

Supplementary Table 1 Information of genetic variants associated with sleep behaviors in the UK
Biobank study

Chromosome	SNP	Effect allele	Effect size
Sleep duration			
11	rs10899257	A	0.068
17	rs17688916	T	0.071
16	rs17817288	A	0.039
11	rs3751046	G	0.070
2	rs6737318	G	0.076
1	rs7534398	A	0.047
11	rs75458655	T	0.185
7	rs11763750	G	0.035
7	rs1229762	T	0.037
5	rs12518468	C	0.032
1	rs12567114	G	0.036
6	rs12661667	T	0.028
18	rs12963463	C	0.029
4	rs13107325	T	0.075
2	rs1380703	G	0.035
11	rs1607227	G	0.031
4	rs17005118	A	0.030
15	rs17388803	C	0.053
3	rs2014830	C	0.030
17	rs205024	C	0.031
1	rs2186122	T	0.024
1	rs2820313	G	0.031
2	rs2863957	C	0.055
5	rs3776864	A	0.032
5	rs4585442	G	0.031
22	rs5757675	G	0.034
16	rs59779556	T	0.025
8	rs60882754	A	0.055
1	rs7524118	C	0.030

2	rs75539574	A	0.045
11	rs7939345	T	0.035
6	rs9321171	C	0.032
6	rs9367621	T	0.024
Chronotype			
1	rs10493596	C	0.086
1	rs11121022	A	0.068
17	rs11545787	A	0.077
1	rs12736689	C	-0.301
16	rs12927162	A	-0.094
18	rs12965577	A	-0.062
2	rs1595824	C	0.077
7	rs2948276	A	-0.083
1	rs34714364	G	0.113
6	rs35833281	C	-0.083
7	rs3972456	A	-0.083
2	rs55694368	G	-0.151
12	rs6582618	A	0.068
6	rs9479402	C	-0.371
13	rs9565309	C	0.174
Insomnia			
9	rs10156602	A	0.039
7	rs10280045	G	0.039
13	rs1031654	C	0.049
11	rs10838708	G	0.030
3	rs10865954	T	0.039
6	rs10947690	G	0.039
4	rs11097861	G	0.039
1	rs11184946	T	0.030
10	rs11191595	A	0.095
2	rs113851554	T	0.182
15	rs11635495	C	0.039
17	rs11651809	G	0.049
19	rs11673344	G	0.039

9	rs11793074	A	0.039
9	rs11793831	G	0.030
1	rs11804386	A	0.039
1	rs12405761	A	0.039
2	rs12713372	C	0.030
5	rs1430205	T	0.030
16	rs1544637	T	0.030
5	rs1592757	C	0.039
16	rs17139246	C	0.030
8	rs17151854	T	0.058
17	rs17669584	G	0.039
4	rs1841625	G	0.030
13	rs1923770	T	0.049
18	rs1942262	A	0.039
16	rs2062113	T	0.039
13	rs2147141	G	0.030
2	rs2192338	C	0.039
10	rs2296580	G	0.049
1	rs2613503	A	0.030
1	rs2644128	G	0.039
5	rs28061	A	0.039
12	rs2956278	G	0.049
7	rs302165	G	0.030
16	rs3104778	A	0.030
6	rs314280	G	0.039
12	rs324017	A	0.049
2	rs35881094	G	0.049
7	rs3824081	T	0.039
2	rs4577309	A	0.030
3	rs4683301	T	0.039
3	rs4688760	T	0.049
1	rs4751	T	0.030
13	rs4886140	G	0.039
15	rs4886860	G	0.049

3	rs55946513	C	0.049
2	rs62158170	A	0.049
7	rs6593005	G	0.030
1	rs6664467	G	0.049
3	rs6785034	A	0.030
12	rs68094047	T	0.039
6	rs6932158	C	0.030
2	rs72826719	A	0.095
5	rs7711696	T	0.049
3	rs9845387	C	0.095
Snoring			
1	rs35915391	C	-0.029
1	rs35562935	A	0.054
2	rs10190879	T	-0.031
2	rs72906130	G	0.055
3	rs9309771	A	0.030
4	rs34811474	A	-0.039
4	rs6855873	T	0.032
5	rs2307111	C	-0.035
5	rs10062026	A	-0.029
5	rs745558	A	-0.034
6	rs947612	G	0.033
6	rs17060460	G	0.033
6	rs9389081	A	-0.052
8	rs2981329	C	0.033
8	rs7007887	T	0.037
8	rs4523230	A	-0.034
9	rs1016013	A	-0.032
10	rs11256034	T	0.038
11	rs2049045	C	-0.042
12	rs10878269	T	0.037
13	rs12427782	T	-0.029
13	rs2762049	C	0.034
13	rs2408111	A	0.044

