

SUPPLEMENTARY DATA

Supplementary Table 1. Missing data

Sample size, N	Missing (N)
Age, years, mean (SD)	0
Gender, %, men / women	0
Country of birth, %, European / Non-European	0
Time of year in protocol, %, spring / summer / autumn / winter	0
Educational level, %, elementary not completed / elementary / lower vocational / lower secondary / intermediate secondary / intermediate vocational / higher secondary / college / university	0
Employment status, %, employed \geq 12 hours/week / other	0
Number of medications, mean (SD)	0
Polypharmacy (\geq 5 medications), %, yes / no	0
Diabetes duration, years, mean (SD)	8
Glucose lowering medication, %, insulin / oral only / none	0
BMI, kg/m ² , mean (SD)	12
Physical activity, MET minutes, median (IQR)	36
Sleep apnea risk, %, low / high	86
Use of alcohol, %, less than weekly / weekly	10
Sleep medication, %, less than weekly / weekly	6
Depressive symptoms, IDS score, median (IQR)	8
Diabetes distress, PAID-5 score, median (IQR)	8
Anxiety, BAI score, median (IQR)	7
<i>Sleep measures*</i>	
Sleep duration, minutes (hours:minutes), mean (SD)	26
Variability in sleep duration, minutes, median (IQR)	28
Mid-sleep time, time, mean (SD)	26
Variability in mid-sleep time, minutes, median (IQR)	28
Sleep efficiency, %, median (IQR)	26
Sleep quality, PSQI score, median (IQR)	6
Insomnia symptoms, ISI score, median (IQR)	7
<i>Glycemic control</i>	
HbA _{1c} , mmol/mol / %, mean (SD)	5

* Actigraphy data could be collected from 179 participants (7 days: N=143, 6 days N=25, 5 days N=5, 4 days N=1, 3 days N=1, 2 days N=2, 1 day N=2): 2 participants did not wear the actigraphy watch, 24 datasets were lost due to technical failure of the actigraphy device. Abbreviations: SD= standard deviation, BMI= body mass index, MET= Metabolic Equivalent of Task, IQR= inter quartile range, IDS= Inventory of Depressive Symptomatology, PAID= Problem Areas in Diabetes, BAI= Beck Anxiety Inventory, Abbreviations: CI= confidence interval, PSQI= Pittsburgh SQ Index, ISI= Insomnia Severity Index.

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Supplementary Table 2. Correlation matrix of sleep measures (correlation coefficient r, p-values (p<0.05 in bold))

Sleep measure	SD, minutes	V-SD, minutes	MST, time	V-MST, minutes	SE, %	SQ, PSQI score
V-SD, minutes	-0.032, p=0.335					
MST, time	0.108, p=0.077	0.082, p=0.139				
V-MST, minutes	-0.174, p=0.011	0.556, p<0.001	0.095, p=0.105			
SE, %	0.468, p<0.001	-0.236, p=0.001	-0.210, p=0.003	-0.190, p=0.006		
SQ, PSQI score	-0.004, p=0.479	0.197, p=0.005	0.282, p<0.001	0.058, p=0.222	-0.129, p=0.044	
INS, ISI score	0.019, p=0.402	0.154, p=0.021	0.143, p=0.029	0.019, p=0.403	-0.066, p=0.193	0.779, p<0.001

Significance one-tailed. Abbreviations: SD= total sleep duration, V-SD= variability in sleep duration, V-MST= variability in mid-sleep time, MST= mid-sleep time, SQ= subjective sleep quality, PSQI= Pittsburgh Sleep Quality Index, INS= subjective insomnia symptoms, ISI= Insomnia Severity Index.

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Supplementary Table 3. Factor analysis of the sleep measures (factor loadings >0.4 in bold)

Sleep measure	Factor loadings		
	1	2	3
SD, minutes	-0.003	-0.012	0.477
V-SD, minutes	0.130	0.990	-0.042
MST, time	0.280	0.039	-0.174
V-MST, minutes	0.021	0.555	-0.089
SE, %	-0.117	-0.181	0.976
SQ, PSQI score	0.778	0.054	0.036
INS, ISI score	0.997	0.067	-0.001

Abbreviations: SD= total sleep duration, V-SD= variability in sleep duration, V-MST= variability in mid-sleep time, MST= mid-sleep time, SQ= subjective sleep quality, PSQI= Pittsburgh Sleep Quality Index, INS= subjective insomnia symptoms, ISI= Insomnia Severity Index

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Supplementary Table 4. Associations of potential confounding or explanatory factors with the individual sleep measures and HbA_{1c} (regression coefficient *B*, p-values (p<0.10 in bold))

