

Supplemental Material

Table S1. The observation number of imputed covariates.

Total number after imputing missing covariates	n=789
	Number of imputed observations for each variable
Age, years	n=0
Women, n (%)	n=0
Education, n (%)	n=0
BMI, kg/m ²	n=6
Waist circumference, cm	n=10
Current smokers, n (%)	n=6
Habitual drinkers, n (%)	n=10
Measures of glucose metabolism	
Fasting glucose, mmol/l	n=0
HOMA-IR,	n=0
HbA1c, mmol/mol	n=0
History of diabetes	n=18
Statin	n=54
Antihyperglycemic medication	n=55
Sleep disordered breathing measures	
REI4P (events/hour)	n=0
REI3P (events/hour)	n=0
Sat<90, %	n=0
MinSaO ₂ , %	n=0
Sleep duration and continuity measures	
Sleep duration, hours	n=0
Sleep maintenance efficiency, %	n=0
Sleep duration variability, minutes	n=0
Fragmented sleep indices, %	n=0

BMI=body mass index; HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation; MinSaO₂=minimum oxygen saturation.

Table S2. Characteristics at the third clinical visit (2012-2016) of JHS participants who were included in the current study and those who were not included.

Characteristics at the third clinical visit	Means \pm SD or counts (percentages)		P value
	Sleep Exam (n=781)	JHS Exam 3 participants (n=3,038)	
Age, years, mean \pm SD	59.84 (10.31)	63.13 (12.43)	<0.001
Women, n (%)	513 (66%)	1924 (63%)	0.222
Education, n (%)			<0.001
< High school	76 (10%)	584 (19%)	
High school or GED	130 (17%)	539 (18%)	
Some college/training, or college degree	575 (74%)	1910 (63%)	
BMI, kg/m ² , mean \pm SD	31.94 (6.58)	32.18 (7.40)	0.598
Waist circumference, cm, mean \pm SD	102.48 (14.69)	103.55 (16.34)	0.185
Current smokers, n (%)	79 (10%)	354 (12%)	0.228
Habitual drinkers, n (%)	367 (47%)	1310 (43%)	0.057
Fasting glucose, mmol/l, median (IQR)	5.39 \pm 0.89	5.39 \pm 1.06	0.132
HOMA-IR, median (IQR)	2.48 \pm 2.16	2.44 \pm 2.20	0.314
HbA1c, mmol/mol, median (IQR)	40.99 \pm 6.56	40.99 \pm 8.74	0.001
Diabetes, n (%)	189 (24%)	1006 (33%)	<0.001
Statin use, n (%)	264 (36%)	1193 (41%)	0.006
Insulin or hypoglycemic medication use, n (%)	145 (20%)	777 (27%)	<0.001

Data are expressed as mean (standard deviation) or percentage. P values were calculated by Kruskal–Wallis test or chi-square test. GED= general educational development; BMI=body mass index; HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c.

Table S3. Associations between sleep disturbances and measures of glucose metabolism, JHS Sleep Study, 2012-2016.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Adjusted for body mass index	Adjusted for waist circumference	Adjusted for body mass index	Adjusted for waist circumference	Adjusted for body mass index	Adjusted for waist circumference
Sleep disordered breathing measures						
REI4P (events/hour)	0.13 (0.02,0.24)*	0.12 (0.00,0.23)*	1.11 (0.43,1.78)†	1.07 (0.41,1.74)†	1.09 (1.03,1.16)†	1.09 (1.03,1.15) †
REI3P (events/hour)	0.13 (0.02,0.25)*	0.12 (0.00,0.23)*	1.11 (0.42,1.79)†	1.07 (0.39,1.74)†	1.11 (1.05,1.18)‡	1.10 (1.04,1.17) ‡
Sat<90, %	0.07 (-0.03,0.18)	0.06 (-0.04,0.17)	0.28 (-0.36,0.93)	0.27 (-0.37,0.91)	1.05 (0.99,1.11)	1.04 (0.98,1.10)
MinSaO2, %	-0.04 (-0.16,0.07)	-0.03 (-0.14,0.08)	-0.45 (-1.15,0.25)	-0.43 (-1.11,0.25)	0.90 (0.85,0.96)†	0.90 (0.85,0.96) ‡
Sleep duration and continuity measures						
Sleep duration, hours	0.08 (-0.03,0.19)	0.09 (-0.02,0.20)	-0.13 (-0.80,0.53)	-0.08 (-0.75,0.59)	1.02 (0.97,1.08)	1.02 (0.97,1.08)
Sleep maintenance efficiency, %	-0.14 (-0.25,-0.02)*	-0.14 (-0.25,-0.02)*	-0.67 (-1.37,0.04)	-0.68 (-1.38,0.03)	0.94 (0.89,1.00)*	0.94 (0.88,0.99)*
Sleep duration variability, mins	0.21 (0.10,0.31)‡	0.21 (0.11,0.32)‡	0.72 (0.08,1.37)*	0.73 (0.09,1.37)	0.99 (0.93,1.04)	1.00 (0.94,1.05)
Fragmented sleep indices, %	0.16 (0.05,0.27)†	0.15 (0.04,0.26)†	0.77 (0.10,1.43)*	0.75 (0.09,1.41)	1.07 (1.01,1.13)*	1.06 (1.01,1.12)*

Sleep disordered breathing measures were obtained through home sleep apnea testing, and sleep duration and continuity measures were obtained using 7-day actigraphy. β = standardized regression coefficient. Adjusted β s (95% CIs) associated with a one-SD increase in each sleep measure are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. The one-SD increments for each sleep measure are as follows: REI4P, 13.68 events/hour; REI3P, 15.89 events/hour; Sat<90, 8.03%; MinSaO2, 6.37%; sleep duration, 1.13 hours; sleep efficiency, 4.83%; sleep duration variability, 33.54 mins; fragmented sleep indices, 8.75%. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI (or waist circumference), antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. * P <0.05; † P <0.01; ‡ P <0.001. HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = hemoglobin A1c; REI4P = apnea-hypopnea index at 4% oxygen desaturation; REI3P = apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % = sleep time with <90% oxyhemoglobin saturation; MinSaO2 = minimum oxygen saturation.

