N = 502,616
In the present UK Biobank dataset.

n = 54,538
Excluded based on disease history:
Total cardiovascular disease (n = 30,696);
Total cancer (n = 21,257);
Both conditions (n = 2,585).

n = 448,078
Before other health conditions and missing/unusable exclusion

n = 66,886
Stepwise exclusion based on health conditions:
Obstructive sleep apnea (n = 1,825);
Class III obesity (n = 7,937).
Another stepwise exclusion missing/unusable data:
Sleep behaviours (n = 10,633);
Physical activity (n = 35,754);
Any confounding (n = 10,737).

n = 381,192
Before exclusion due to coronavirus and early cases

n = 1,137
Excluded because participants died:
From the coronavirus (n = 235);
In the first two years of follow-up (n = 902).

n = 380,055
Included in the present study

Supplementary Figure S1. Participants recruitment flowchart
### (a) All-cause mortality

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hazard ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sleep</strong></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>1</td>
</tr>
<tr>
<td>Poor</td>
<td>1.23 (1.13, 1.34)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.05 (1.02, 1.09)</td>
</tr>
<tr>
<td><strong>Physical Activity</strong></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>No MVPA</td>
<td>1.25 (1.2, 1.31)</td>
</tr>
<tr>
<td>Low</td>
<td>1.08 (1.02, 1.14)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.05 (1.01, 1.1)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>Each year older</td>
<td>1.1 (1.09, 1.1)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Male</td>
<td>1.59 (1.53, 1.64)</td>
</tr>
<tr>
<td><strong>Socioeconomic status</strong></td>
<td></td>
</tr>
<tr>
<td>Each one unit up*</td>
<td>1.04 (1.03, 1.05)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
</tr>
<tr>
<td>Employed not in shift work</td>
<td>1</td>
</tr>
<tr>
<td>Retired/not in the workforce</td>
<td>1.36 (1.31, 1.42)</td>
</tr>
<tr>
<td>Employed in night shift work</td>
<td>1.04 (0.95, 1.14)</td>
</tr>
<tr>
<td>Employed in day shift work</td>
<td>1.09 (1.1, 1.2)</td>
</tr>
<tr>
<td><strong>Body mass index</strong></td>
<td></td>
</tr>
<tr>
<td>Each 1 kg/m² more</td>
<td>1.01 (1.01, 1.01)</td>
</tr>
<tr>
<td><strong>Cigarette smoking</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous smoker</td>
<td>1.27 (1.23, 1.32)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>2.51 (2.4, 2.63)</td>
</tr>
<tr>
<td><strong>Vegetable and fruit intake</strong></td>
<td></td>
</tr>
<tr>
<td>Each serve more</td>
<td>0.99 (0.98, 0.99)</td>
</tr>
<tr>
<td><strong>Alcohol consumption</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous drinker</td>
<td>1.23 (1.11, 1.37)</td>
</tr>
<tr>
<td>Occasional drinker</td>
<td>0.87 (0.8, 0.94)</td>
</tr>
<tr>
<td>Within guidelines</td>
<td>0.76 (0.7, 0.83)</td>
</tr>
<tr>
<td>Above guidelines</td>
<td>0.75 (0.69, 0.82)</td>
</tr>
<tr>
<td>Double guidelines</td>
<td>0.9 (0.83, 0.99)</td>
</tr>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
</tr>
<tr>
<td>Each hour more</td>
<td>1.02 (1.01, 1.03)</td>
</tr>
<tr>
<td><strong>Mental health issue</strong></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>1.08 (1.05, 1.12)</td>
</tr>
</tbody>
</table>

**Supplementary Figure S2.** The Independent (and Mutually Adjusted) Associations of All Selected Variables with Mortality (n = 380,055) of (a) All-Cause, (b) Total Cardiovascular Disease, and (c) Total Cancer.

* 'Townsend area deprivation index' served as an indicator of socioeconomic status, with higher scores indicating greater socioeconomic deprivation.*
### (b) Total cardiovascular disease mortality

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hazard ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sleep</strong></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>1</td>
</tr>
<tr>
<td>Poor</td>
<td>1.39 (1.19, 1.62)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.09 (1.03, 1.17)</td>
</tr>
<tr>
<td><strong>Physical Activity</strong></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>No MVPA</td>
<td>1.31 (1.21, 1.42)</td>
</tr>
<tr>
<td>Low</td>
<td>1.09 (0.98, 1.21)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.06 (0.97, 1.16)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>Each year older</td>
<td>1.11 (1.1, 1.12)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Male</td>
<td>2.3 (2.14, 2.47)</td>
</tr>
<tr>
<td><strong>Socioeconomic status</strong></td>
<td></td>
</tr>
<tr>
<td>Each one unit up*</td>
<td>1.06 (1.05, 1.07)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
</tr>
<tr>
<td>Employed not in shift work</td>
<td>1</td>
</tr>
<tr>
<td>Retired/not in the workforce</td>
<td>1.54 (1.42, 1.66)</td>
</tr>
<tr>
<td>Employed in night shift work</td>
<td>1.14 (0.95, 1.35)</td>
</tr>
<tr>
<td>Employed in day shift work</td>
<td>1.11 (0.92, 1.33)</td>
</tr>
<tr>
<td><strong>Body mass index</strong></td>
<td></td>
</tr>
<tr>
<td>Each 1 kg/m² 2 more</td>
<td>1.04 (1.03, 1.05)</td>
</tr>
<tr>
<td><strong>Cigarette smoking</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous smoker</td>
<td>1.27 (1.18, 1.36)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>2.69 (2.46, 2.94)</td>
</tr>
<tr>
<td><strong>Vegetable and fruit intake</strong></td>
<td></td>
</tr>
<tr>
<td>Each serve more</td>
<td>0.99 (0.98, 1)</td>
</tr>
<tr>
<td><strong>Alcohol consumption</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous drinker</td>
<td>1.13 (0.93, 1.39)</td>
</tr>
<tr>
<td>Occasional drinker</td>
<td>0.83 (0.7, 0.97)</td>
</tr>
<tr>
<td>Within guidelines</td>
<td>0.68 (0.58, 0.8)</td>
</tr>
<tr>
<td>Above guidelines</td>
<td>0.66 (0.56, 0.78)</td>
</tr>
<tr>
<td>Double guidelines</td>
<td>0.84 (0.71, 0.99)</td>
</tr>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
</tr>
<tr>
<td>Each hour more</td>
<td>1.01 (1, 1.03)</td>
</tr>
<tr>
<td><strong>Mental health issue</strong></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>1.09 (1.02, 1.16)</td>
</tr>
</tbody>
</table>

