Volume of Light Versus Moderate-to-Vigorous Physical Activity: Similar Benefits for All-Cause Mortality?

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Background—It is unclear whether the greater benefits of moderate-to-vigorous physical activity (PA) over light PA are attributed to the higher-intensity PA or simply the greater volume of PA accumulated per unit time for moderate-to-vigorous PA. We examined this question using estimates of the volume of light and moderate-to-vigorous PA in relation to all-cause mortality.

Methods and Results—We used National Health and Nutrition Examination Survey 2003–2006 accelerometer records in adults (≥40 years; n=4840) and mortality data collected through 2011 (n=700 deaths). We estimated intensity-specific PA volume using activity counts (AC) accumulated in light (100–759 AC/min), moderate-to-vigorous PA (≥760 AC/min), and total PA (≥100 AC/min). We examined quartiles of each exposure using Cox proportional hazard models (hazard ratios [95% confidence interval] adjusted for demographic and behavioral risk factors, health status, and body mass index. Mortality risk was less across increasing quartiles of light PA volume (AC×1000) when compared with the least quartile (AC≤61.8); the least risk occurred in the upper quartile of light PA, AC>98.5 (hazard ratios=0.69, 95% confidence interval: 0.47, 1.00). The benefits for mortality risk were greater across quartiles of moderate-to-vigorous PA and reached a hazard ratio of 0.28 (95% confidence interval: 0.17, 0.46, P trend ≤0.05) for AC>187.9, when compared with the referent group (AC≤50.8). Results examining various combinations of light and moderate-to-vigorous intensity-specific volumes demonstrated the strong influence of total activity on mortality risk.

Conclusions—in this population, increasing light PA was associated with less mortality, but at an approximately equal volume of PA, moderate-to-vigorous PA appeared to have greater benefits. (J Am Heart Assoc. 2018;7:e008815. DOI: 10.1161/JAHA.118.008815.)

Key Words: epidemiology • health outcomes • lifestyle • measurement • physical exercise

Physical inactivity—defined as not achieving physical activity (PA) guidelines—accounts for as much as 6% to 10% of the incidence of type 2 diabetes mellitus, coronary heart disease, and cancer1—conditions that collectively account for nearly half of all deaths.2 It is therefore not surprising that the United States and other countries have endorsed PA guidelines for health. The general recommendation is that adults should engage in adequate moderate-to-vigorous PA, with moderate-intensity activities defined as those with an energy cost of 3 to 5.9 metabolic equivalents, and vigorous intensity activities as those expending 6 or more metabolic equivalents.3–5 The Physical Activity Guidelines for Americans specifically suggest that adults can meet the recommendation by achieving a minimum overall volume of PA activity by accumulating 150 min/wk of moderate-intensity activity or 75 min/wk of vigorous intensity activity or an equivalent combination of the 2 intensities. This is consistent with the idea that an equal volume (ie, duration×intensity) of moderate or vigorous intensity physical activity rather than intensity per se is associated with substantial health benefits.4 Although this recommendation emphasizes the importance of the volume of moderate-intensity PA for better health, it is unclear whether even lower intensity physical activities (nonsedentary light-intensity activities, <3 metabolic equivalents) also confer similar health benefits.

Accelerometer-based studies demonstrate the mortality benefits for the duration (hours per day) of light and moderate-to-vigorous intensity activity; most studies suggest a stronger association for greater-intensity activity.6–15 For example,

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Matthews et al found that a 1 h/d increase of light-intensity activity was associated with 16% less mortality, whereas a 1 h/d increase of moderate-to-vigorous activity was associated with 40% less mortality. However, these studies focused only on PA duration; they did not account for the greater volume of energy expended per hour for moderate-to-vigorous intensity activity. Thus, it is unclear whether the stronger associations for moderate-to-vigorous activity are simply because of the greater volume of activity accumulated per unit of time in moderate or vigorous activity when compared with light-intensity activity.

The benefits of an equivalent volume of moderate- or vigorous-intensity activity is generally accepted; however, whether an equal volume of light-intensity activity confers benefits similar to those associated with higher-intensity activity of the same volume is still an open question. Here, we sought to test the hypothesis that equal volumes of light and moderate-to-vigorous intensity activity have similar mortality benefits using device-based measures of PA from the National Health and Nutrition Examination Survey (NHANES) 2003–2006 cycles with mean mortality follow-up of 6.6 years.

### Methods

#### Study Population

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure. This study used publicly available accelerometer data for the US population from the 2003–2006 NHANES cycles. The NHANES includes several health behavior indicators including PA; it is based on a complex, multistage, probability sampling design of all ages in order to reflect the health status of the US population. Mortality was ascertained using information available from the National Death Index through December 31, 2011. The study population was restricted to adults aged ≥40 years (N=6355 respondents). The NHANES study was approved by the National Center for Health Statistics Research Ethics Review Board, and all participants were required to provide signed consent for participation.