13	rs592333	G	0.041
14	rs2664299	C	-0.033
16	rs9933881	C	0.054
16	rs732172	T	0.032
16	rs8047587	T	0.031
17	rs7217107	G	-0.032
17	rs12449843	A	-0.032
17	rs1641511	G	0.033
17	rs57222984	G	0.038
17	rs4792897	G	-0.037
17	rs1563304	T	0.035
17	rs2924251	A	0.031
17	rs79275904	T	-0.052
17	rs180107	A	-0.030
18	rs4987719	T	0.075
19	rs10415992	G	-0.049
20	rs34107769	C	-0.031
20	rs6099273	T	0.032
23	rs17435	T	-0.042
Excessive daytime sleepiness			
1	rs2787120	A	0.008
1	rs12140153	G	0.017
1	rs17131124	C	-0.011
1	rs57746981	C	0.007
1	rs825127	T	0.006
2	rs4665972	T	0.007
2	rs7598712	G	0.006
2	rs6741951	G	0.007
2	rs11123962	T	-0.008
2	rs9712275	C	-0.006
2	rs7607363	A	-0.006
2	rs13010456	A	0.008
3	rs13097760	A	-0.006
3	rs34478464	C	-0.009

3	rs960986	C	0.007
3	rs843372	C	0.008
4	rs11942333	G	-0.006
4	rs13135092	A	-0.010
5	rs6897863	A	0.006
5	rs12153518	A	0.007
6	rs6923811	T	0.007
6	rs55960940	T	0.008
6	rs3122170	C	0.010
8	rs62519825	T	-0.009
8	rs285793	G	0.007
8	rs7837226	A	-0.006
9	rs55818482	T	-0.010
9	rs1566362	T	0.006
10	rs7476897	G	0.007
12	rs4765939	G	-0.006
12	rs1846644	T	-0.011
14	rs8015449	A	0.006
15	rs17356118	A	-0.008
16	rs886114	C	0.006
17	rs11078398	G	0.008
17	rs62066119	C	0.008
18	rs2048522	A	0.006

Supplementary Table 2 Adjusted HRs ^a and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors after further adjustment for milk consumption, cereal intake, and vitamin D supplement use in the UK Biobank study

Serum 25-hydroxyvitamin D (quintiles)					HR (95% CI) for a 10 nmol/L increase	<i>P</i> for trend
Q1	Q2	Q3	Q4	Q5		
1.00	0.85 (0.80-0.91)	0.76 (0.70-0.81)	0.60 (0.55-0.65)	0.50 (0.46-0.55)	0.88 (0.87-0.89)	<0.001
<i>P</i> for interaction with sleep behaviors						
Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
0.001	0.07	0.23	0.35	0.25	0.0006	

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes (yes, no, and “do not know” or missing), milk consumption, cereal intake, and vitamin D supplement use (yes, no, and “do not know” or missing).

Supplementary Table 3 Adjusted HRs ^a and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors after further adjustment for skin color, sunscreen use, and PM_{2.5} in the UK Biobank study

Serum 25-hydroxyvitamin D (quintiles)					HR (95% CI) for a 10 nmol/L increase	<i>P</i> trend
Q1	Q2	Q3	Q4	Q5		
1.00	0.86 (0.80-0.92)	0.77 (0.72-0.83)	0.61 (0.56-0.66)	0.52 (0.47-0.57)	0.88 (0.87-0.90)	<0.001
<i>P</i> for interaction with sleep behaviors						
Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
0.001	0.06	0.25	0.36	0.27	0.0005	

PM_{2.5}: particulate matter with diameters ≤ 2.5 μm .

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes (yes, no, and “do not know” or missing), skin color (very fair, fair, light olive, dark olive, brown, black, and “do not know” or missing), sunscreen use (never/rarely, sometimes, most of the time, always, do not go out in sunshine, and “do not know” or missing), and PM_{2.5} ($\mu\text{g}/\text{m}^3$).

