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# Association of wearable device-measured vigorous intermittent lifestyle physical activity with mortality

In the format provided by the authors and unedited

**Device-measured vigorous intermittent lifestyle physical activity and mortality: the UK Biobank**

# Supplementary Material

| **Supplementary Table1:** Exercisers' characteristics by average daily frequency of (exercise or non-exercise) vigorous intensity physical activity (VPA) bouts (n=62,344) | | | | | |
|---|---|---|---|---|---|
| | **Number of VPA bouts lasting up to two minutes per day** | | | | |
| | 0 | 1 to 2 | 3 to 4 | >=4 | Overall |
| n | 4,281 | 15,380 | 21,908 | 20,775 | 62,344 |
| Follow up, yrs | 6.9 (0.9) | 6.9 (0.8) | 6.9 (0.7) | 7.0 (0.7) | 6.9 (0.8) |
| Age, mean (SD) | 65.2 (7.0) | 63.1 (7.6) | 61.1 (7.8) | 58.9 (7.8) | 61.1 (7.9) |
| Male, n (%) | 1,249 (29.2) | 5,242 (34.1) | 9,551 (43.6) | 11,012 (53.0) | 27,054 (43.4) |
| Ethnicity, n (%) | | | | | |
| Asian | 37 (0.9) | 137 (0.9) | 222 (1.0) | 247 (1.2) | 643 (1.0) |
| Black | 21 (0.5) | 92 (0.6) | 141 (0.6) | 187 (0.9) | 441 (0.7) |
| Mixed | 14 (0.3) | 69 (0.4) | 106 (0.5) | 129 (0.6) | 318 (0.5) |
| Other | 28 (0.7) | 111 (0.7) | 155 (0.7) | 184 (0.9) | 478 (0.8) |
| White | 4,181 (97.7) | 14,971 (97.3) | 21,284 (97.2) | 20,028 (96.4) | 60,464 (97.0) |
| Smoking history, n (%) | | | | | |
| Current | 299 (7.0) | 980 (6.4) | 1,264 (5.8) | 1,066 (5.1) | 3,609 (5.8) |
| Previous | 1,598 (37.3) | 5,755 (37.4) | 8,033 (36.7) | 7,104 (34.2) | 22,490 (36.1) |
| Never | 2,384 (55.7) | 8,645 (56.2) | 12,611 (57.6) | 12,605 (60.7) | 36,245 (58.1) |
| Body Mass Index | 28.3 (5.2) | 27.2 (4.6) | 26.2 (4.0) | 25.3 (3.6) | 26.3 (4.2) |
| Alcohol consumption, n (%)[1] | | | | | |
| Never | 151 (3.5) | 460 (3.0) | 485 (2.2) | 470 (2.3) | 1,566 (2.5) |
| Ex-drinker | 157 (3.7) | 406 (2.6) | 515 (2.4) | 443 (2.1) | 1,521 (2.4) |
| Within guidelines | 2,680 (62.6) | 8,987 (58.4) | 12,151 (55.5) | 11,213 (54.0) | 35,031 (56.2) |
| Above guidelines | 1,293 (30.2) | 5,527 (35.9) | 8,757 (40.0) | 8,649 (41.6) | 24,226 (38.9) |
| Education, n (%) | | | | | |
| College | 1,773 (41.4) | 6,861 (44.6) | 10,117 (46.2) | 10,103 (48.6) | 28,854 (46.3) |
| A/AS level | 538 (12.6) | 2,002 (13.0) | 3,020 (13.8) | 2,748 (13.2) | 8,308 (13.3) |

| | | | | | |
|---|---|---|---|---|---|
| O level | 883 (20.6) | 3,148 (20.5) | 4,285 (19.6) | 3,963 (19.1) | 12,279 (19.7) |
| CSE | 118 (2.8) | 442 (2.9) | 753 (3.4) | 814 (3.9) | 2,127 (3.4) |
| NVQ/HND/HNC | 220 (5.1) | 729 (4.7) | 1,092 (5.0) | 1,036 (5.0) | 3,077 (4.9) |
| Other | 749 (17.5) | 2,198 (14.3) | 2,641 (12.1) | 2,111 (10.2) | 7,699 (12.3) |
| Fruit and vegetable consumption, n (%)[2] | | | | | |
| High | 1,346 (31.4) | 4,784 (31.1) | 6,665 (30.4) | 6,436 (31.0) | 19,231 (30.8) |
| Moderate | 1,920 (44.8) | 6,988 (45.4) | 9,804 (44.8) | 9,147 (44.0) | 27,859 (44.7) |
| Low | 1,015 (23.7) | 3,608 (23.5) | 5,439 (24.8) | 5,192 (25.0) | 15,254 (24.5) |
| Family history of CVD, n (%) | 2,575 (60.1) | 9,050 (58.8) | 11,934 (54.5) | 10,693 (51.5) | 34,252 (54.9) |
| Family history of cancer, n (%) | 1,130 (26.4) | 4,023 (26.2) | 5,567 (25.4) | 4,938 (23.8) | 15,658 (25.1) |
| Medication, n (%) | | | | | |
| Cholesterol | 925 (21.6) | 2,593 (16.9) | 2,778 (12.7) | 1,870 (9.0) | 8,166 (13.1) |
| Blood pressure | 1,167 (27.3) | 3,147 (20.5) | 3,177 (14.5) | 2,064 (9.9) | 9,555 (15.3) |
| Insulin | 51 (1.2) | 106 (0.7) | 104 (0.5) | 84 (0.4) | 345 (0.6) |
| Self-rated health, n (%) | | | | | |
| Poor | 149 (3.5) | 350 (1.2) | 268 (1.2) | 146 (0.7) | 913 (1.5) |
| Fair | 851 (19.9) | 2,459 (16.0) | 2,675 (12.2) | 1,851 (8.9) | 7,836 (12.6) |
| Good | 2,646 (61.8) | 9,495 (61.7) | 13,427 (61.3) | 12,207 (58.8) | 37,775 (60.6) |
| Excellent | 625 (14.6) | 3,049 (19.8) | 5,523 (25.2) | 6,558 (31.6) | 15,755 (25.2) |
| Sleep (hrs/day), median [IQR] | 7.4 [6.4, 8.2] | 7.3 [6.4, 8.1] | 7.4 [6.6, 8.1] | 7.4 [6.6, 8.1] | 7.4 [6.5, 8.1] |
| Acceleration magnitude [IQR][4] | 22.3 [18.6, 26.4] | 25.8 [22.0, 30.4] | 29.7 [25.5, 35.1] | 36.6 [31.2, 44.0] | 30.3 [25.0, 37.7] |
| Total activity (min/day), median [IQR][3] | 113.5 [76.3, 170.9] | 125.6 [90.0, 188.3] | 139.7 [106.9, 185.8] | 165.9 [147.4, 232.2] | 145.4 [99.7, 211.4] |
| Light activity (min/day), median [IQR] | 94.1 [62.9, 145.3] | 98.3 [67.6, 151.5] | 99.4 [71.3, 149.9] | 109.0 [79.0, 154.3] | 102.2 [72.2, 151.5] |
| Moderate activity (min/day), median [IQR] | 14.7 [7.9, 27.3] | 22.2 [12.8, 36.3] | 30.9 [19.3, 47.7] | 42.1 [27.4, 62.4] | 30.9 [18.0, 49.7] |