Table S4. Differences in measures of glucose metabolism across REI4P subgroups: a multiple imputation sample.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Adjusted for body mass index	Adjusted for waist circumference	Adjusted for body mass index	Adjusted for waist circumference	Adjusted for body mass index	Adjusted for waist circumference
Adjusted model REI4P < 5	Reference	Reference	Reference	Reference	Reference	Reference
5 ≤ REI4P < 15	0.03 (-0.22,0.28)	0.02 (-0.23,0.26)	-0.09 (-1.61,1.43)	-0.10 (-1.58,1.37)	1.11 (0.99,1.26)	1.15 (1.01,1.29)*
15 ≤ REI4P < 30	0.03 (-0.30,0.36)	0.00 (-0.32,0.33)	0.20 (-1.77,2.17)	0.11 (-1.83,2.06)	1.31 (1.11,1.55)†	1.32 (1.12,1.56)‡
REI4P ≥ 30	0.49 (0.08,0.90)*	0.47 (0.06,0.87)*	4.44 (2.02,6.85)‡	4.44 (2.04,6.83)‡	1.30 (1.05,1.62)*	1.27 (1.04,1.59)*

Differences in adjusted β s (95% CIs) associated with $5 \leq \text{REI4P} < 15$, $15 \leq \text{REI4P} < 30$, or $\text{REI4P} \geq 30$ (vs. $\text{REI4P} < 5$) are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. Of the 789 participants in analyses for fasting glucose, 340 had $\text{REI4P} < 5$, 263 had $\text{REI4P} \geq 5$ and < 15 , 116 had $\text{REI4P} \geq 15$ and < 30 , and 70 had $\text{REI4P} \geq 30$. Of the 772 participants in analyses for HbA1c, 330 had $\text{REI4P} < 5$; 257 had $\text{REI4P} \geq 5$ and < 15 , 115 had $\text{REI4P} \geq 15$ and < 30 , and 70 had $\text{REI4P} \geq 30$. Of the 576 participants in analyses for HOMA-IR, 266 had $\text{REI4P} < 5$; 187 had $\text{REI4P} \geq 5$ and < 15 , 79 had $\text{REI4P} \geq 15$ and < 30 , and 44 had $\text{REI4P} \geq 30$. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI (or waist circumference), antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. * $P < 0.05$; † $P < 0.01$; ‡ $P < 0.001$. HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = hemoglobin A1c; REI4P = apnea-hypopnea index at 4% oxygen desaturation.

Table S5. Associations between sleep disturbances and measures of glucose metabolism, JHS Sleep Study, 2012-2016.

	Fasting glucose, mmol/l (n=789)			HbA1c, mmol/mol (n=772)			HOMA-IR (n=576)		
	Adjusted	p values	q values	Adjusted	p values	q values	Adjusted	p values	q values
Sleep disordered breathing measures									
REI4P (events/hour)	0.13 (0.02,0.24)	0.03	0.05	1.11 (0.43,1.78)	0.001	0.008	1.09 (1.03,1.16)	0.003	0.01
REI3P (events/hour)	0.13 (0.02,0.25)	0.03	0.05	1.11 (0.42,1.79)	0.002	0.008	1.11 (1.05,1.18)	0.001	0.01
Sat<90, %	0.07 (-0.03,0.18)	0.18	0.26	0.28 (-0.36,0.93)	0.38	0.48	1.05 (0.99,1.11)	0.11	0.17
MinSaO2, %	-0.04 (-0.16,0.07)	0.48	0.57	-0.45 (-1.15,0.25)	0.20	0.27	0.90 (0.85,0.96)	0.001	0.01
Sleep duration and continuity measures									
Sleep duration, hours	0.08 (-0.03,0.19)	0.16	0.23	-0.13 (-0.80,0.53)	0.69	0.69	1.02 (0.96,1.08)	0.52	0.57
Sleep maintenance efficiency, %	-0.14 (-0.25,-0.02)	0.02	0.05	-0.67 (-1.37,0.04)	0.06	0.10	0.94 (0.89,1.00)	0.045	0.08
Sleep duration variability, mins	0.21 (0.10,0.31)	0.0001	0.002	0.72 (0.08,1.37)	0.03	0.05	0.99 (0.93,1.04)	0.61	0.70
Fragmented sleep indices, %	0.16 (0.05,0.27)	0.006	0.02	0.77 (0.10,1.43)	0.02	0.05	1.07 (1.01,1.13)	0.02	0.05

In order to minimize low false positive rates, we calculated false discovery rates and analogous q-values. β = standardized regression coefficient. Adjusted β s (95% CIs) associated with a one-SD increase in each sleep measure are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. The one-SD increments for each sleep measure are as follows: REI4P, 13.68 events/hour; REI3P, 15.89 events/hour; Sat<90, 8.03%; MinSaO2, 6.37%; sleep duration, 1.13 hours; sleep efficiency, 4.83%; sleep duration variability, 33.54 mins; fragmented sleep indices, 8.75%. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-

IR. Sleep duration was not used in modeling of sleep duration as an exposure. HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = hemoglobin A1c; REI4P = apnea-hypopnea index at 4% oxygen desaturation; REI3P = apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % = sleep time with <90% oxyhemoglobin saturation; MinSaO2 = minimum oxygen saturation.