**Supplementary Figure S2 (cont.).** The Independent (and Mutually Adjusted) Associations of All Selected Variables with Mortality (n = 380,055) of (a) All-Cause, (b) Total Cardiovascular Disease, and (c) Total Cancer.

* 'Townsend area deprivation index' served as an indicator of socioeconomic status, with higher scores indicating greater socioeconomic deprivation.
### (c) Total cancer mortality

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hazard ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sleep</strong></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>1</td>
</tr>
<tr>
<td>Poor</td>
<td>1.13 (1.1, 1.7)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.03 (0.99, 1.08)</td>
</tr>
<tr>
<td><strong>Physical Activity</strong></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>No MVPA</td>
<td>1.16 (1.1, 1.23)</td>
</tr>
<tr>
<td>Low</td>
<td>1.03 (0.96, 1.11)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.02 (0.96, 1.08)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>Each year older</td>
<td>1.1 (1.09, 1.1)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Male</td>
<td>1.29 (1.23, 1.35)</td>
</tr>
<tr>
<td><strong>Socioeconomic status</strong></td>
<td></td>
</tr>
<tr>
<td>Each one unit up*</td>
<td>1.03 (1.02, 1.03)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
</tr>
<tr>
<td>Employed not in shift work</td>
<td>1</td>
</tr>
<tr>
<td>Retired/not in the workforce</td>
<td>1.13 (1.08, 1.19)</td>
</tr>
<tr>
<td>Employed in night shift work</td>
<td>0.98 (0.87, 1.11)</td>
</tr>
<tr>
<td>Employed in day shift work</td>
<td>1.05 (0.94, 1.18)</td>
</tr>
<tr>
<td><strong>Body mass index</strong></td>
<td></td>
</tr>
<tr>
<td>Each 1 kg/m²2 more</td>
<td>1.01 (1.01, 1.02)</td>
</tr>
<tr>
<td><strong>Cigarette smoking</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous smoker</td>
<td>1.33 (1.27, 1.39)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>2.49 (2.34, 2.65)</td>
</tr>
<tr>
<td><strong>Vegetable and fruit intake</strong></td>
<td></td>
</tr>
<tr>
<td>Each serve more</td>
<td>0.98 (0.97, 0.99)</td>
</tr>
<tr>
<td><strong>Alcohol consumption</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td>Previous drinker</td>
<td>1.29 (1.11, 1.49)</td>
</tr>
<tr>
<td>Occasional drinker</td>
<td>0.96 (0.86, 1.08)</td>
</tr>
<tr>
<td>Within guidelines</td>
<td>0.87 (0.78, 0.98)</td>
</tr>
<tr>
<td>Above guidelines</td>
<td>0.89 (0.79, 1)</td>
</tr>
<tr>
<td>Double guidelines</td>
<td>1.02 (0.9, 1.15)</td>
</tr>
<tr>
<td><strong>Sedentary behaviour</strong></td>
<td></td>
</tr>
<tr>
<td>Each hour more</td>
<td>1.02 (1.01, 1.03)</td>
</tr>
<tr>
<td><strong>Mental health issue</strong></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>0.99 (0.95, 1.04)</td>
</tr>
</tbody>
</table>

**Supplementary Figure S2 (cont.).** The Independent (and Mutually Adjusted) Associations of All Selected Variables with Mortality (n = 380,055) of (a) All-Cause, (b) Total Cardiovascular Disease, and (c) Total Cancer.