#### PA Measures

PA was measured with a uniaxial accelerometer (AM-7164; ActiGraph) and a standard 7-day measurement protocol; participants were instructed to wear the monitor at the waist at all times except for bathing and sleep. The devices were initialized to collect activity counts (AC) in 1-minute epochs. Accumulated AC provide an accurate estimate of the duration and intensity of body movement at the waist and were summed across the whole day to assess total PA volume. Using established cut points, we summed the accumulated volume of activity as AC in non-sedentary light (100<AC<760) and moderate-to-vigorous activity (>760 AC). We also summed non-sedentary total activity counts (TAC; AC>100). These cut points provide useful approximations of time spent in light and moderate-to-vigorous activity in a variety of free-living studies. After screening the activity data for non-wear time, 4840 subjects had at least 1 valid day of accelerometer data (wear ≥10 h/d).

#### Covariates

Consistent with our previous work with this data set, we included a number of covariates in our modeling of the association between PA and mortality. These included age (years), sex, race-ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or other), education (less than high school, high school diploma, or high school or more), alcohol consumption (never, former, or current), smoking status (never, former, or current), body mass index (in kg/m²: <25, 25–29.9, or ≥30), and self-reported diagnosis (yes/no) of diabetes mellitus, coronary artery disease, stroke, cancer, and reduced mobility (difficulty in walking a quarter mile or up 10 stairs).

#### Statistical Analysis

To accommodate expected nonlinear relationships between PA and mortality, the distributions of AC in light, AC in

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Our primary analysis used Cox proportional hazard models to estimate hazard ratios (HR) and 95% confidence intervals (HR [95% CI]) for mortality when adjusted for all covariates. We first examined the distributions of light- and moderate-to-vigorous PA across each stratum of covariates. To examine main effects using the respective bottom quartile as the referent group (ie, bottom quartiles, ≤61.8 AC for light PA, ≤50.8 AC for moderate-to-vigorous PA; and ≤122.3 AC for total PA), Cox proportional hazard models were computed separately for light, moderate-to-vigorous PA, and total PA quartiles. To examine the relative benefits of various combinations of light and moderate-to-vigorous PA volumes, we then computed additional Cox proportional models for the joint associations of light and moderate-to-vigorous PA quartiles. The referent group for these analyses was defined by the least PA quartiles for both light and for moderate-to-vigorous PA, with ≤61.8 AC for light PA and ≤50.8 AC for moderate-to-vigorous PA. The HRs associated with these joint combinations were plotted against total PA volume (average total PA; TAC) accumulated by each joint combination of quartiles.

Supplemental analyses included a more detailed examination of accelerometer compliance (wear time) and distributions of sedentary, light, moderate-to-vigorous, and total PA across quartiles of light and moderate-to-vigorous PA (Table S1). The distributions of activity (Table S2) and death records (Table S3) were also examined by joint quartiles of light- and moderate-to-vigorous PA. Sensitivity analyses were conducted to account for possible reverse causality by replicating our fully adjusted models and excluding participants with <1 and 2 years of follow-up. We tested and confirmed the proportional hazards assumption for all our key exposures (light, moderate-to-vigorous PA, and total PA). All analyses were conducted using SAS 9.3v® and SUDAAN® to incorporate sample weights and adjust for the complex survey design. For descriptive statistics, we used Proc Descript (continuous variables) and Proc Crosstab (categorical variables) while the associations between mortality and PA were assessed using Proc Survival.

Table 1. Weighted US Proportions (Standard Error) for Covariates by Quartiles of Light and Moderate-to-Vigorous PA