| | | | | | |
|---|---|---|---|---|---|
| Vigorous activity (min/day), median [IQR] | - | 1.7 [1.0, 2.4] | 5.9 [4.9, 7.7] | 9.6 [9.1, 14.0] | 6.2 [2.4, 14.3] |
| Percent of total activity in vigorous activity [IQR] | - | 0.8 [0.3, 1.7] | 4.8 [3.1, 6.5] | 8.2 [6.9, 9.5] | 4.9 [1.7, 9.4] |
| VILPA bouts frequency (up to 1 minute duration), median [IQR] | - | 2.[1, 2] | 4 [3, 4] | 9 [8, 12] | 3 [2, 10] |
| VILPA bouts frequency (up to 2 minutes duration), median [IQR] | - | 2 [1, 2] | 4 [3, 4] | 10 [8, 13] | 4 [2, 11] |

Values represent mean (SD) unless specified otherwise.
[1]1 unit = 8g, above guidelines > 14 units/week
[2]Fruits and vegetables servings/day, low<5 servings/day, high>8 servings/day
[3] Duration of light, moderate, and vigorous intensity activity
[4]milligravity

**Supplementary Table 2:** Questions to assess participation in leisure time physical activity

| | |
|---|---|
| Types of physical activity in last 4 weeks UK Biobank Field ID: 6164: | • Walking for pleasure (not as a means of transport)<br>• Other exercises (eg: swimming, cycling, keep fit, bowling)<br>• Strenuous sports<br>• Light DIY (eg: pruning, watering the lawn)<br>• Heavy DIY (eg: weeding, lawn mowing, carpentry, digging)<br>• None of the above<br>• Prefer not to answer<br>• |
| Each time you did strenuous sports, about how long did you spend doing it? (UK Biobank field ID: 1001) | • Less than 15 minutes<br>• between 15 and 30 minutes<br>• between 30 minutes and 1 hour<br>• between 1 hour and 1.5 hours<br>• between 1.5 hours and 2 hours between 2 and 3 hours<br>• over 3 hours, do not know<br>• prefer not to answer |
| How many times in the last 4 weeks did you do strenuous sports? (UK Biobank field ID: 991) | • Once in the last 4 weeks<br>• 2-3 times in the last 4 weeks<br>• Once a week<br>• 2-3 times a week<br>• 4-5 times a week<br>• Every day<br>• Do not know<br>• Prefer not to answer |
| Each time you did other exercises such as swimming, cycling, keep fit, about how long did you spend doing it? (UK Biobank field ID: 3647) | • Less than 15 minutes<br>• between 15 and 30 minutes<br>• between 30 minutes and 1 hour<br>• between 1 hour and 1.5 hours<br>• between 1.5 hours and 2 hours between 2 and 3 hours<br>• over 3 hours, do not know<br>• prefer not to answer |
| How many times in the last 4 weeks did you do other exercises such as swimming, cycling, keep fit? (UK Biobank field ID: 3637) | • Once in the last 4 weeks<br>• 2-3 times in the last 4 weeks<br>• Once a week<br>• 2-3 times a week<br>• 4-5 times a week<br>• Every day<br>• Do not know<br>• Prefer not to answer |

| | |
|---|---|
| How many times in the last 4 weeks did you go walking for pleasure? (UK Biobank field ID: 971) | • Once in the last 4 weeks<br>• 2-3 times in the last 4 weeks<br>• Once a week<br>• 2-3 times a week<br>• 4-5 times a week<br>• Every day<br>• Do not know<br>• Prefer not to answer |