* ‘Townsend area deprivation index’ served as an indicator of socioeconomic status, with higher scores indicating greater socioeconomic deprivation.*
Supplementary Table S1. The Definition of Diseases

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cardiovascular disease (CVD)</td>
<td>The total CVD definition is aligned with Zao et al. (2020) (<a href="https://doi.org/10.1136/bmj.m2031">https://doi.org/10.1136/bmj.m2031</a>). In brief, the ICD-10 code described in the Chapter IX Diseases of the circulatory system (I0, I11, I13, I20-I51, I60-I69) or the ICD-9 code within (390.0-398.9/ 402.0- 402.9/ 404.0-404.9/ 411.1-436.9) were included.</td>
</tr>
<tr>
<td>Sub-type CVD</td>
<td></td>
</tr>
<tr>
<td>Coronary heart diseases</td>
<td>The ICD-10 code described in Chapter IX Diseases of the circulatory system – Ischemic heart disease (I20-I25) was included.</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>The definition of hemorrhagic stroke (both intracerebral and subarachnoid) is aligned with UK Biobank. The ICD-10 code beginning with ('I60 'I61') was included.</td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>The definition of ischemic stroke is aligned with UK Biobank. The ICD-10 code beginning with ('I63 'I64') was included.</td>
</tr>
<tr>
<td>Total cancers</td>
<td>The definition of total cancer excludes in situ, benign, uncertain, or non-well-defined cancers. In brief, the ICD-10 code beginning with ('C0 'C1 'C2 'C3 'C4 'C5 'C6 'C70 'C71 'C72 'C73 'C74 'C75 'C7A 'C8 'C9') or the ICD-9 code within (140.0-194.9/ 199.0-209.3) were included.</td>
</tr>
<tr>
<td>Sub-type malignant neoplasm</td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>The ICD-10 code beginning with ('C33 'C34') was included.</td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Obstructive sleep apnea</td>
<td>The ICD-10 code 'G47.3' and ICD-9 code '327.2' and '780.5' were applied.</td>
</tr>
<tr>
<td>Coronavirus disease (COVID-19)</td>
<td>The ICD-10 code 'U07.1' and 'U07.2' were applied.</td>
</tr>
</tbody>
</table>

Primary/secondary inpatient diseases diagnosis is based on both ICD-9 and ICD-10 code. All death cause was based on both primary and secondary cause of death with ICD-10 code only.
### Supplementary Table S2. The Scoring System of Sleep Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>UK BioBank Code</th>
<th>UK BioBank Questionnaire</th>
<th>Healthy Answer (%)</th>
<th>Unhealthy Answer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronotype</td>
<td>1180</td>
<td>Do you consider yourself to be?</td>
<td>Definitely a &quot;morning&quot; person; More a &quot;morning&quot; than &quot;evening&quot; person. (57%)</td>
<td>More an &quot;evening&quot; than a &quot;morning&quot; person; Definitely an &quot;evening&quot; person. (43%)</td>
</tr>
<tr>
<td>Sleep Duration</td>
<td>1160</td>
<td>About how many hours do you get in every 24 hours? (please include naps)</td>
<td>7-8 hr/d. (69%)</td>
<td>&lt;7 or &gt;=9 hr/d. (31%)</td>
</tr>
<tr>
<td>Insomnia</td>
<td>1200</td>
<td>Do you have trouble falling asleep at night or do you wake up in the middle of the night?</td>
<td>Never/rarely; Sometimes (73%)</td>
<td>Usually (27%)</td>
</tr>
<tr>
<td>Snoring</td>
<td>1210</td>
<td>Does your partner or a close relative or friend complain about your snoring?</td>
<td>No (60%)</td>
<td>Yes (40%)</td>
</tr>
<tr>
<td>Daytime Sleepiness</td>
<td>1220</td>
<td>How likely are you to doze off or fall asleep during the daytime when you don't mean to? (e.g. when working, reading or driving)</td>
<td>Never/rarely; Sometimes (98%)</td>
<td>Often; All the Time (2%)</td>
</tr>
</tbody>
</table>

For further information, please refer to the UK Biobank data showcase [https://biobank.ndph.ox.ac.uk/showcase/search.cgi](https://biobank.ndph.ox.ac.uk/showcase/search.cgi)
### Supplementary Table S3. Number of Mortality Events by Joint Category of Physical Activity and Sleep Scores (n = 380,055)

