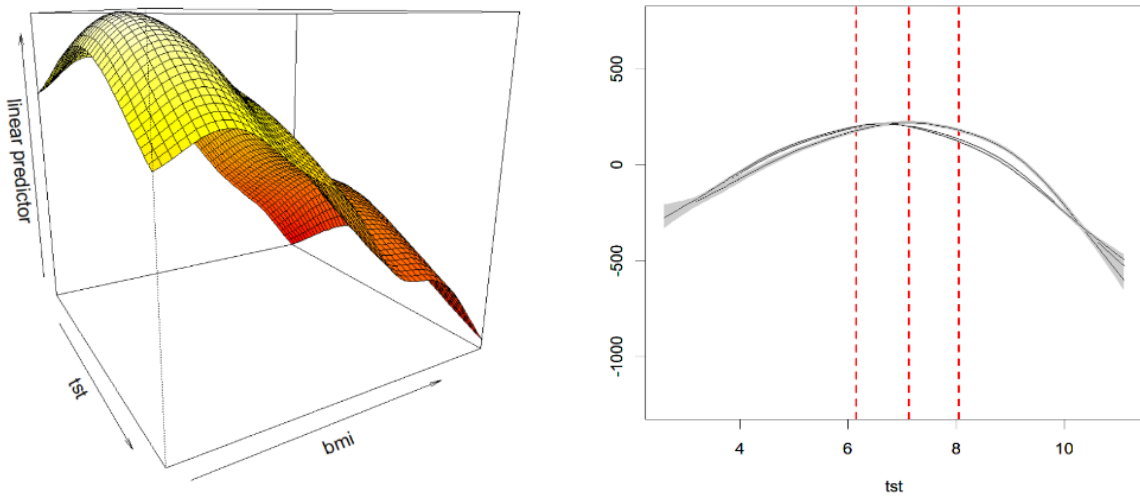


Figure S2 | Region-specific sensitivity analysis for step count as a function of demographic and time-based variables – Berlin (Germany)

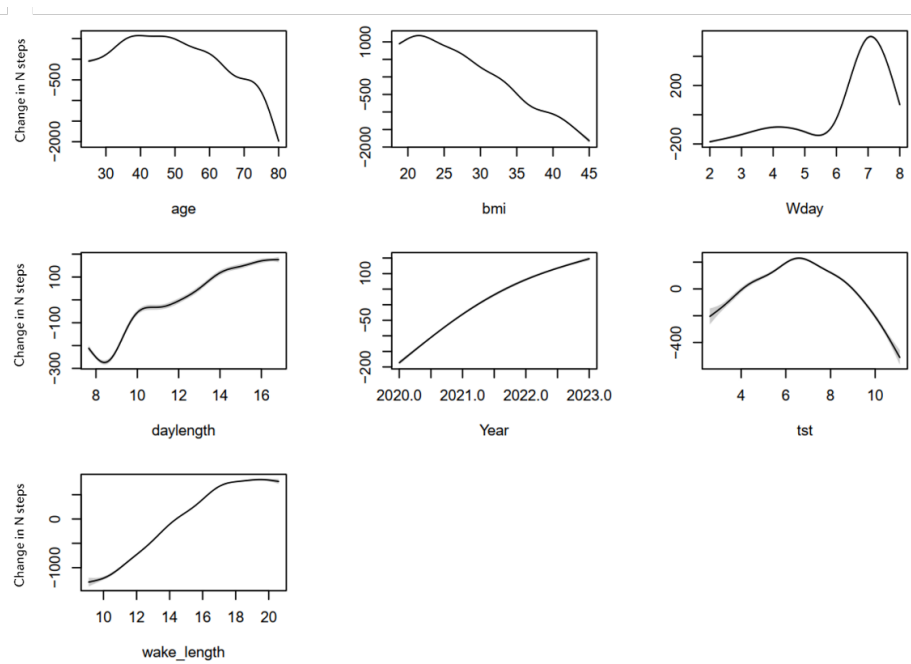


Figure S3 | Region-specific sensitivity analysis for step count as a function of demographic and time-based variables – Paris (France)