Table S6. Interaction by sex for associations between sleep disturbances and measures of glucose metabolism using multiplicative interaction terms.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values
Sleep disordered breathing measures						
REI4P (events/hour)	0.25 (0.04,0.46)	0.0224	1.77 (0.50,3.04)	0.0063	1.03 (0.93,1.15)	0.5574
REI3P (events/hour)	0.23 (0.01,0.44)	0.0395	1.84 (0.56,3.12)	0.0050	1.04 (0.93,1.16)	0.4996
Sat<90, %	0.05 (-0.16,0.27)	0.6283	0.25 (-1.04,1.55)	0.6999	1.03 (0.91,1.16)	0.6651
MinSaO2, %	-0.26 (-0.48,-0.05)	0.0170	-1.26 (-2.56,0.03)	0.0555	0.95 (0.85,1.06)	0.3493
Sleep duration and continuity measures						
Sleep duration, hours	-0.01 (-0.24,0.21)	0.8973	-0.06 (-1.42,1.30)	0.9258	0.98 (0.87,1.09)	0.6669
Sleep maintenance efficiency, %	-0.19 (-0.40,0.03)	0.0865	-0.57 (-1.90,0.76)	0.4027	1.01 (0.91,1.13)	0.8183
Sleep duration variability, minutes	-0.10 (-0.33,0.12)	0.3670	-0.12 (-1.49,1.25)	0.8647	0.89 (0.79,0.99)	0.0395
Fragmented sleep indices, %	0.06 (-0.15,0.28)	0.5587	0.11 (-1.18,1.40)	0.8704	0.99 (0.89,1.11)	0.9231

Interactions by sex for associations between sleep characteristic measures and measures of glucose metabolism were evaluated with the inclusion of multiplicative interaction terms (i.e., each sleep measure × sex). Regression coefficient and p values for each multiplicative interaction term are shown. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. Of the 789 participants included in analyses for fasting glucose, 271 were men and 518 were women. Of the 772 participants included in analyses for HbA1c, 265 were men and 507 were women. Of the 576 participants included in analyses for HOMA-IR, 203 were men and 373 were women. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation; MinSaO2=minimum oxygen saturation.

Table S7. Associations between sleep disturbances and measures of glucose metabolism by sex in a multiple imputation sample.						
	Fasting glucose, mmol/l		HbA1c, mmol/mol		Log-transformed HOMA-IR	
	Women (n= 518)	Men (n= 271)	Women (n= 507)	Men (n= 265)	Women (n=373)	Men (n=203)
Sleep disordered breathing measures						
REI4P (events/hour)	-0.01 (-0.16,0.15)	0.27 (0.10,0.44)†	0.14 (-0.73,1.01)	2.16 (1.05,3.28)‡	1.10 (1.01,1.20)*	1.06 (0.98,1.15)
REI3P (events/hour)	0.01 (-0.14,0.16)	0.27 (0.09,0.45)†	0.15 (-0.69,0.99)	2.30 (1.11,3.49)‡	1.12 (1.03,1.21)†	1.08 (0.99,1.18)
Sat<90, %	0.06 (-0.07,0.19)	0.09 (-0.11,0.28)	0.25 (-0.48,0.98)	0.33 (-0.93,1.60)	1.05 (0.97,1.13)	1.02 (0.92,1.14)
MinSaO2, %	0.08 (-0.07,0.23)	-0.20 (-0.40,-0.00)*	0.17 (-0.64,0.98)	-1.21 (-2.53,0.11)	0.90 (0.83,0.97)†	0.92 (0.83,1.01)
Sleep duration and continuity measures						
Sleep duration, hours	0.05(-0.07,0.16)	0.11(-0.06,0.29)	-0.24(-0.90,0.42)	-0.06(-1.22,1.10)	1.02(0.96,1.09)	1.00(0.93,1.08)
Sleep maintenance efficiency, %	-0.06 (-0.20,0.08)	-0.26 (-0.46,-0.07)†	-0.41 (-1.20,0.38)	-0.98 (-2.35,0.38)	0.93 (0.86,1.01)	0.96 (0.88,1.05)
Sleep duration variability, minutes	0.27 (0.14,0.39)‡	0.08 (-0.12,0.29)	0.87 (0.17,1.57)*	0.39 (-0.98,1.77)	1.03 (0.96,1.10)	0.91 (0.84,1.00)
Fragmented sleep indices, %	0.12 (-0.02,0.26)	0.20 (0.03,0.38)*	0.64 (-0.16,1.44)	0.82 (-0.34,1.99)	1.08 (1.00,1.17)	1.06 (0.98,1.14)

Sleep disordered breathing measures were obtained through home sleep apnea testing, and sleep duration and continuity measures were obtained using 7-day actigraphy. β = standardized regression coefficient. Adjusted β s (95% CIs) associated with a one-SD increase in each sleep measure are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. The one-SD increments for each sleep measure in women are as follows: REI4P, 11.87 events/hour; REI3P, 14.30 events/hour; Sat<90, 7.77 %; MinSaO2, 6.14 %; sleep duration, 1.09 hours; sleep efficiency, 4.68 %; sleep duration variability, 34.23 minutes; fragmented sleep indices, 7.77%. The one-SD increments for each sleep measure in men are as follows: REI4P, 16.01 events/hour; REI3P, 17.81 events/hour; Sat<90, 8.46 %; MinSaO2, 6.72 %; sleep duration, 1.18 hours; sleep maintenance efficiency, 6.38%; sleep duration variability, 32.11 minutes; fragmented sleep indices, 9.93 %. Each sleep measure was analyzed in a separate model. Models include adjustment for age, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P=

apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation; MinSaO2=minimum oxygen saturation.