<table>
<thead>
<tr>
<th>Joint Category</th>
<th>All-cause</th>
<th>Total cardiovascular disease</th>
<th>Total cancer</th>
<th>Coronary heart diseases</th>
<th>Hemorrhagic stroke</th>
<th>Ischemic stroke</th>
<th>Lung cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>No MVPA, Poor (n = 2,510)</td>
<td>187/2,323</td>
<td>56/2,454</td>
<td>99/2,411</td>
<td>26/2,484</td>
<td>4/2,506</td>
<td>8/2,502</td>
<td>28/2,482</td>
</tr>
<tr>
<td>No MVPA, Intermediate (n = 28,289)</td>
<td>1,570/26,719</td>
<td>469/27,820</td>
<td>851/27,438</td>
<td>237/28,052</td>
<td>36/28,253</td>
<td>43/28,246</td>
<td>201/28,088</td>
</tr>
<tr>
<td>No MVPA, Healthy (n = 28,742)</td>
<td>1,293/27,449</td>
<td>325/28,417</td>
<td>738/28,004</td>
<td>155/28,587</td>
<td>31/28,711</td>
<td>37/28,705</td>
<td>138/28,604</td>
</tr>
<tr>
<td>Low, Poor (n = 1,291)</td>
<td>79/1,212</td>
<td>28/1,263</td>
<td>43/1,248</td>
<td>15/1,276</td>
<td>1/1,290</td>
<td>1/1,290</td>
<td>11/1,280</td>
</tr>
<tr>
<td>Low, Intermediate (n = 17,757)</td>
<td>765/16,992</td>
<td>197/17,560</td>
<td>442/17,315</td>
<td>95/17,662</td>
<td>13/17,744</td>
<td>17/17,740</td>
<td>72/17,685</td>
</tr>
<tr>
<td>Low, Healthy (n = 20,250)</td>
<td>689/19,561</td>
<td>182/20,068</td>
<td>406/19,844</td>
<td>83/20,167</td>
<td>17/20,233</td>
<td>24/20,226</td>
<td>72/2,0178</td>
</tr>
<tr>
<td>Medium, Poor (n = 1,384)</td>
<td>67/1,317</td>
<td>21/1,363</td>
<td>35/1,349</td>
<td>7/1,377</td>
<td>1/1,383</td>
<td>6/1,378</td>
<td>4/1,380</td>
</tr>
<tr>
<td>Medium, Intermediate (n = 24,110)</td>
<td>1,050/23,060</td>
<td>279/23,831</td>
<td>605/23,505</td>
<td>125/23,985</td>
<td>24/24,086</td>
<td>34/24,076</td>
<td>103/24,007</td>
</tr>
<tr>
<td>Medium, Healthy (n = 32,277)</td>
<td>1,128/31,149</td>
<td>283/31,994</td>
<td>675/31,602</td>
<td>121/32,156</td>
<td>27/32,250</td>
<td>43/32,234</td>
<td>110/32,167</td>
</tr>
<tr>
<td>High, Poor (n = 4,981)</td>
<td>262/4,719</td>
<td>80/4,901</td>
<td>130/4,851</td>
<td>33/4,948</td>
<td>5/4,976</td>
<td>11/4,970</td>
<td>28/4,953</td>
</tr>
<tr>
<td>High, Healthy (n = 130,517)</td>
<td>4,709/125,808</td>
<td>1,179/129,338</td>
<td>2,864/127,653</td>
<td>529/129,988</td>
<td>114/130,403</td>
<td>117/130,400</td>
<td>444/130,073</td>
</tr>
<tr>
<td>Overall (n = 380,055)</td>
<td>15,503/364,552</td>
<td>4,095/375,960</td>
<td>9,064/370,991</td>
<td>1,932/378,123</td>
<td>359/379,696</td>
<td>450/379,605</td>
<td>1,595/378,460</td>
</tr>
</tbody>
</table>

a. Physical activity levels were categorized based on public health guidelines: No MVPA (those reported 0 MET-mins/wk from MVPA, regardless of total MET-mins/wk); low (< 600 MET-mins/wk); medium (600 to < 1200 MET-mins/wk); and high (≥ 1200 MET-mins/wk). Sleep scores were categorized into: poor, 0~1; intermediate, 2~3; healthy, 4~5.
**Supplementary Table S4.** The Resource and Definition of the Selected Covariates (except for Age, Sex, and BMI)

<table>
<thead>
<tr>
<th>Covariates</th>
<th>UK BioBank Code</th>
<th>Description</th>
<th>Type</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socioeconomic status</td>
<td>189</td>
<td>The existing variable 'Townsend area deprivation index' (189) served as an indicator of socioeconomic status, with higher scores indicating greater socioeconomic deprivation.</td>
<td>Continuous</td>
<td>-</td>
</tr>
<tr>
<td>Vegetable and fruit intake</td>
<td>1299, 1309</td>
<td>The sum of the daily servings of 'salad /raw vegetable intake' (1299) and 'fresh fruit intake' (1309) served as a proxy of a healthy diet.</td>
<td>Continuous</td>
<td>-</td>
</tr>
<tr>
<td>Sedentary behaviour</td>
<td>1070, 1080, 1090</td>
<td>The total daily hours of television viewing (1070), computer use (1080), and driving (1090) as a marker of sedentary behaviour.</td>
<td>Continuous</td>
<td>-</td>
</tr>
<tr>
<td>Mental health issue</td>
<td>2090, 2100</td>
<td>Participants having ever seen a doctor (GP) (2090) or psychiatrist (2100) for nerves, anxiety, or depression were classified as having mental health issues.</td>
<td>Categorical</td>
<td>Yes; No</td>
</tr>
<tr>
<td>Cigarette smoking</td>
<td>20116</td>
<td>The existing variable 'smoking status' (20116) was applied.</td>
<td>Categorical</td>
<td>never; previous smoker; current smoker</td>
</tr>
<tr>
<td>Employment</td>
<td>6142 3426 826</td>
<td>We derived four groups based on 'Current employment status' (6142), 'Job involves night shift work' (3426), and 'Job involves shift work' (826).</td>
<td>Categorical</td>
<td>retired/not in the workforce; employed not in shift work; employed in night shift work; employed in day shift work never; previous drinker; occasional drinker; within guidelines (14 units per week); above guidelines (14-28 units/wk); double guidelines (&gt;28 units/wk).</td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td>1558, 1568, 1578, 1588, 1598, 1608, 5364, 20117</td>
<td>The level of overall alcohol consumption as the number of UK units of alcohol (10 mL/unit) consumed per week was calculated; participants were categorized based on the consumption according to the UK guideline (14 UK units/wk).</td>
<td>Categorical</td>
<td>-</td>
</tr>
</tbody>
</table>