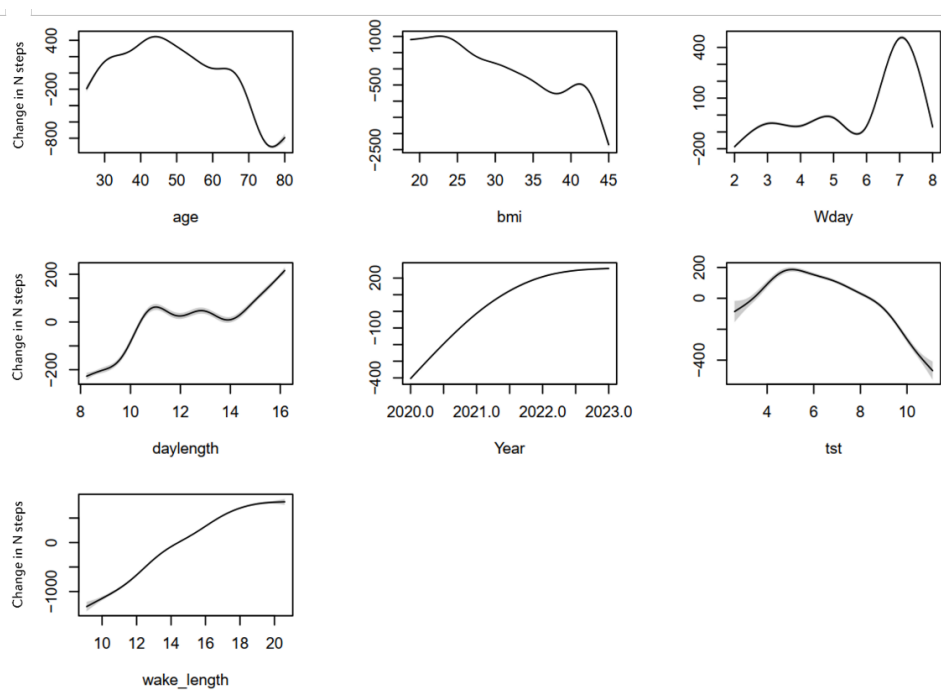


Figure S4 | Region-specific sensitivity analysis for step count as a function of demographic and time-based variables – New York (U.S)

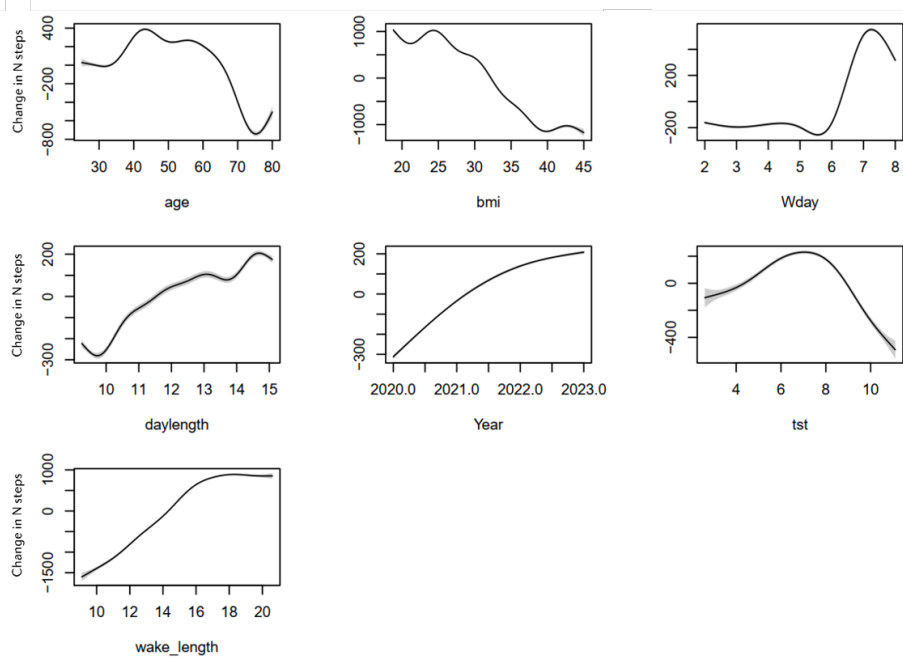


Figure S5 | Region-specific sensitivity analysis for step count as a function of demographic and time-based variables – London (U.K)