Table S8. Interaction by body mass index (≥ 30 versus < 30 kg/m²) for associations between sleep disturbances and measures of glucose metabolism using multiplicative interaction terms.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values
Sleep disordered breathing measures						
REI4P (events/hour)	-0.03 (-0.28,0.22)	0.82	0.34 (-1.11,1.78)	0.65	0.93 (0.82,1.05)	0.24
REI3P (events/hour)	-0.03 (-0.28,0.22)	0.81	0.44 (-1.02,1.89)	0.56	0.90 (0.80,1.03)	0.12
Sat<90, %	-0.20 (-0.44,0.03)	0.09	-1.56 (-2.97,-0.16)	0.03	0.92 (0.78,1.07)	0.27
MinSaO ₂ , %	0.12 (-0.12,0.36)	0.31	-0.05 (-1.47,1.38)	0.95	1.06 (0.94,1.20)	0.33
Sleep duration and continuity measures						
Sleep duration, hours	0.16 (-0.06,0.37)	0.15	0.15 (-1.15,1.44)	0.82	0.98 (0.88,1.09)	0.71
Sleep maintenance efficiency, %	0.01 (-0.20,0.23)	0.89	-0.64 (-1.96,0.69)	0.35	0.95 (0.85,1.06)	0.39
Sleep duration variability, minutes	0.04 (-0.17,0.25)	0.72	0.28 (-0.98,1.55)	0.66	0.96 (0.86,1.07)	0.46
Fragmented sleep indices, %	0.03 (-0.19,0.24)	0.82	0.44 (-0.87,1.75)	0.51	1.08 (0.97,1.21)	0.15

Interactions by categorical BMI (≥ 30 versus < 30 kg/m²) for associations between sleep characteristic measures and measures of glucose metabolism were evaluated with the inclusion of multiplicative interaction terms (i.e., each sleep measure \times categorical BMI). Regression coefficients and p values for each multiplicative interaction term are shown. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, categorical BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. Of the 789 participants included in analyses for fasting glucose, 352 were non-obese and 437 were obese. Of the 772 participants included in analyses for HbA1c, 347 were non-obese and 425 were obese. Of the 576 participants included in analyses for HOMA-IR, 278 were non-obese, and 298 were obese. HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = hemoglobin A1c; REI4P = apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % = sleep time with <90% oxyhemoglobin saturation; MinSaO₂ = minimum oxygen saturation.

Table S9. Interaction by smoking status for associations between sleep disturbances and measures of glucose metabolism using multiplicative interaction terms.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values
Sleep disordered breathing measures						
REI4P (events/hour)	-0.03 (-0.34,0.28)	0.86	0.96 (-0.87,2.79)	0.30	1.05 (0.91,1.22)	0.47
REI3P (events/hour)	0.02 (-0.29,0.33)	0.89	1.33 (-0.50,3.15)	0.15	1.05 (0.91,1.22)	0.50
Sat<90, %	0.01 (-0.28,0.29)	0.96	0.41 (-1.30,2.12)	0.64	1.05 (0.92,1.20)	0.44
MinSaO2, %	-0.01 (-0.35,0.33)	0.96	-0.57 (-2.60,1.46)	0.58	0.98 (0.84,1.15)	0.80
Sleep duration and continuity measures						
Sleep duration, hours	-0.01 (-0.35,0.32)	0.94	0.89 (-1.13,2.91)	0.39	0.96 (0.83,1.11)	0.55
Sleep maintenance efficiency, %	-0.05 (-0.35,0.26)	0.76	-0.02 (-1.83,1.80)	0.98	0.96 (0.83,1.11)	0.57
Sleep duration variability, minutes	-0.10 (-0.41,0.21)	0.53	0.24 (-1.63,2.11)	0.80	1.13 (0.97,1.31)	0.12
Fragmented sleep indices, %	0.00 (-0.33,0.34)	0.98	0.06 (-1.93,2.04)	0.95	0.96 (0.82,1.13)	0.61

Interactions by smoking status for the associations between sleep characteristic measures and measures of glucose metabolism were evaluated with the inclusion of multiplicative interaction terms (i.e., each sleep measure × smoking status). Non-current smokers (ex- or never-smokers) were treated as the reference group. Regression coefficients and p values for each multiplicative interaction term are shown. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. Of the 789 participants included in analyses for fasting glucose, 65 were current smokers and 724 were

non-current smokers. Of the 772 participants included in analyses for HbA1c, 65 were current smokers and 707 were non-current smokers. Of the 576 participants included in analyses for HOMA-IR, 56 were current smokers and 520 were non-current smokers. HOMA-IR = homeostatic model assessment of insulin resistance; HbA1c = hemoglobin A1c; REI4P = apnea-hypopnea index at 4% oxygen desaturation; REI3P = apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % = sleep time with <90% oxyhemoglobin saturation; MinSaO2 = minimum oxygen saturation.

Table S10. Interaction by prevalent diabetes for associations between sleep disturbances and measures of glucose metabolism using multiplicative interaction terms.

	Fasting glucose, mmol/l (n= 773)		HbA1c, mmol/mol (n= 756)	
	Regression coefficient for interaction term	P values	Regression coefficient for interaction term	P values
Sleep disordered breathing measures				
REI4P (events/hour)	0.24 (0.00,0.48)	0.0471	2.38 (0.97,3.78)	0.0009
REI3P (events/hour)	0.19 (-0.04,0.43)	0.1102	1.88 (0.48,3.28)	0.0085
Sat<90, %	0.14 (-0.08,0.36)	0.2038	1.25 (-0.06,2.55)	0.0612
MinSaO2, %	0.01 (-0.22,0.24)	0.9375	-0.40 (-1.76,0.96)	0.5617
Sleep duration and continuity measures				
Sleep duration, hours	0.17 (-0.06,0.41)	0.1513	0.03 (-1.39,1.45)	0.9678
Sleep maintenance efficiency, %	-0.17 (-0.40,0.06)	0.1459	-1.25 (-2.67,0.18)	0.0860
Sleep duration variability, minutes	0.83 (0.60,1.06)	<0.001	3.50 (2.10,4.89)	<0.001
Fragmented sleep indices, %	0.27 (0.03,0.50)	0.0255	1.48 (0.05,2.90)	0.0420