For further information, please refer to the UK Biobank data showcase [https://biobank.ndph.ox.ac.uk/showcase/search.cgi](https://biobank.ndph.ox.ac.uk/showcase/search.cgi)
### Supplementary Table S5. Comparison of the Characteristics between Included and Excluded Samples.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Included Sample (n = 380,055)</th>
<th>Excluded Sample (n = 122,561)</th>
<th>Missing Count in Excluded Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean (SD))</td>
<td>55.9 (8.1)</td>
<td>58.60 (7.7)</td>
<td>-</td>
</tr>
<tr>
<td>Male (n (%))</td>
<td>171,315 (45)</td>
<td>57848 (47)</td>
<td>-</td>
</tr>
<tr>
<td>BMI (kg/m^2) (mean (SD))</td>
<td>26.9 (4.1)</td>
<td>29.13 (6.17)</td>
<td>3,194</td>
</tr>
<tr>
<td>Socioeconomic Status (mean (SD))</td>
<td>a</td>
<td>-1.5 (3.0)</td>
<td>-0.65 (3.4)</td>
</tr>
<tr>
<td>Vegetable and Fruit Intake (serves/d) (mean (SD))</td>
<td>4.4 (2.9)</td>
<td>4.43 (3.2)</td>
<td>8,801</td>
</tr>
<tr>
<td>Sedentary Behaviour (hr/d) (mean (SD))</td>
<td>4.7 (2.4)</td>
<td>5.10 (2.6)</td>
<td>7,763</td>
</tr>
<tr>
<td>Mental Health Issue (n (%))</td>
<td>b</td>
<td>127,943 (34)</td>
<td>45257 (38)</td>
</tr>
<tr>
<td>Cigarette Smoking (n (%))</td>
<td></td>
<td>2,952</td>
<td></td>
</tr>
<tr>
<td>- Never</td>
<td>213,618 (56)</td>
<td>59,970 (50)</td>
<td></td>
</tr>
<tr>
<td>- Previous Smoker</td>
<td>128,597 (34)</td>
<td>44,494 (37)</td>
<td></td>
</tr>
<tr>
<td>- Current Smoker</td>
<td>37,840 (10)</td>
<td>15,145 (13)</td>
<td></td>
</tr>
<tr>
<td>Employment Status (n (%))</td>
<td></td>
<td>5,759</td>
<td></td>
</tr>
<tr>
<td>- Retired/not in the workforce</td>
<td>144,090 (38)</td>
<td>65,557 (56)</td>
<td></td>
</tr>
<tr>
<td>- Employed not in shift work</td>
<td>197,803 (52)</td>
<td>39,725 (34)</td>
<td></td>
</tr>
<tr>
<td>- Employed in night shift work</td>
<td>19,365 (5)</td>
<td>6,006 (5)</td>
<td></td>
</tr>
<tr>
<td>- Employed in day shift work</td>
<td>18,797 (5)</td>
<td>5,514 (5)</td>
<td></td>
</tr>
<tr>
<td>Alcohol Consumption (n (%))</td>
<td>c</td>
<td>1,658</td>
<td></td>
</tr>
<tr>
<td>- Never</td>
<td>13,843 (4)</td>
<td>8,551 (7)</td>
<td></td>
</tr>
<tr>
<td>- Previous Drinker</td>
<td>11,512 (3)</td>
<td>6,599 (5)</td>
<td></td>
</tr>
<tr>
<td>- Occasional Drinker</td>
<td>81,191 (21)</td>
<td>32,704 (27)</td>
<td></td>
</tr>
<tr>
<td>- Within Guideline</td>
<td>130,901 (34)</td>
<td>36,254 (30)</td>
<td></td>
</tr>
<tr>
<td>- Above Guideline</td>
<td>84,936 (22)</td>
<td>21,627 (18)</td>
<td></td>
</tr>
<tr>
<td>- Above Double Guideline</td>
<td>57,672 (15)</td>
<td>15,168 (13)</td>
<td></td>
</tr>
<tr>
<td>Sleep Score (n (%))</td>
<td>d</td>
<td>12,458</td>
<td></td>
</tr>
<tr>
<td>- Poor</td>
<td>10,166 (3)</td>
<td>5,401 (5)</td>
<td></td>
</tr>
<tr>
<td>- Intermediate</td>
<td>158,103 (42)</td>
<td>53,394 (48)</td>
<td></td>
</tr>
<tr>
<td>- Healthy</td>
<td>211,786 (56)</td>
<td>51,308 (47)</td>
<td></td>
</tr>
<tr>
<td>Physical Active (n (%))</td>
<td>e</td>
<td>47,153</td>
<td></td>
</tr>
<tr>
<td>- No MVPA</td>
<td>59,541 (16)</td>
<td>9,871 (13)</td>
<td></td>
</tr>
<tr>
<td>- Low</td>
<td>39,298 (10)</td>
<td>14,344 (19)</td>
<td></td>
</tr>
<tr>
<td>- Medium</td>
<td>57,771 (15)</td>
<td>12,290 (16)</td>
<td></td>
</tr>
<tr>
<td>- High</td>
<td>223,445 (59)</td>
<td>38,903 (52)</td>
<td></td>
</tr>
</tbody>
</table>

a. Townsend area deprivation index was used.
b. Had ever seen a doctor or psychiatrist for nerves, anxiety or depression.
c. The UK guideline (14 UK units/wk) was used.
d. Sleep scores were categorized into: poor, 0–1; intermediate, 2–3; healthy, 4–5.
e. Categorization based on public health guidelines: no MVPA (those reported 0 MET-mins/wk from MVPA, regardless of total MET-mins/wk); low (< 600 MET-mins/wk); medium (600 to < 1200 MET-mins/wk); and high (≥ 1200 MET-mins/wk).
**Supplementary Table S6.** The Joint Association of Physical Activity and Sleep Scores with Mortality for All-Cause, Total Cardiovascular Disease, and Total Cancer (n = 380,055)