**Supplementary Table 3:** Covariate definitions

| **Variable** | **Definition** | **UK Biobank field ID (if applicable)** |
|---|---|---|
| Age | Continuous | 34, 52, accelerometer date-timestamp |
| Sex | Female/Male | 31 |
| Light intensity | Standing utilitarian movements, slow walking (<3 METs) | Derived from accelerometer data (see Online Methods) |
| Moderate intensity | Brisk walking, energetic activities (≥3 to <6 METs) | Derived from accelerometer data (see see Online Methods) |
| Frequency/duration of bouts above the specified bout in each frequency/duration analysis | Number of bouts above the specified bout in the analysis. Eg, for the analysis of bouts lasting up to 2 minutes in duration, this variable contained bouts/duration that were more than 2 minutes in duration | Derived from accelerometer data (see see Online Methods) |
| Smoking status | Never, past, current | 20116 |
| Alcohol consumption | Never, ex-drinker, within guidelines, above guidelines | 20117, 1558 |
| Sleep duration | Hours spent sleeping | Derived from accelerometer data (see Online Methods) |
| Diet | Fruits and vegetables servings/day, categorised as low (<5 servings/day), moderate (5 to 8 servings/day) and high (>8 servings/day) | 1309, 1319, 1289, 1299 |
| Prevalent cancer | Identified by self-report and cancer registry | 20001, 100092 |
| Prevalent CVD | Identified by self-report and hospitalisation | 20002, 2000 |
| Education | College/University; A/AS level; O levels; CSE; NVQ/HND/HNC; other | 6138 |

| | | |
|---|---|---|
| Parental history of CVD | Self-reported mother or father diagnosed with heart disease or stroke | 20107, 20110 |
| Use of cholesterol medication | Yes/No | 6177, 6153 |
| Use of blood pressure medication | Yes/No | 6177, 6153 |
| Use of diabetes medication | Yes/No | 6177, 6153 |

**Supplementary Table 4:** Hazard ratios associated with the minimum dose and median and maximum VILPA values among non-exercisers for up to 1 and up to 2 minute bouts

A. All-cause mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 1 min bout minimum dose | 1.5 | 0.75 | 0.66 | 0.85 |
| up to 1 min bout VILPA median dose | 3.0 | 0.61 | 0.50 | 0.74 |
| up to 1 min bout VILPA maximum dose | 11.0 | 0.52 | 0.37 | 0.72 |
| | | | | |
| up to 2 min bout minimum dose | 1.4 | 0.76 | 0.68 | 0.86 |
| up to 2 min bout VILPA median dose | 3.0 | 0.62 | 0.51 | 0.76 |
| up to 2 min bout VILPA maximum dose | 11.0 | 0.52 | 0.38 | 0.71 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 1 min bout minimum dose | 3.4 | 0.78 | 0.70 | 0.88 |
| up to 1 min bout median VILPA dose | 4.4 | 0.73 | 0.63 | 0.85 |
| up to 1 min bout VILPA maximum dose | 16.0 | 0.59 | 0.46 | 0.74 |
| | | | | |
| up to 2 min bout minimum dose | 4.1 | 0.77 | 0.68 | 0.87 |
| up to 2 min bout median VILPA dose | 4.4 | 0.74 | 0.65 | 0.85 |
| up to 2 min bout VILPA maximum dose | 16.0 | 0.57 | 0.45 | 0.71 |

Minimal dose (ED50 value): defined as the duration/frequency of VILPA associated with 50% of the optimal risk reduction. The VILPA duration and frequency median values were calculated in the sample excluding participants with zero VILPA. Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent cancer and CVD. All analyses were additionally adjusted for vigorous physical activity duration/frequency lasting more than one/two minute as appropriate.

B. Cardiovascular disease mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 1 min bout minimum dose | 1.4 | 0.67 | 0.52 | 0.86 |
| up to 1 min bout VILPA median | 3.0 | 0.51 | 0.35 | 0.74 |
| up to 1 min bout VILPA maximum | 11.0 | 0.35 | 0.15 | 0.81 |
| | | | | |
| up to 2 min bout minimum dose | 1.5 | 0.67 | 0.52 | 0.87 |
| up to 2 min bout VILPA median | 3.0 | 0.52 | 0.36 | 0.75 |
| up to 2 min bout VILPA maximum | 11.0 | 0.35 | 0.16 | 0.78 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 1 min bout minimum dose | 3.4 | 0.73 | 0.58 | 0.91 |
| up to 1 min bout VILPA median | 4.4 | 0.66 | 0.50 | 0.88 |
| up to 1 min bout VILPA maximum | 16.0 | 0.45 | 0.29 | 0.72 |
| | | | | |
| up to 2 min bout minimum dose | 4.1 | 0.72 | 0.57 | 0.91 |
| up to 2 min bout VILPA median | 4.4 | 0.68 | 0.52 | 0.89 |
| up to 2 min bout VILPA maximum | 16.0 | 0.45 | 0.30 | 0.69 |

Minimal dose (ED50 value): defined as the duration/frequency of VILPA associated with 50% of the optimal risk reduction. The VILPA duration and frequency median values were calculated in the sample excluding participants with zero VILPA. Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent cancer. All analyses were additionally adjusted for vigorous physical activity duration/bouts lasting more than one/two minute as appropriate.