We did not impute missing data for a variable “history of diabetes” in this stratified analysis by a history of diabetes. Therefore, the sample size was reduced. Interactions by prevalent diabetes for associations between sleep characteristic measures and measures of glucose metabolism were evaluated with the inclusion of multiplicative interaction terms (i.e., each sleep measure × prevalent diabetes). Regression coefficient and p values for each multiplicative interaction term are shown. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Sleep duration was not used in modeling of sleep duration as an exposure. Of the 789 participants included in analyses for fasting glucose, 212 were participants with diabetes and 561 were participants without diabetes. Of the 772 participants included in analyses for HbA1c, 207 were participants with diabetes and 549 were participants without diabetes. HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation; MinSaO2=minimum oxygen saturation.

Table S11. Associations between sleep disturbances and measures of glucose metabolism by prevalent diabetes in a multiple imputation sample.

	Fasting glucose, mmol/l		HbA1c, mmol/mol	
	Non-diabetes (n= 561)	Diabetes (n= 212)	Non-diabetes (n=549)	Diabetes (n= 207)
Sleep disordered breathing measures				
REI4P (events/hour)	0.00(-0.00,0.01)	0.03(-0.00,0.06)	0.03(-0.00,0.06)	0.22(0.06,0.39)†
REI3P (events/hour)	0.00(0.00,0.01)*	0.02(-0.00,0.05)	0.03(0.00,0.06)*	0.16(0.02,0.31)*
Sat<90, %	0.00(-0.00,0.01)	0.03(-0.01,0.07)	-0.02(-0.07,0.03)	0.17(-0.06,0.40)
MinSaO2, %	-0.01(-0.01,0.00)	-0.01(-0.07,0.05)	-0.05(-0.12,0.02)	-0.10(-0.44,0.25)
Sleep duration and continuity measures				
Sleep duration, hours	-0.01(-0.05,0.04)	0.23(-0.10,0.57)	-0.35(-0.71,0.01)	0.39(-1.52,2.30)
Sleep maintenance efficiency, %	-0.01(-0.02,-0.00)*	-0.07(-0.15,0.01)	-0.04(-0.12,0.05)	-0.32(-0.80,0.16)
Sleep duration variability, minutes	-0.00(-0.00,0.00)	0.02(0.01,0.03)‡	-0.00(-0.02,0.01)	0.09(0.02,0.15)†
Fragmented sleep indices, %	0.01(0.00,0.01)*	0.05(0.01,0.09)*	0.04(-0.01,0.08)	0.23(-0.03,0.48)

We did not impute missing data for a variable “history of diabetes” in this stratified analysis by a history of diabetes. Therefore, the sample size was reduced. β = standardized regression coefficient. Adjusted β s (95% CIs) associated with a one-SD increase in each sleep measure are shown. The one-SD increments for each sleep measure in the diabetes group are as follows: REI4P, 13.82 events/hour; REI3P, 16.36 events/hour; Sat<90, 9.55%; MinSaO2, 6.91 %; sleep duration, 1.19 hours; sleep efficiency, 5.04 %; sleep duration variability, 34.40 minutes; fragmented sleep indices, 8.96 %. The one-SD increments for each sleep measure in the non-diabetes group are as follows: REI4P, 13.69 events/hour; REI3P, 15.74 events/hour; Sat<90, 7.55 %; MinSaO2, 6.19 %; sleep duration, 1.07 hours; sleep efficiency, 4.78 %; sleep duration variability, 33.37 minutes; fragmented sleep indices, 8.65 %. Each sleep characteristic was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Sleep duration was not used in modeling of sleep duration as an exposure. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at

4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation;
MinSaO2=minimum oxygen saturation.

Table S12. Differences in measures of glucose metabolism across REI3P subgroups: a multiple imputation sample.

	Fasting glucose, mmol/l (n=789)	HbA1c, mmol/mol (n=772)	HOMA-IR (n=576)
Unadjusted model			
REI3P < 5	Reference	Reference	Reference
5 ≤ REI3P < 15	-0.18 (-0.49,0.14)	-1.69 (-3.67,0.29)	1.24 (1.08,1.43)†
15 ≤ REI3P < 30	0.34 (-0.02,0.69)	0.70 (-1.54,2.95)	1.68 (1.42,1.99)‡
REI3P ≥ 30	0.39 (-0.00,0.79)	3.04 (0.57,5.50)*	1.62 (1.35,1.96)‡
Adjusted model			
REI3P < 5	Reference	Reference	Reference
5 ≤ REI3P < 15	-0.15 (-0.44,0.13)	-1.20 (-2.93,0.53)	1.17 (1.02,1.35)*
15 ≤ REI3P < 30	0.08 (-0.25,0.42)	-0.71 (-2.75,1.33)	1.47 (1.23,1.73)‡
REI3P ≥ 30	0.13 (-0.24,0.51)	1.69 (-0.56,3.94)	1.39 (1.15,1.69)‡

Differences in adjusted β s (95% CIs) associated with $5 \leq \text{REI3P} < 15$, $15 \leq \text{REI3P} < 30$, or $\text{REI3P} \geq 30$ (vs. $\text{REI3P} < 5$) are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiply the expected value of HOMA-IR by $\exp(\beta)$. Of the 789 participants included in analyses for fasting glucose, 192 had $\text{REI3P} < 5$, 301 had $\text{REI3P} \geq 5$ and < 15 , 173 had $\text{REI3P} \geq 15$ and < 30 , and 123 had $\text{REI3P} \geq 30$. Of the 772 participants included in analyses for HbA1c, 185 had $\text{REI3P} < 5$, 295 had $\text{REI3P} \geq 5$ and < 15 , 170 had $\text{REI3P} \geq 15$ and < 30 , and 122 had $\text{REI3P} \geq 30$. Of the 576 participants included in analyses for HOMA-IR, 143 had $\text{REI3P} < 5$, 237 had $\text{REI3P} \geq 5$ and < 15 , 114 had $\text{REI3P} \geq 15$ and < 30 , and 82 had $\text{REI3P} \geq 30$. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. * $P < 0.05$; † $P < 0.01$; ‡ $P < 0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index 4% oxygen desaturation; REI3P= apnea-hypopnea index 3% oxygen desaturation.