<table>
<thead>
<tr>
<th>Joint Category *</th>
<th>Guideline Physical Activity, Sleep Scores</th>
<th>Hazard Ratio for Mortality Risks (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All-cause</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total cardiovascular disease</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total cancer</td>
</tr>
<tr>
<td></td>
<td>Model 1 *</td>
<td>Model 2 *</td>
</tr>
<tr>
<td></td>
<td>Model 1 *</td>
<td>Model 2 *</td>
</tr>
<tr>
<td></td>
<td>Model 1 *</td>
<td>Model 2 *</td>
</tr>
<tr>
<td></td>
<td>Model 1 *</td>
<td>Model 2 *</td>
</tr>
<tr>
<td></td>
<td>Model 1 *</td>
<td>Model 2 *</td>
</tr>
<tr>
<td>No MVPA, Poor</td>
<td>2.18</td>
<td>1.57</td>
</tr>
<tr>
<td>(n = 2,510)</td>
<td>(1.88, 2.52)</td>
<td>(1.35, 1.82)</td>
</tr>
<tr>
<td>No MVPA, Intermediate</td>
<td>1.56</td>
<td>1.33</td>
</tr>
<tr>
<td>(n = 28,289)</td>
<td>(1.48, 1.65)</td>
<td>(1.25, 1.40)</td>
</tr>
<tr>
<td>No MVPA, Healthy</td>
<td>1.3</td>
<td>1.22</td>
</tr>
<tr>
<td>(n = 28,742)</td>
<td>(1.22, 1.38)</td>
<td>(1.15, 1.30)</td>
</tr>
<tr>
<td>Low, Poor</td>
<td>1.8</td>
<td>1.46</td>
</tr>
<tr>
<td>(n = 1,291)</td>
<td>(1.44, 2.24)</td>
<td>(1.17, 1.83)</td>
</tr>
<tr>
<td>Low, Intermediate</td>
<td>1.24</td>
<td>1.13</td>
</tr>
<tr>
<td>(n = 17,757)</td>
<td>(1.15, 1.34)</td>
<td>(1.05, 1.22)</td>
</tr>
<tr>
<td>Low, Healthy</td>
<td>1.04</td>
<td>1.05</td>
</tr>
<tr>
<td>(n = 20,250)</td>
<td>(0.96, 1.12)</td>
<td>(0.97, 1.13)</td>
</tr>
<tr>
<td>Medium, Poor</td>
<td>1.33</td>
<td>1.15</td>
</tr>
<tr>
<td>(n = 1,384)</td>
<td>(1.05, 1.69)</td>
<td>(0.90, 1.46)</td>
</tr>
<tr>
<td>Medium, Intermediate</td>
<td>1.19</td>
<td>1.11</td>
</tr>
<tr>
<td>(n = 24,110)</td>
<td>(1.12, 1.28)</td>
<td>(1.04, 1.19)</td>
</tr>
<tr>
<td>Medium, Healthy</td>
<td>1.04</td>
<td>1.04</td>
</tr>
<tr>
<td>(n = 32,277)</td>
<td>(0.97, 1.11)</td>
<td>(0.98, 1.11)</td>
</tr>
<tr>
<td>High, Poor</td>
<td>1.44</td>
<td>1.21</td>
</tr>
<tr>
<td>(n = 4,981)</td>
<td>(1.27, 1.63)</td>
<td>(1.06, 1.37)</td>
</tr>
<tr>
<td>High, Intermediate</td>
<td>1.12</td>
<td>1.03</td>
</tr>
<tr>
<td>(n = 87,947)</td>
<td>(1.07, 1.17)</td>
<td>(0.99, 1.08)</td>
</tr>
<tr>
<td>High, Healthy</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>(n = 130,517)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Physical activity levels were categorized based on public health guidelines: No MVPA (those reported 0 MET-mins/wk from MVPA, regardless of total MET-mins/wk); low (< 600 MET-mins/wk); medium (600 to < 1200 MET-mins/wk); and high (≥ 1200 MET-mins/wk). Sleep scores were categorized into: poor, 0–1; intermediate, 2–3; healthy, 4–5.

b Adjusted for age and sex.

* Further adjusted for body mass index, socioeconomic status, vegetable and fruit intake, sedentary behaviour, mental health, cigarette smoking, employment status and alcohol consumption.
### Supplementary Table S7. The Joint Association of Physical Activity and Sleep Scores with Mortality for Sub-Type Conditions (n = 380,055)