Supplementary Table 4 Adjusted HRs and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors in the UK Biobank study

Serum 25-hydroxyvitamin D (quintiles)							<i>P</i> trend
	Q1	Q2	Q3	Q4	Q5	HR (95% CI) for a 10 nmol/L increase	
Model ^a	1.00	0.85 (0.80-0.91)	0.76 (0.71-0.82)	0.60 (0.56-0.65)	0.51 (0.47-0.56)	0.88 (0.87-0.90)	<0.001
Model ^b	1.00	0.86 (0.80-0.92)	0.77 (0.72-0.83)	0.61 (0.56-0.66)	0.52 (0.47-0.57)	0.89 (0.87-0.90)	<0.001
Model ^c	1.00	0.86 (0.81-0.92)	0.78 (0.73-0.84)	0.63 (0.58-0.68)	0.55 (0.50-0.60)	0.89 (0.88-0.91)	<0.001
Model ^d	1.00	0.92 (0.86-0.98)	0.82 (0.77-0.89)	0.66 (0.61-0.72)	0.57 (0.52-0.62)	0.90 (0.89-0.91)	<0.001
<i>P</i> for interaction with sleep behaviors							
	Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
Model ^a	0.001	0.07	0.25	0.35	0.27	0.0006	
Model ^b	0.0004	0.05	0.17	0.26	0.23	0.0002	
Model ^c	0.002	0.08	0.25	0.38	0.28	0.002	
Model ^d	0.003	0.03	0.07	0.68	0.87	0.002	

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes, and north co-ordinate.

^b Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes (yes, no, and “do not know” or missing), sleep apnea (yes/no), and depressive symptoms (not at all, several days, more than half days, nearly every day, and missing).

^c Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes (yes, no, and “do not know” or missing), and waist circumferences (cm).

^d Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), family history of diabetes (yes, no, and “do not know” or missing), and serum glucose levels (mmol/L).

Supplementary Table 5 Adjusted HRs ^a and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors after excluding participants with CVD or cancer at baseline in the UK Biobank study (N=309 940)

Serum 25-hydroxyvitamin D (quintiles)					HR (95% CI) for a 10 nmol/L increase	<i>P</i> trend
Q1	Q2	Q3	Q4	Q5		
1.00	0.86 (0.80-0.93)	0.76 (0.70-0.83)	0.58 (0.53-0.64)	0.48 (0.43-0.53)	0.87 (0.86-0.89)	<0.001
<i>P</i> for interaction with sleep behaviors						
Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
0.0008	0.34	0.10	0.30	0.04	0.004	

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), and family history of diabetes (yes, no, and “do not know” or missing).

Supplementary Table 6 Adjusted HRs ^a and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors after limiting participants with follow-up time of more than 2 years in the UK Biobank study (N=348 005)

Serum 25-hydroxyvitamin D (quintiles)					HR (95% CI) for a 10 nmol/L increase	<i>P</i> trend
Q1	Q2	Q3	Q4	Q5		
1.00	0.86 (0.80-0.92)	0.78 (0.72-0.84)	0.61 (0.56-0.66)	0.51 (0.47-0.56)	0.88 (0.87-0.90)	<0.001
<i>P</i> for interaction with sleep behaviors						
Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
0.007	0.22	0.32	0.33	0.40	0.0007	

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), and family history of diabetes (yes, no, and “do not know” or missing).

Supplementary Table 7 Adjusted HRs ^a and 95% CI for serum 25-hydroxyvitamin D levels with type 2 diabetes and interaction analyses with sleep behaviors after limiting participants with vitamin D deficiency in the UK Biobank study (N=189 505)

Serum 25-hydroxyvitamin D (quintiles)					HR (95% CI) for a 10 nmol/L increase	<i>P</i> trend
Q1	Q2	Q3	Q4	Q5		
1.00	0.84 (0.79-0.90)	0.75 (0.69-0.82)	-	-	0.87 (0.84-0.90)	<0.001
<i>P</i> for interaction with sleep behaviors						
Healthy sleep scores	Sleep duration	Chronotype	Insomnia	Snoring	Daytime sleepiness	
<0.001	0.20	<0.001	0.33	0.13	0.02	

^a Adjusted for age, sex, race (white European, mixed, South Asian, black, others), UK Biobank assessment centre, average total annual household income (<£18 000, £18 000-£30 999, £31 000-£51 999, £52 000-£100 000, >£100 000, and “do not know” or missing), Townsend Deprivation index, alcohol consumption (current, former, never, missing), smoking status (current, former, never, missing), body mass index, physical activity (MET-minutes), healthy diet score (0, 1, 2, 3, 4, 5), sun exposure time in the summer (hours/d), season of blood collection (winter: December-February; spring: March-May; summer: June-August; autumn: September-November), antihypertensive medications use (yes/no), cholesterol medications use (yes/no), and family history of diabetes (yes, no, and “do not know” or missing).