Table S13. Differences in measures of glucose metabolism across REI4P subgroups by sex: a multiple imputation sample.

	Fasting glucose, mmol/l (n=789)		HbA1c, mmol/mol (n=772)		HOMA-IR (n=576)	
	Women (n= 518)	Men (n= 271)	Women (n= 507)	Men (n= 265)	Women (n= 373)	Men (n=203)
Unadjusted model						
REI4P < 5	Reference	Reference	Reference	Reference	Reference	Reference
5 ≤ REI4P < 15	0.23 (-0.10,0.57)	0.19 (-0.33,0.71)	1.48 (-0.51,3.47)	0.19 (-3.29,3.68)	1.23 (1.05,1.45)*	1.24 (1.00,1.54)*
15 ≤ REI4P < 30	0.09 (-0.35,0.54)	0.65 (0.01,1.30)*	1.04 (-1.61,3.69)	3.57 (-0.79,7.92)	1.59 (1.28,1.98)‡	1.61 (1.21,2.14)†
REI4P ≥ 30	0.36 (-0.29,1.02)	1.29 (0.62,1.95)‡	3.05 (-0.82,6.92)	9.79 (5.36,14.21)‡	1.55 (1.12,2.17)†	1.65 (1.23,2.23)†
Adjusted model						
REI4P < 5	Reference	Reference	Reference	Reference	Reference	Reference
5 ≤ REI4P < 15	-0.02 (-0.32,0.28)	0.09 (-0.38,0.55)	-0.01 (-1.69,1.67)	-0.63 (-3.69,2.43)	1.14 (0.97,1.33)	1.06 (0.87,1.29)
15 ≤ REI4P < 30	-0.14 (-0.53,0.26)	0.31 (-0.28,0.91)	-0.41 (-2.61,1.79)	0.97 (-2.93,4.87)	1.35(1.09,1.68)†	1.18 (0.90,1.55)
REI4P ≥ 30	0.12 (-0.46,0.70)	0.83 (0.21,1.45)†	1.50 (-1.71,4.70)	6.93 (2.90,10.96)‡	1.29 (0.93,1.79)	1.20 (0.90,1.61)

Differences in adjusted β s (95% CIs) associated with 5 ≤ REI4P < 15, 15 ≤ REI4P < 30, or REI4P ≥ 30 (vs. REI4P < 5) are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. Of the 518 women included in analyses for fasting glucose, 247 had REI4P<5, 170 had REI4P ≥5 and <15, 72 had REI4P ≥15 and <30, and 29 had REI4P ≥30. Of the 507 women included in analyses for HbA1c, 241 had REI4P<5, 165 had REI4P ≥5 and <15, 72 had REI4P ≥15 and <30, and 29 had REI4P ≥30. Of the 373 women included in analyses for HOMA-IR, 189 had REI4P<5, 115 had REI4P ≥5 and <15, 50 had REI4P ≥15 and <30, and 19 had REI4P ≥30. Of the 271 men included in analyses for fasting glucose, 93 had REI4P<5, 93 had REI4P ≥5 and <15, 44 had REI4P ≥15 and <30, and 41 had REI4P ≥30. Of the 265 men included in analyses for HbA1c, 89 had REI4P<5, 92 had REI4P ≥5 and <15, 43 had REI4P ≥15 and <30, and 41 had REI4P ≥30. Of the 203 men included in analyses for HOMA-IR, 77 had REI4P<5, 72 had REI4P ≥5 and <15, 29 had REI4P ≥15 and <30, and 25 had REI4P ≥30. Models include adjustment for age, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation.

Table S14. Differences in measures of glucose metabolism by Sat<90 in a multiple imputation sample.

	Fasting glucose, mmol/l	HbA1c, mmol/mol	HOMA-IR
Sat<90 less than 5%	Reference	Reference	Reference
Sat<90 5% or more	0.15(-0.18,0.48)	2.03(0.09,3.97)*	1.11(0.93,1.33)

Of the 798 participants included in analyses for fasting glucose, 686 had Sat<90 less than 5% and 103 had Sat<90 5% or more. Of the 772 participants included in analyses for HbA1c, 669 had Sat<90 less than 5% and 103 had Sat<90 5% or more. Of the 576 participants included in analyses for HOMA-IR, 514 had Sat<90 less than 5% and 62 had Sat<90 5% or more. Differences in adjusted β s (95% CIs) by Sat<90 are shown. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; Sat<90, % sleep time with <90% oxyhemoglobin saturation.

Table S15. Sex-specific differences in measures of glucose metabolism by Sat<90 in a multiple imputation sample.