C. Cancer mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 1 min bout minimum dose | 1.5 | 0.75 | 0.63 | 0.88 |
| up to 1 min bout VILPA median | 3.0 | 0.60 | 0.46 | 0.78 |
| up to 1 min bout VILPA maximum | 11.0 | 0.49 | 0.31 | 0.75 |
| | | | | |
| up to 2 min bout minimum dose | 1.6 | 0.74 | 0.62 | 0.88 |
| up to 2 min bout VILPA median | 3.0 | 0.62 | 0.48 | 0.80 |
| up to 2 min bout VILPA maximum | 11.0 | 0.49 | 0.32 | 0.74 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 1 min bout minimum dose | 3.4 | 0.76 | 0.66 | 0.87 |
| up to 1 min bout VILPA median | 4.4 | 0.70 | 0.59 | 0.84 |
| up to 1 min bout VILPA maximum | 16.0 | 0.51 | 0.38 | 0.69 |
| | | | | |
| up to 2 min bout minimum dose | 4.1 | 0.74 | 0.63 | 0.85 |
| up to 2 min bout VILPA median | 4.4 | 0.70 | 0.60 | 0.83 |
| up to 2 min bout VILPA maximum | 16.0 | 0.50 | 0.38 | 0.66 |

Minimal dose (ED50 value): defined as the duration/frequency of VILPA associated with 50% of the optimal risk reduction. The VILPA duration and frequency median values were calculated in the sample excluding participants with zero VILPA. Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent CVD. All analyses were additionally adjusted for vigorous physical activity duration/bouts lasting more than one/two minute as appropriate.

**Supplementary Table 5**: E-values for minimum dose, and median/maximum VILPA values for all-cause, cardiovascular disease mortality, and cancer mortality

A. All-cause mortality

| Frequency | E-Value |
|---|---|
| | |
| up to 1 min bout minimum dose | 2.01 (1.64) |
| up to 1 min bout VILPA median | 2.66 (2.04) |
| up to 1 min bout VILPA maximum | 3.26 (2.12) |
| up to 2 min bout minimum dose | 1.95 (1.60) |
| up to 2 min bout VILPA median | 2.61 (1.96) |
| up to 2 min bout VILPA maximum | 3.26 (2.17) |
| | |
| Duration | |
| | |
| up to 1 min bout minimum dose | 1.87 (1.54) |
| up to 1 min bout VILPA median | 2.08 (1.63) |
| up to 1 min bout VILPA maximum | 2.78 (2.04) |
| up to 2 min bout minimum dose | 1.92 (1.56) |
| up to 2 min bout VILPA median | 2.04 (1.63) |
| up to 2 min bout VILPA maximum | 2.90 (2.17) |
| | |

B. Cardiovascular disease mortality

| Frequency | E-value |
|---|---|
| | |
| up to 1 min bout minimum dose | 2.34 (1.60) |
| up to 1 min bout VILPA median | 3.33 (2.04) |
| up to 1 min bout VILPA maximum | 5.16 (1.77) |
| up to 2 min bout minimum dose | 2.34 (1.58) |
| up to 2 min bout VILPA median | 3.26 (2.00) |
| up to 2 min bout VILPA maximum | 5.16 (1.88) |
| | |
| Duration | |
| | |
| up to 1 min bout minimum dose | 2.10 (1.44) |
| up to 1 min bout VILPA median | 2.40 (1.53) |
| up to 1 min bout VILPA maximum | 3.87 (2.12) |
| up to 2 min bout minimum dose | 2.14 (1.44) |
| up to 2 min bout VILPA median | 2.30 (1.50) |
| up to 2 min bout VILPA maximum | 3.87 (2.26) |

C. Cancer mortality

| Frequency | E-value |
|---|---|
| | |
| up to 1 min bout minimum dose | 2.02 (1.53) |
| up to 1 min bout VILPA median | 2.72 (1.88) |
| up to 1 min bout VILPA maximum | 3.50 (2.00) |
| up to 2 min bout minimum dose | 2.05 (1.53) |
| up to 2 min bout VILPA median | 2.61 (1.81) |
| up to 2 min bout VILPA maximum | 3.50 (2.04) |
| | |
| Duration | |
| | |
| up to 1 min bout minimum dose | 1.97 (1.56) |
| up to 1 min bout VILPA median | 2.21 (1.67) |
| up to 1 min bout VILPA maximum | 3.33 (2.26) |
| up to 2 min bout minimum dose | 2.04 (1.63) |
| up to 2 min bout VILPA median | 2.21 (1.70) |
| up to 2 min bout VILPA maximum | 3.41 (2.40) |

Values represent: point estimate (and lower limit of the confidence interval in brackets) that an unmeasured confounder would need to have with both the exposure and outcome, conditional on the measured covariates to explain away the exposure-outcome association.

**Supplementary Table 6:** Hazard ratios associated with the minimum dose and median and maximum VPA values among exercisers for up to 2 minute bouts

All-cause mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 2 min bout minimum dose | 1.7 | 0.76 | 0.70 | 0.82 |
| up to 2 min bout VILPA median dose | 4.0 | 0.59 | 0.51 | 0.68 |
| up to 2 min bout VILPA maximum dose | 14.0 | 0.53 | 0.43 | 0.65 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 2 min bout minimum dose | 4.8 | 0.78 | 0.72 | 0.84 |
| up to 2 min bout median VILPA dose | 6.2 | 0.73 | 0.67 | 0.80 |
| up to 2 min bout VILPA maximum dose | 18.0 | 0.58 | 0.49 | 0.67 |

Cardiovascular disease mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 2 min bout minimum dose | 1.6 | 0.63 | 0.54 | 0.73 |
| up to 2 min bout VILPA median dose | 4.0 | 0.39 | 0.29 | 0.52 |
| up to 2 min bout VILPA maximum dose | 14.0 | 0.27 | 0.16 | 0.46 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 2 min bout minimum dose | 4.4 | 0.67 | 0.57 | 0.79 |
| up to 2 min bout median VILPA dose | 6.2 | 0.58 | 0.47 | 0.72 |
| up to 2 min bout VILPA maximum dose | 18.0 | 0.34 | 0.23 | 0.51 |