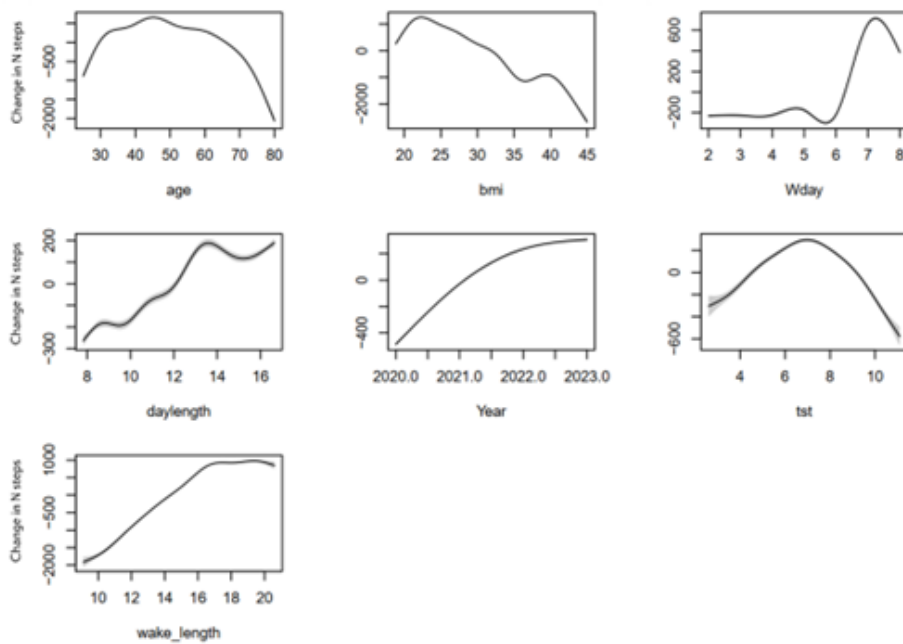
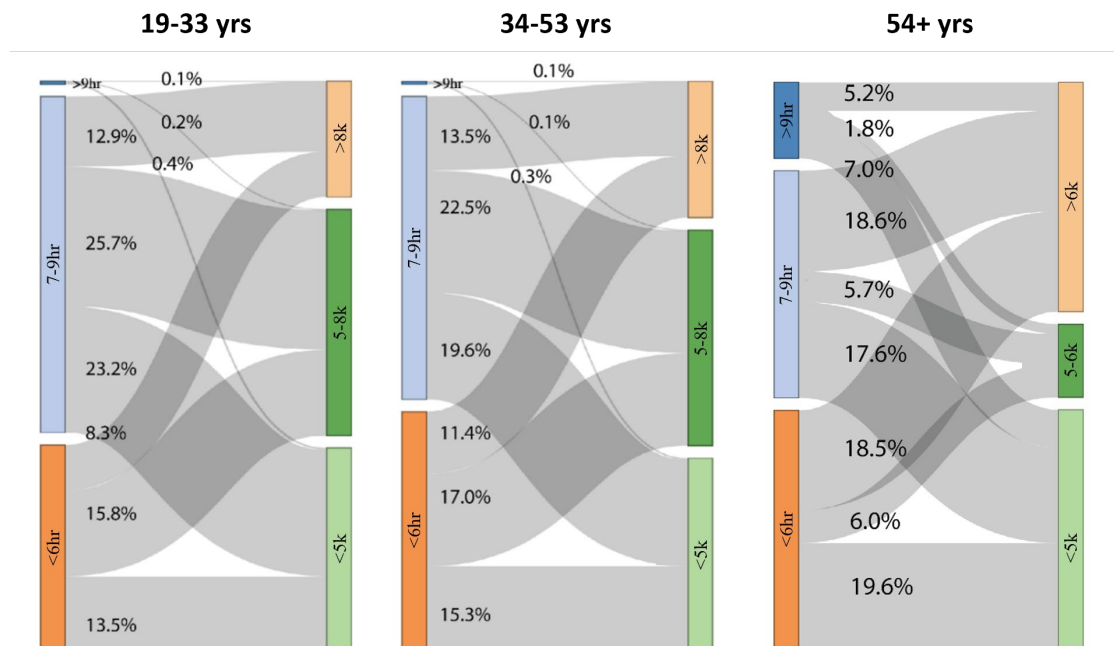


Figure S6 | Proportion of sample achieving specified sleep duration and step count thresholds, stratified by age group.



Note. Sleep and step count thresholds differ for 54+ year group in accordance with the National Sleep Foundation's recommendations and recent research indicating the probable health benefits of 6,000 steps per day for older adults.

Figure S7 | Sensitivity analysis for exposure-response relationships at different levels of obstructive sleep apnoea (OSA) severity: Mild (AHI: <15 events/hr), moderate (15-30), severe (>30).