	Fasting glucose, mmol/l	HbA1c, mmol/mol	HOMA-IR
Men			
Sat<90 less than 5 %	Reference	Reference	Reference
Sat<90 5% or more	0.63(0.12,1.13)*	4.12(0.79,7.45)*	1.12(0.87,1.43)
Women			
Sat<90 less than 5 %	Reference	Reference	Reference
Sat<90 5% or more	-0.30(-0.74,0.13)	-0.01(-2.41,2.39)	1.06(0.82,1.37)

Of the 271 men included in analyses for fasting glucose, 220 had Sat<90 less than 5% and 51 had Sat<90 5% or more. Of the 518 women included in analyses for fasting glucose, 466 had Sat<90 less than 5% and 52 had Sat<90 5% or more. Of the 265 men included in analyses for HbA1c, 214 had Sat<90 less than 5% and 51 had Sat<90 5% or more. Of the 507 women included in analyses for HbA1c, 455 had Sat<90 less than 5% and 52 had Sat<90 5% or more. Of the 203 men included in analyses for HOMA-IR, 173 had Sat<90 less than 5% and 30 had Sat<90 5% or more. Of the 373 women included in analyses for HOMA-IR, 341 had Sat<90 less than 5% and 32 had Sat<90 5% or more. Differences in adjusted β s (95% CIs) by Sat<90 are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. Models include adjustment for age, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; Sat<90, % sleep time with <90% oxyhemoglobin saturation.

Table S16. Differences in measures of glucose metabolism by tertiles of sleep duration in a multiple imputation sample.

	Fasting glucose, mmol/l	HbA1c, mmol/mol	HOMA-IR
1 st tertile of sleep duration	0.06 (-0.20,0.32)	1.03 (-0.55,2.61)	0.97 (0.86,1.11)
2 nd tertile of sleep duration	Reference	Reference	Reference
3 rd tertile of sleep duration	0.21 (-0.05,0.47)	0.65 (-0.92,2.22)	1.04 (0.91,1.18)

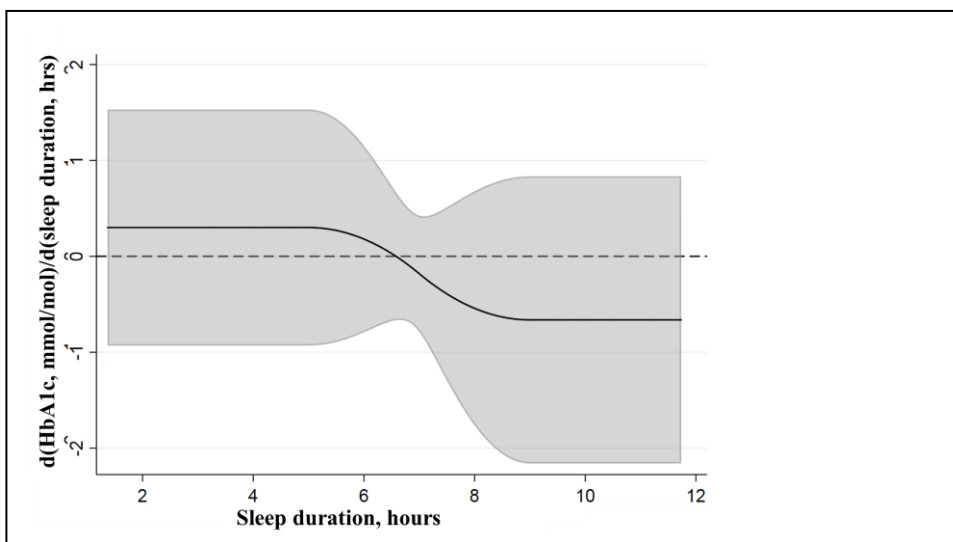
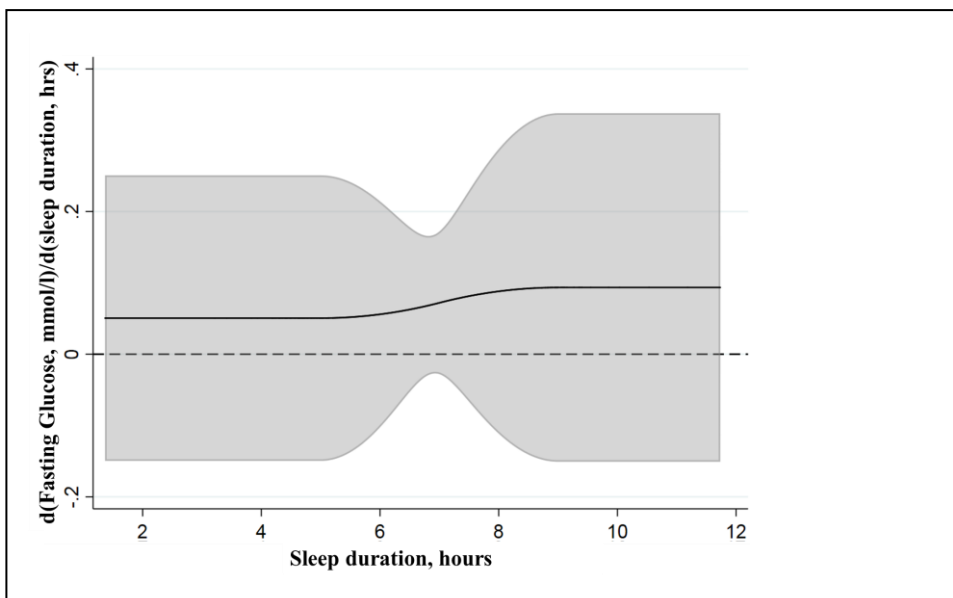
Differences in adjusted β s (95% CIs) by tertiles of sleep duration are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiply the expected value of HOMA-IR by $\exp(\beta)$. The range of sleep duration for each group is as follows: 1st tertile; 1.37-6.2, 2nd tertile; 6.22-7.15; and 3rd tertile, 7.17-11.73 hours per night. Of the 789 participants included in analyses for fasting glucose, 265 were categorized into the 1st tertile group, 263 were categorized into the 2nd tertile group, and 261 were categorized into the 3rd tertile group. Of the 772 participants included in analyses for HbA1c, 259 were categorized into the 1st tertile group, 257 were categorized into the 2nd tertile group, and 256 were categorized into the 3rd tertile group. Of the 576 participants included in analyses for HOMA-IR, 198 were categorized into the 1st tertile group, 197 were categorized into the 2nd tertile group, and 181 were categorized into the 3rd tertile group. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, and statin use. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c.