Cancer mortality

| Frequency | Dose | HR | Lower 95 CI | Upper 95 CI |
|---|---|---|---|---|
| up to 2 min bout minimum dose | 1.7 | 0.76 | 0.69 | 0.84 |
| up to 2 min bout VILPA median dose | 4.0 | 0.59 | 0.49 | 0.71 |
| up to 2 min bout VILPA maximum dose | 14.0 | 0.53 | 0.41 | 0.69 |
| | | | | |
| Duration | Dose | HR | Lower 95 CI | Upper 95 CI |
| up to 2 min bout minimum dose | 5.0 | 0.77 | 0.70 | 0.85 |
| up to 2 min bout median VILPA dose | 6.2 | 0.73 | 0.65 | 0.82 |
| up to 2 min bout VILPA maximum dose | 18.0 | 0.55 | 0.44 | 0.67 |

Minimal dose (ED50 value): defined as the duration/frequency of VPA associated with 50% of the optimal risk reduction. The VPA duration and frequency median values were calculated in the sample excluding participants with zero VPA. Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent cancer and CVD. All analyses were additionally adjusted for vigorous physical activity duration/frequency lasting more than two minutes.

**Supplementary Table 7:** Mean durations to reach vigorous intensity across five activities (unpublished data)

| | $\%HR_{max}$ | $\%VO_{2max}$ | Rating of perceived exertion |
|---|---|---|---|
| Walking at a fast pace on a flat surface | 76.2 (22.9) sec. | 71.5 (18.9) sec | 53.6 (19.7) sec |
| Walking at a fast pace carrying 5% of body weight | 64.4 (32.4) sec | 60.8 (25.2) sec | 44.1 (23.7) sec |
| Walking at a fast pace carrying 10% of body weight | 73.1 (34.6) sec | 68.8 (21.3) sec | 40.1 (20.3) sec |
| Walking at a fast pace on a 2.5% incline | 85.4 (20.3) sec | 83.0 (20.2) sec | 66.8 (21.3) sec |
| Walking at a fast pace on a 7.0% incline | 80.3 (28.0) sec | 75.7 (15.8) sec | 63.6 (21.9) sec |

**Supplementary Table 8**: Intensity classification performance in 98 US and Australian adults

| | Sensitivity | Specificity | Precision | F-score | Overall Accuracy | Weighted Kappa | Overall F-score |
|---|---|---|---|---|---|---|---|
| Sedentary | 86.5 | 93.7 | 90.5 | 88.5 | | | |
| Light | 71.2 | 89.4 | 55.8 | 62.6 | | | |
| Moderate | 85.4 | 96.6 | 92.7 | 88.9 | | | |
| Vigorous | 95.4 | 99.4 | 94.6 | 95.0 | | | |
| | | | | | 84.6 | 0.78 | 83.8 |

**Supplementary Table 9**: Confusion matrix of activity classification in 98 US and Australian adults

| | Sedentary | Light | Moderate | Vigorous |
|---|---|---|---|---|
| Sedentary | **36,904** | 5,232 | 508 | 2 |
| Light | 3,120 | **11,712** | 1,612 | 17 |
| Moderate | 502 | 4,016 | **29,528** | 526 |
| Vigorous | 226 | 17 | 214 | **9,470** |

Rows= ground truth; columns=predictions; bold=correct labels; numbers represent each 10-second window; Derived from the US and Australian datasets

**Supplementary Table 10:** STROBE Statement

| | Item No | Recommendation | Page No |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 1, 2 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 3 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 3, 4 |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | 17-19 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 17-19 |
| Participants | 6 | (*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br><br>*Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br><br>*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants | 17, Figure 1 |
| | | (*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed<br><br>*Case-control study*—For matched studies, give matching criteria and the number of controls per case | NA |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 17-20 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 17-20 |

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| Bias | 9 | Describe any efforts to address potential sources of bias | 19-20 |
| Study size | 10 | Explain how the study size was arrived at | Figure 1 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 19-20 |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 19-20 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | NA |
| | | (*c*) Explain how missing data were addressed | 17 |
| | | (*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed<br><br>*Case-control study*—If applicable, explain how matching of cases and controls was addressed<br><br>*Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy | NA |
| | | (*e*) Describe any sensitivity analyses | 19-20 |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Figure 1 |
| | | (b) Give reasons for non-participation at each stage | Figure 1 |
| | | (c) Consider use of a flow diagram | Figure 1 |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Table 1 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Figure 1 |
| | | (c) *Cohort study*—Summarise follow-up time (eg, average and total amount) | 3 |
| Outcome data | 15* | *Cohort study*—Report numbers of outcome events or summary measures over time | 3, Table 1, Figures 1-4 |
| | | *Case-control study*—Report numbers in each exposure category, or summary measures of exposure | *NA* |