<table>
<thead>
<tr>
<th>Joint Category</th>
<th>Coronary heart disease</th>
<th>Hemorrhagic stroke</th>
<th>Ischemic stroke</th>
<th>Lung cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazard Ratio for Mortality Risks (95% CI)</td>
<td>Hazard Ratio for Mortality Risks (95% CI)</td>
<td>Hazard Ratio for Mortality Risks (95% CI)</td>
<td>Hazard Ratio for Mortality Risks (95% CI)</td>
</tr>
<tr>
<td>Guideline Physical Activity, Sleep Scores</td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>No MVPA, Poor</td>
<td>2.70 (1.82, 4.00)</td>
<td>1.59 (2.20)</td>
<td>1.95 (1.07, 3.37)</td>
<td>1.63</td>
</tr>
<tr>
<td>(n = 2,510)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No MVPA, Intermediate</td>
<td>2.11 (1.81, 2.46)</td>
<td>1.63 (1.40, 1.91)</td>
<td>1.48 (1.02, 2.10)</td>
<td>1.35</td>
</tr>
<tr>
<td>(n = 28,289)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No MVPA, Healthy</td>
<td>1.47 (1.23, 1.76)</td>
<td>1.31 (1.09, 1.56)</td>
<td>1.24 (0.83, 1.84)</td>
<td>1.20</td>
</tr>
<tr>
<td>(n = 28,742)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low, Poor</td>
<td>3.09 (1.45, 5.15)</td>
<td>2.20 (1.31, 3.69)</td>
<td>0.94 (0.13, 6.75)</td>
<td>0.86</td>
</tr>
<tr>
<td>(n = 1,291)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low, Intermediate</td>
<td>1.34 (1.07, 1.66)</td>
<td>1.15 (0.92, 1.44)</td>
<td>0.91 (0.52, 1.62)</td>
<td>0.89</td>
</tr>
<tr>
<td>(n = 17,757)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low, Healthy</td>
<td>1.22 (1.20, 1.45)</td>
<td>1.13 (0.90, 1.43)</td>
<td>0.84 (0.64, 1.28)</td>
<td>0.79</td>
</tr>
<tr>
<td>(n = 20,250)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium, Poor</td>
<td>1.22 (0.58, 2.57)</td>
<td>0.96 (0.46, 2.03)</td>
<td>0.84 (0.12, 5.99)</td>
<td>0.79</td>
</tr>
<tr>
<td>(n = 1,384)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium, Intermediate</td>
<td>1.24 (1.02, 1.51)</td>
<td>1.12 (0.92, 1.36)</td>
<td>0.84 (0.74, 1.79)</td>
<td>0.80</td>
</tr>
<tr>
<td>(n = 24,110)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium, Healthy</td>
<td>1.02 (1.24, 1.57)</td>
<td>1.12 (1.02, 1.36)</td>
<td>1.01 (0.74, 1.79)</td>
<td>1.03</td>
</tr>
<tr>
<td>(n = 32,277)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High, Poor</td>
<td>1.57 (1.10, 2.33)</td>
<td>1.17 (1.02, 1.36)</td>
<td>1.16 (0.84, 1.54)</td>
<td>1.03</td>
</tr>
<tr>
<td>(n = 4,981)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High, Intermediate</td>
<td>1.31 (1.10, 2.23)</td>
<td>1.17 (1.02, 1.36)</td>
<td>1.11 (0.85, 1.73)</td>
<td>1.05</td>
</tr>
<tr>
<td>(n = 32,277)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High, Healthy</td>
<td>1.16 (1.07, 1.28)</td>
<td>1.14 (1.02, 1.36)</td>
<td>0.84 (0.85, 1.73)</td>
<td>0.79</td>
</tr>
<tr>
<td>(n = 37,947)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Physical activity levels were categorized based on public health guidelines: No MVPA (those reported 0 MET-mins/wk from MVPA, regardless of total MET-mins/wk); low (< 600 MET-mins/wk); medium (600 to < 1200 MET-mins/wk); and high (≥ 1200 MET-mins/wk). Sleep scores were categorized into: poor, 0–1; intermediate, 2–3; healthy, 4–5.

b Adjusted for age and sex.

c Further adjusted for body mass index, socioeconomic status, vegetable and fruit intake, sedentary behaviour, mental health, cigarette smoking, employment status and alcohol consumption.
## Supplementary Table S8. Analyses on Interaction of Sleep Scores and Physical Activity with Mortality Risks for All-Cause, Total Cardiovascular Disease, and Total Cancer (n = 380,055)

<table>
<thead>
<tr>
<th></th>
<th>Healthy Sleep</th>
<th>Intermediate and Poor Sleep</th>
<th>Hazard Ratio (95% CI) for Sleep Scores within Strata of Physical Activity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N With/Without Events</td>
<td>Hazard Ratio (95% CI)</td>
<td>N With/Without Events</td>
</tr>
<tr>
<td><strong>All-cause death</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any MVPA</td>
<td>6,526/183,044</td>
<td>1.00</td>
<td>5,927/137,470</td>
</tr>
<tr>
<td>No MVPA</td>
<td>1,293/28,742</td>
<td><strong>1.20 (1.13, 1.28)</strong></td>
<td>1.757/30,799</td>
</tr>
<tr>
<td>Hazard Ratio (95% CI) for No MVPA within Strata of Sleep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>P &lt; .0001</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total cardiovascular disease death</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any MVPA</td>
<td>1,644/183,044</td>
<td>1.00</td>
<td>1,601/137,470</td>
</tr>
<tr>
<td>No MVPA</td>
<td>325/28,742</td>
<td><strong>1.19 (1.05, 1.34)</strong></td>
<td>525/30,799</td>
</tr>
<tr>
<td>Hazard Ratio (95% CI) for No MVPA within Strata of Sleep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>P = 0.0050</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total cancer death</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any MVPA</td>
<td>3,945/183,044</td>
<td>1.00</td>
<td>3,431/137,470</td>
</tr>
<tr>
<td>No MVPA</td>
<td>738/28,742</td>
<td><strong>1.13 (1.04, 1.22)</strong></td>
<td>9,50/30,799</td>
</tr>
<tr>
<td>Hazard Ratio (95% CI) for No MVPA within Strata of Sleep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>P = .0033</strong></td>
<td></td>
</tr>
</tbody>
</table>