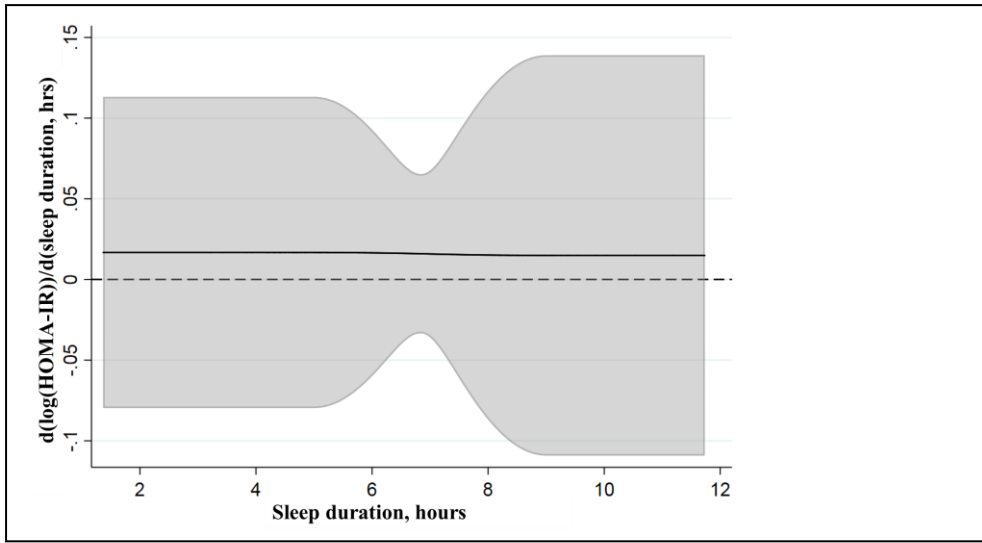
Table S17. Associations between sleep disturbances and measures of glucose metabolism: a complete case analysis.

	Fasting glucose, mmol/l		HbA1c, mmol/mol		HOMA-IR	
	Unadjusted (n=789)	Adjusted (n=714)	Unadjusted (n=772)	Adjusted (n=697)	Unadjusted (n=589)	Adjusted (n=538)
Sleep disordered breathing measures						
REI4P (events/hour)	0.22 (0.09,0.34)‡	0.19 (0.08,0.30)‡	1.54 (0.78,2.30)‡	1.35 (0.70,2.01)‡	1.17 (1.11,1.24)‡	1.10 (1.03,1.17)†
REI3P (events/hour)	0.23 (0.11,0.35)‡	0.20 (0.09,0.31)‡	1.60 (0.85,2.36)‡	1.36 (0.70,2.02)‡	1.19 (1.12,1.26)‡	1.11 (1.05,1.19)†
Sat<90, %	0.13 (0.01,0.26)*	0.09 (-0.01,0.19)	0.71 (-0.05,1.47)	0.45 (-0.15,1.06)	1.12 (1.05,1.19)‡	1.03 (0.97,1.10)
MinSaO2, %	-0.19 (-0.31,-0.07)†	-0.13 (-0.24,-0.02)*	-1.39 (-2.16,-0.63)‡	-0.79 (-1.45,-0.12)*	0.82 (0.78,0.87)‡	0.91 (0.86,0.97)†
Sleep duration and continuity measures						
Sleep duration, hours	0.10 (-0.03,0.22)	0.11 (0.00,0.21)*	0.08 (-0.70,0.85)	0.00 (-0.62,0.62)	0.98 (0.93,1.04)	1.01 (0.95,1.07)
Sleep maintenance efficiency, %	-0.12 (-0.25,-0.00)*	-0.12 (-0.23,-0.02)*	-0.84 (-1.62,-0.06)*	-0.66 (-1.32,-0.00)*	0.92 (0.87,0.98)†	0.96 (0.90,1.01)
Sleep duration variability, minutes	0.20 (0.08,0.33)†	0.23 (0.13,0.32)‡	0.87 (0.10,1.64)*	0.85 (0.26,1.44)†	1.02 (0.96,1.08)	0.98 (0.92,1.03)
Fragmented sleep indices, %	0.18 (0.06,0.31)†	0.16 (0.06,0.27)†	0.95 (0.18,1.72)*	0.89 (0.27,1.51)†	1.08 (1.01,1.14)*	1.08 (1.02,1.14)*

β = standardized regression coefficient. Adjusted β s (95% CIs) associated with a one-SD increase in each sleep measure are shown. For HOMA-IR, exponential β s were calculated, interpreted as a one-SD increase in each sleep measure would multiplies the expected value of HOMA-IR by $\exp(\beta)$. Each sleep measure was analyzed in a separate model. Models include adjustment for age, sex, educational level, alcohol use, smoking status, BMI, antihyperglycemic medication use and prevalent diabetes, statin use, and sleep duration. Antihyperglycemic medication use and prevalent diabetes were not used in modeling for HOMA-IR. Sleep duration was not used in modeling of sleep duration as an exposure. * $P<0.05$; † $P<0.01$; ‡ $P<0.001$. HOMA-IR= homeostatic model assessment of insulin resistance; HbA1c= hemoglobin A1c; REI4P= apnea-hypopnea index at 4% oxygen desaturation; REI3P= apnea-hypopnea index at 3% oxygen desaturation; Sat<90, % sleep time with <90% oxyhemoglobin saturation; MinSaO2=minimum oxygen saturation.

Figure S1. Restricted cubic spline regression of sleep duration and measures of glucose metabolism were shown.





Knots were established at sleep durations of 5, 7, and 9 hours.