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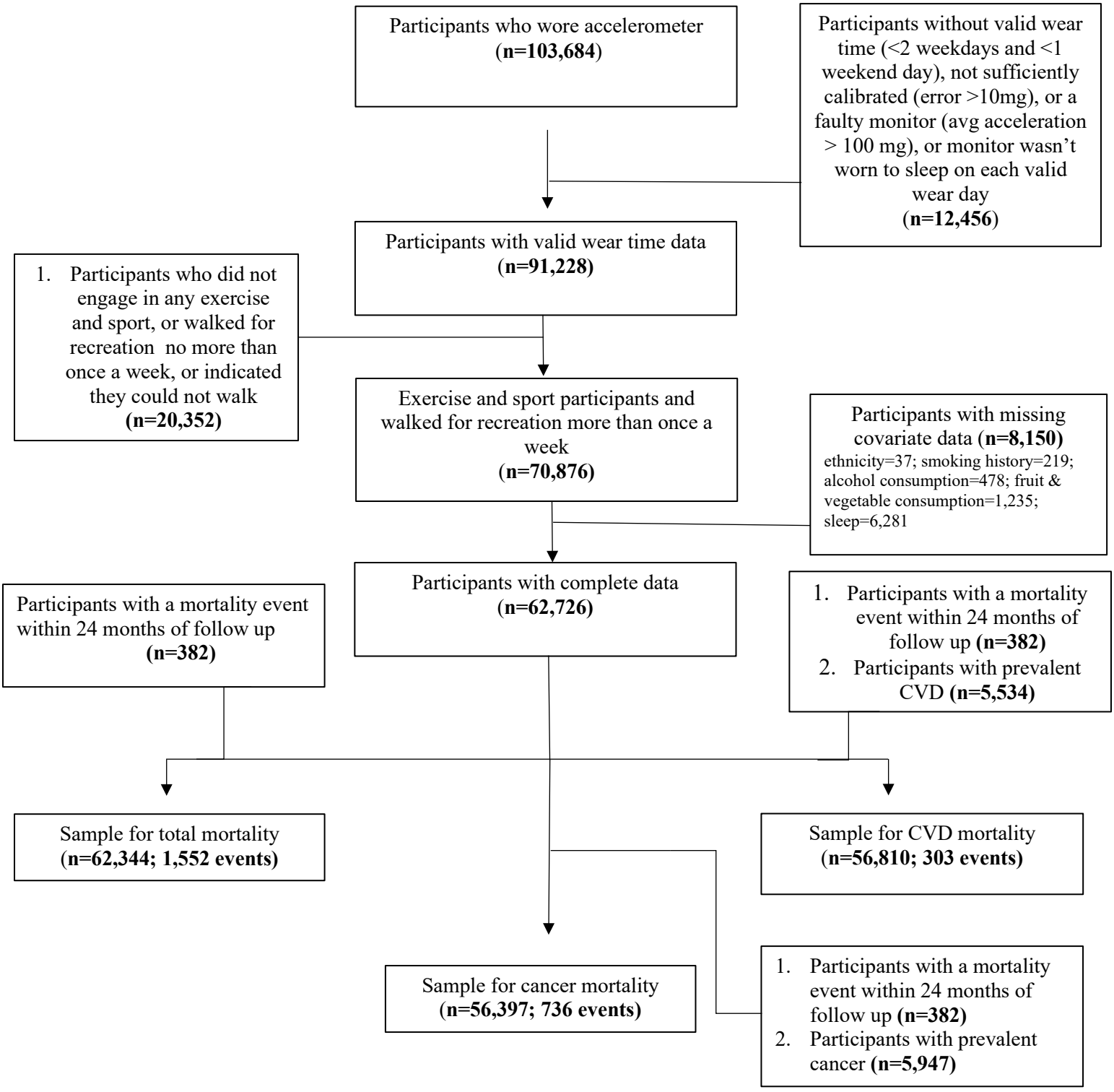
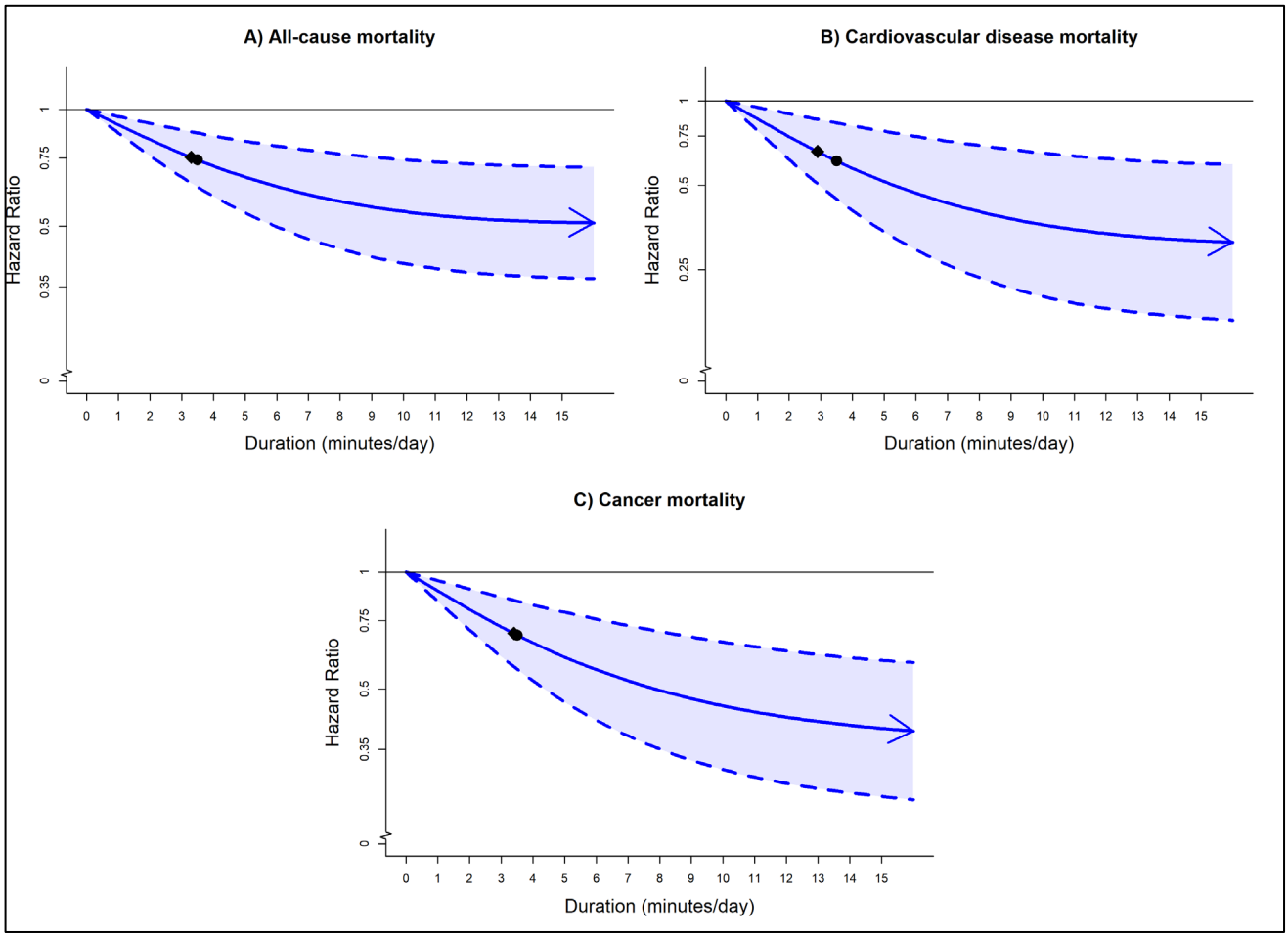
| | | *Cross-sectional study*—Report numbers of outcome events or summary measures | *NA* |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 3-6, Figures 2-4 |
| | | (*b*) Report category boundaries when continuous variables were categorized | NA |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | NA |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 5-6 |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 6 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 7-8 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 6-8 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 6, 8 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 8 |
| | | | |