Measure of interaction on additive scale: for all-cause death, RERI (95% CI) = 0.07 (-0.03, 0.16), AP (95% CI) = 0.05 (-0.02, 0.12), and S = 1.26 (0.89, 1.79); for cardiovascular diseases death, RERI (95% CI) = 0.21 (0.01, 0.40), AP (95% CI) = 0.14 (0.02, 0.26), and S = 1.76 (0.93, 3.31); for total cancers death, RERI (95% CI) = 0.05 (-0.07, 0.18), AP (95% CI) = 0.05 (-0.05, 0.14), and S = 1.34 (0.66, 2.73).

Measure of interaction on multiplicative scale: for all-cause death, hazard ratios (HR) (95% CI) = 1.25 (1.19, 1.32), P < .0001; for cardiovascular diseases death, HR (95% CI) = 1.36 (1.23, 1.51), P < .0001; for total cancers death, HR (95% CI) = 1.17 (1.09, 1.26), P < .0001.

a Sleep scores were categorized into: poor, 0-1; intermediate, 2-3; healthy, 4-5.

b Physical activity levels were categorized based on MET-mins/wk from MVPA, regardless of total MET-mins/wk.

c Hazard ratios were adjusted for age, sex, body mass index, socioeconomic status, vegetable and fruit intake, sedentary behaviour, mental health, cigarette smoking, employment status and alcohol consumption.
## Supplementary Table S9. Analyses on Interaction of Sleep Scores \( ^a \) and Physical Activity \( ^b \) with Sub-Type Conditions Mortality (n = 380,055)

| Measure of interaction on additive scale: for coronary heart diseases death, RERI (95% CI) = 0.04 (-0.56, 0.64), AP (95% CI) = -0.03 (-0.39, 0.45), and S = 1.12 (0.24, 5.31); for ischemic stroke death, RERI (95% CI) = 0.23 (-0.06, 0.53), AP (95% CI) = 0.16 (-0.03, 0.35), and S = 2.01 (0.63, 6.35). | Measure of interaction on multiplicative scale: for coronary heart diseases death, HR (95% CI) = 1.39 (1.21, 1.60), \( P < .0001 \); for hemorrhagic stroke death, HR (95% CI) = 1.33 (0.93, 1.90), \( P = 0.1211 \); for ischemic stroke death, hazard ratios (HR) (95% CI) = 1.26 (0.92, 1.73), \( P = 0.1438 \); for lung cancer death, HR (95% CI) = 1.43 (1.22, 1.67), \( P < .0001 \). | \( a \) Sleep scores were categorized into: poor, 0~1; intermediate, 2~3; healthy, 4~5. | \( b \) Physical activity levels were categorized based on MET-mins/wk from MVPA, regardless of total MET-mins/wk. | \( c \) Hazard ratios were adjusted for age, sex, body mass index, socioeconomic status, vegetable and fruit intake, sedentary behaviour, mental health, cigarette smoking, employment status and alcohol consumption. |

<table>
<thead>
<tr>
<th>Healthy Sleep</th>
<th>Intermediate</th>
<th>Poor Sleep</th>
<th>Hazard Ratio (95% CI) for Sleep Scores within Strata of Physical Activity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>N With/Without Events</td>
<td>N With/Without Events</td>
<td>N With/Without Events</td>
<td>Hazard Ratio (95% CI) for No MVPA within Strata of Sleep</td>
</tr>
<tr>
<td>Coronary heart diseases death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any MVPA</td>
<td>733/183,044</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>No MVPA</td>
<td>155/28,742</td>
<td>1.28 (1.08, 1.52)</td>
<td>1.28 (1.08, 1.52)</td>
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<tr>
<td>Hemorrhagic stroke death</td>
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</tr>
<tr>
<td>Any MVPA</td>
<td>158/183,044</td>
<td>1.18 (0.80, 1.75)</td>
<td>1.28 (1.08, 1.52)</td>
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<tr>
<td>No MVPA</td>
<td>31/28,742</td>
<td>1.35 (0.95, 1.93)</td>
<td>1.35 (0.95, 1.93)</td>
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<tr>
<td>Ischemic stroke death</td>
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<tr>
<td>Any MVPA</td>
<td>184/183,044</td>
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<td>1.25 (0.88, 1.79)</td>
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<tr>
<td>No MVPA</td>
<td>37/28,742</td>
<td>1.42 (1.03, 1.94)</td>
<td>1.42 (1.03, 1.94)</td>
</tr>
<tr>
<td>Lung cancer death</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Any MVPA</td>
<td>626/183,044</td>
<td>1.21 (1.00, 1.45)</td>
<td>1.21 (1.00, 1.45)</td>
</tr>
<tr>
<td>No MVPA</td>
<td>138/28,742</td>
<td>1.21 (1.00, 1.45)</td>
<td>1.21 (1.00, 1.45)</td>
</tr>
</tbody>
</table>

Supplementary Table S9. Analyses on Interaction of Sleep Scores \( ^a \) and Physical Activity \( ^b \) with Sub-Type Conditions Mortality (n = 380,055)