	SD, minutes	V-SD, minutes	MST, time	V-MST, minutes	SE, %	SQ, PSQI score	INS, ISI score	HbA _{1c} , mmol/mol
Age, years	0.100, p=0.856	-0.056, p<0.001	0.115, p=0.997	-0.300, p=0.008	7.782, p=0.472	-0.004, p=0.486	-0.025, p=0.042	-0.324, p=0.002
Gender (men reference)	1.016, p=0.917	0.047, p=0.870	733.309, p=0.194	-0.071, p=0.972	169.057, p=0.375	0.386, p<0.001	0.907, p<0.001	1.930, p=0.320
Country of birth (European reference)	-12.030, p=0.423	0.855, p=0.050	871.554, p=0.317	3.518, p=0.253	-386.701, p=0.187	0.301, p=0.048	0.912, p=0.008	7.207, p=0.011
Natural day length (shorter day length reference)	5.856, p=0.544	-0.588, p=0.037	-487.105, p=0.384	-2.882, p=0.145	189.517, p=0.315	-0.265, p=0.005	-0.717, p=0.001	-3.211, p=0.092
Educational level	1.007, p=0.610	0.014, p=0.811	-120.397, p=0.292	-0.086, p=0.832	-15.217, p=0.693	-0.062, p=0.001	-0.103, p=0.020	0.367, p=0.343
Employment status (employed ≥ 12 hours/week reference)	20.019, p=0.080	-0.640, p=0.055	1306.241, p=0.048	-5.865, p=0.012	18.460, p=0.934	0.181, p=0.116	0.157, p=0.548	-6.913, p=0.002
Number of medications	1.655, p=0.189	0.003, p=0.927	135.415, p=0.058	-0.079, p=0.7762	10.691, p=0.664	0.436, p<0.001	0.128, p<0.001	-0.148, p=0.560
Glucose lowering medication (oral only or none reference)	-4.334, p=0.651	0.520, p=0.063	579.170, p=0.297	3.359, p=0.087	-177.713, p=0.343	0.146, p=0.132	0.295, p=0.179	8.417, p<0.001
BMI, kg/m ²	0.337, p=0.683	0.005, p=0.846	-21.360, p=0.654	0.112, p=0.531	13.435, p=0.407	0.016, p=0.052	0.030, p=0.103	0.127, p=0.437
Physical activity, MET minutes	-0.262, p=0.148	0.002, p=0.729	-24.471, p=0.011	-0.008, p=0.831	3.772, p=0.280	-0.005, p=0.005	-0.008, p=0.048	0.011, p=0.754
Sleep apnea risk (low reference)	2.674, p=0.845	0.183, p=0.627	1156.724, p=0.127	0.883, p=0.751	150.459, p=0.526	0.390, p=0.003	0.758, p=0.014	1,409, p=0.608
Use of alcohol (less than weekly reference)	15.796, p=0.148	-0.125, p=0.729	-	-0.982, p=0.831	242.673, p=0.280	-0.213, p=0.005	-0.374, p=0.048	-2.286, p=0.754

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	p=0.105	p=0.664	116.565.160, p=0.837	p=0.628	p=0.205	p=0.030	p=0.097	p=0.249
Sleep medication (less than weekly reference)	16.365, p=0.223	0.688, p=0.079	2334.624, p=0.002	1.047, p=0.705	-300.929, p=0.251	0.736, p<0.001	0.966, p=0.001	0.930, p=0.735
Depressive symptoms, IDS score	1.034, p=0.765	0.193, p=0.055	294.904, p=0.136	0.779, p=0.275	-6.296, p=0.926	0.299, p<0.001	0.745, p<0.001	0.408, p=0.559
Diabetes distress, PAID-5 score	-0.424, p=0.908	0.309, p=0.004	306.850, p=0.145	1.414, p=0.062	53.662, p=0.455	0.141, p<0.001	0.442, p<0.001	2.287, p=0.002
Anxiety, BAI score	0.838, p=0.798	0.145, p=0.128	190.414, p=0.310	0.535, p=0.426	14.811, p=0.816	0.245, p<0.001	0.625, p<0.001	0.238, p=0.720

Abbreviations: SD= total sleep duration, V-SD= variability in sleep duration, V-MST= variability in mid-sleep time, MST= mid-sleep time, SQ= subjective sleep quality, PSQI= Pittsburgh Sleep Quality Index, INS= subjective insomnia symptoms, ISI= Insomnia Severity Index, BMI= body mass index, MET= Metabolic Equivalent of Task, IQR= inter quartile range, IDS= Inventory of Depressive Symptomatology, PAID= Problem Areas in Diabetes, BAI= Beck Anxiety Inventory

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Supplemental Table 5. Univariate associations between individual sleep measures and HbA_{1c} (parameters of unadjusted and adjusted regression models; p<0.05 in bold)

		Age	Gender	Sleep apnea risk	Depressive symptoms	Number of medications
Underlying sleep variable	Sleep measure	p-value interaction effect	p-value interaction effect	p-value interaction effect	p-value interaction effect	p-value interaction effect
Sleep quantity	Sleep duration, minutes	0.228	0.073	0.640	0.820	0.259
	Sleep efficiency, %	0.408	0.309	0.969	0.526	0.709
Sleep variability	Variability in sleep duration, minutes	0.146	0.155	0.217	0.618	0.070
	Variability in mid-sleep time, minutes	0.131	0.135	0.028	0.593	0.479
Mid-sleep time	Mid-sleep time, time	0.994	0.317	0.031	0.142	0.843
Sleep complaints	Sleep quality, PSQI score	0.335	0.891	0.658	0.533	0.716
	Insomnia symptoms, ISI score	0.151	0.964	0.531	0.799	0.496

Abbreviations: CI= confidence interval, PSQI= Pittsburgh Sleep Quality Index, ISI= Insomnia Severity Index

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Supplementary Table 6. Subgroup analyses based on the risk for sleep apnea for the association between (variability in) mid-sleep time and HbA_{1c} (p<0.05 in bold)

Risk for sleep apnea	N	Variability in mid-sleep time				Mid-sleep time			
		beta	95% CI	p-value	R ²	beta	95% CI	P-value	R ²
Low	31	-0.126	-0.411 to 0.158	0.371	2.8%	0.516	(0.159 to 0.873)	0.006	23.1%
High	70	0.308	0.075 to 0.541	0.010	9.3%	-0.043	(-0.290 to 0.203)	0.726	0.2%