**Supplementary Figure 1:** Flow diagram of exercisers

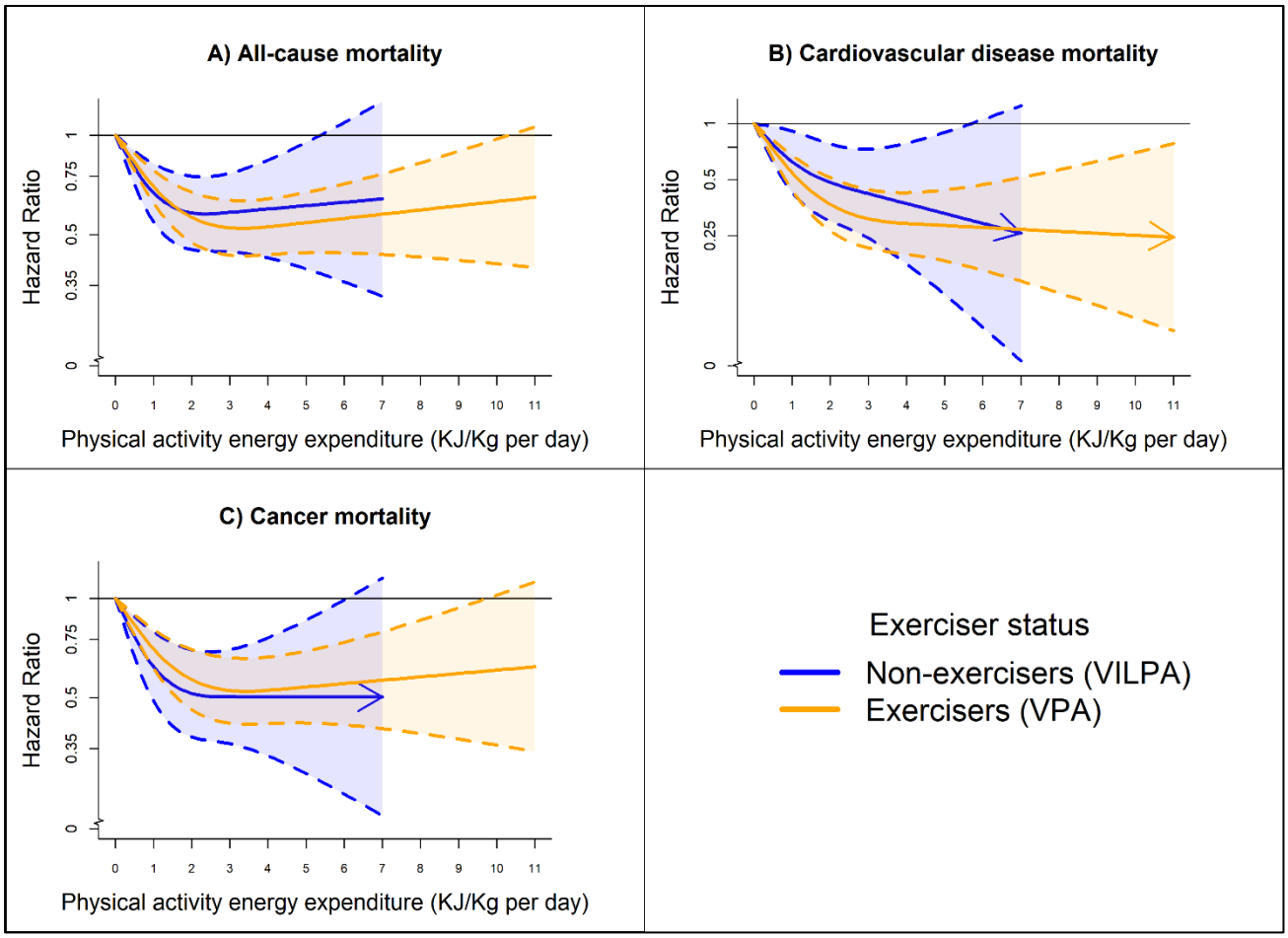


**Supplementary Figure 2:** Dose-response association of daily duration of vigorous intermittent lifestyle physical activity (VILPA) duration of bouts up to 2 minutes among those who reported no leisure time exercise and *no* recreational walking