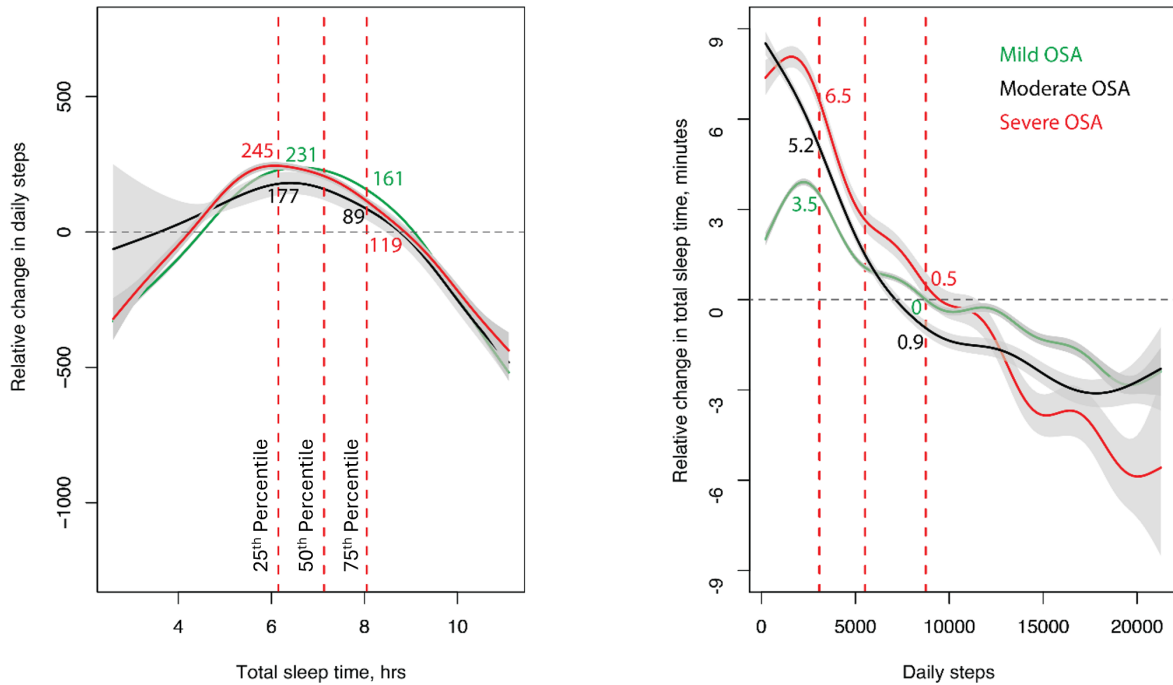


Figure S8 | ‘Sleep duration to next-day step count’ exposure-response curves split by country: Australia, Germany, USA, Japan. Red vertical lines indicate 25th, 50th, and 75th total sleep time percentiles, respectively.

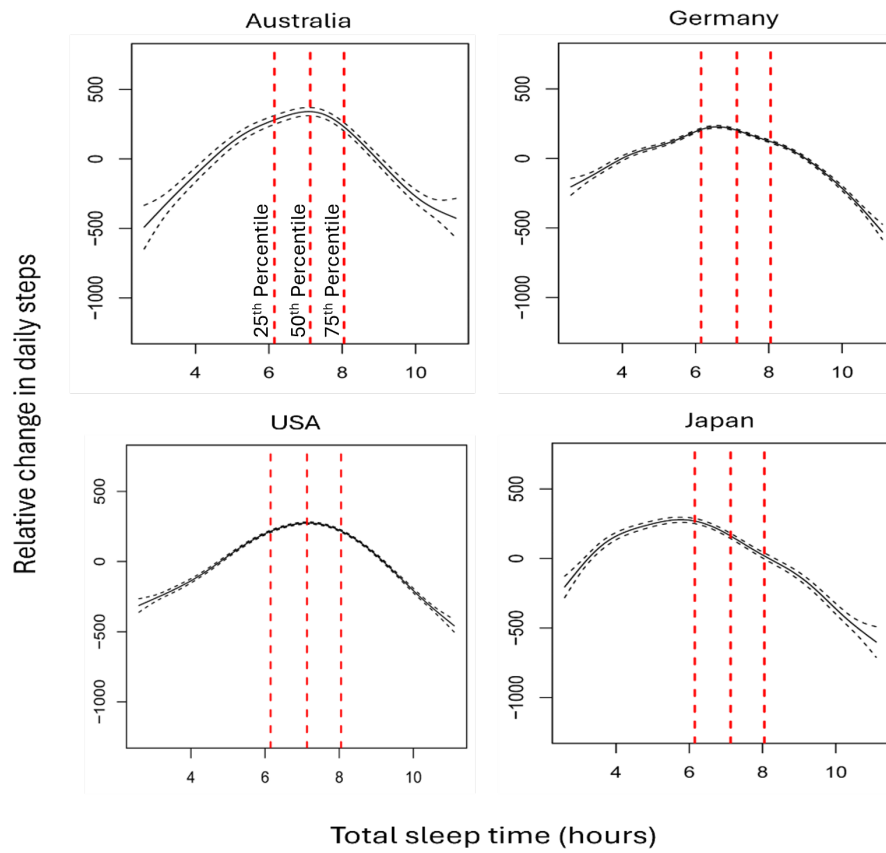


Figure S9 | Sensitivity analysis for all sleep-activity exposure-response relationships stratified by specified age group categories: young adults (19-33 years), middle-aged adults (34-53 years), and older adults (54+ years).