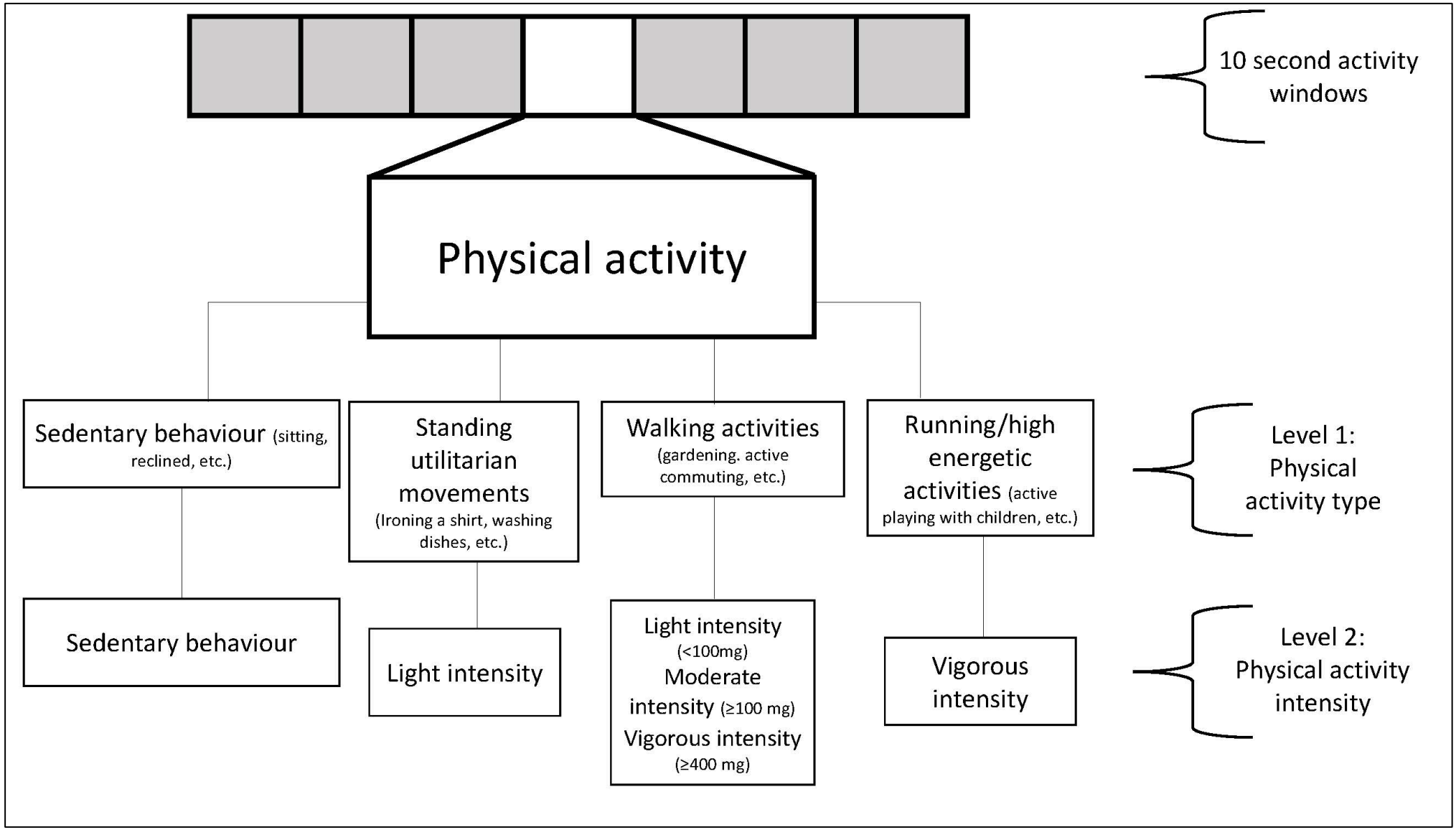

n= 10,230 were included in the all-cause mortality (411 events), n=10,161 in the CVD mortality (126 events) and n=10,092 in the cancer mortality analyses (226 events). Diamond: ED50 value, the minimal dose, defined as the duration of VILPA associated with 50% of the optimal risk reduction. Circle: effect associated with the median VILPA value. Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent cancer and CVD (for all-cause mortality). All analyses were additionally adjusted for vigorous physical activity frequency of bouts lasting more than two minutes. See **Online Methods** for further details on the statistical methodology.

**Supplementary Figure 3:** Dose-response associations of energy expenditure-based volume of vigorous intermittent lifestyle physical activity (non-exercisers) and vigorous intensity physical activity (exercisers) with mortality (bouts lasting up to 2 minutes).




VILPA: vigorous intermittent lifestyle physical activity (non-exercisers); VPA: vigorous intensity physical activity (exercisers). Analyses adjusted for age, sex, duration of light intensity physical activity, duration of moderate intensity physical activity, smoking history, alcohol consumption, accelerometer estimated sleep duration, fruit and vegetable consumption, education, self-reported parental history of cardiovascular disease and cancer, and self-reported medication use (cholesterol, blood pressure, and diabetes), and prevalent cancer and CVD (for all-cause mortality). All analyses were additionally adjusted for vigorous physical activity frequency of bouts lasting more than two minutes. See Online Methods for further details on the statistical methodology.

**Supplementary Figure 4:** Physical activity type and intensity diagram



**Supplementary Figure 5:** Participant-level specific recall and precision of activity classification in 151 UK adults