| Light PA | Moderate-to-Vigorous PA |
|----------|-------------------------|
| Q1 (n=1159) | Q2 (n=1215) | Q3 (n=1236) | Q4 (n=1230) | Q1 (n=1174) | Q2 (n=1217) | Q3 (n=1229) | Q4 (n=1220) |
| % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) |
| Sex (male) | 54.5 (2.4) | 50.1 (1.8) | 44.7 (2.2) | 38.7 (1.6) | 34.4 (1.6) | 36.9 (1.9) | 44.4 (1.5) | 63.1 (1.5) |
| Ethnicity (non-Hispanic white) | 80.2 (1.8) | 80.3 (2.3) | 77.8 (2.0) | 72.3 (3.3) | 81.7 (1.9) | 75.7 (2.9) | 76.3 (2.4) | 77.3 (2.4) |
| BMI status (obese) | 41.8 (1.9) | 33.9 (1.9) | 36.5 (1.8) | 32.9 (1.7) | 38.9 (1.7) | 44.5 (1.6) | 36.5 (2.0) | 27.1 (1.4) |
| Education (<high school) | 21.2 (1.8) | 13.8 (1.8) | 17.2 (1.5) | 18.4 (1.3) | 29.2 (2.6) | 17.3 (1.2) | 13.7 (1.4) | 14.1 (1.4) |
| Alcohol consumption (current) | 54.1 (2.3) | 64.0 (2.0) | 63.5 (2.3) | 64.7 (2.5) | 41.1 (2.5) | 59.6 (1.9) | 66.1 (2.7) | 72.4 (2.1) |
| Smoking habits (current) | 18.0 (1.6) | 19.6 (1.9) | 23.5 (1.8) | 22.4 (1.6) | 18.3 (1.5) | 24.1 (2.1) | 20.9 (1.1) | 20.7 (1.2) |
| Diabetes mellitus (yes) | 22.8 (1.6) | 11.6 (1.6) | 11.5 (0.9) | 8.0 (0.8) | 28.1 (1.9) | 15.1 (1.1) | 10.6 (0.9) | 4.5 (0.8) |
| Stroke (yes) | 9.6 (1.2) | 2.9 (0.6) | 2.5 (0.4) | 2.1 (0.4) | 12.0 (1.4) | 3.4 (0.5) | 2.5 (0.5) | 1.0 (0.3) |
| Chronic heart failure (yes) | 22.3 (1.7) | 10.3 (1.0) | 8.7 (1.3) | 5.7 (0.7) | 29.1 (1.8) | 11.0 (1.5) | 7.5 (1.0) | 4.0 (0.6) |
| Reduced mobility (yes) | 19.2 (1.4) | 14.5 (1.6) | 10.3 (1.2) | 8.6 (0.9) | 30.0 (1.4) | 14.7 (1.2) | 9.5 (1.2) | 4.1 (0.7) |
| Cancer/malignancy (yes) | 17.7 (1.4) | 15.0 (1.2) | 11.1 (0.9) | 9.1 (0.8) | 24.6 (1.5) | 13.4 (1.4) | 10.9 (1.0) | 7.6 (1.0) |

Light PA Quartiles: Q1—first Quartile (AC ≤61.8); Q2—second Quartile (61.8<AC≤80.5); Q3—third Quartile (80.5<AC≤98.5); Q4—fourth Quartile (AC >98.5). Moderate-to-Vigorous PA Quartiles: Q1—first Quartile (AC ≤50.8); Q2—second Quartile (50.8<AC≤110.2); Q3—third Quartile (110.2<AC≤187.9); Q4—fourth Quartile (AC >187.9). Weighted mean (standard error) age for quartiles 1–4 of Light PA were 62.5 (0.6), 57.1 (0.4), 55.3 (0.6), and 53.6 (0.2) years of age, respectively; Weighted mean (standard error) age for quartiles 1–4 of Moderate-to-Vigorous PA were 69.9 (0.4); 58.0 (0.5), 54.2 (0.4), and 50.6 (0.4) years of age, respectively. AC indicates activity counts; BMI, body mass index; PA, physical activity; SE, standard error.
We first examined the mortality associations separately for the volumes of light- and moderate-to-vigorous intensity activity, as well as total activity (Table 2). Significantly less mortality risk was noted for greater light-intensity activity volume before and after adjusting for covariates and moderate-to-vigorous activity. In fully adjusted models, participants in the greatest light-intensity category (>98.5 AC x 1000) had 31% less risk (HR=0.69 [95% CI, 0.47–1.00]) than those with less than 61.8 AC x 1000.

Greater moderate-to-vigorous activity was also inversely associated with mortality risk after adjustment for covariates and light activity. Notably, the second quartile of moderate-to-vigorous PA (50.8 to ≤110.2 AC/1000) had roughly the same volume of PA as the greatest quartile of light activity (noted above); and was associated with 46% less risk (HR=0.54 [95% CI, 0.42–0.70]) compared with the least quartile of moderate-to-vigorous PA. Greater volume of moderate-to-vigorous activity was associated with even lower mortality risk. It is important to note that because of the large differences in the distributions of PA volume accumulated in light and moderate-to-vigorous PA, there was limited overlap in terms of equal volume of PA in the quartiles for each intensity of PA. The strength of associations for total PA was comparable to those for moderate-to-vigorous activity.

Given the significant mortality benefits for both light and moderate-to-vigorous intensity PA, we next explored the combined influence of both intensities, by jointly classifying PA exposure. In all comparisons, the referent group was the least in light- and moderate-to-vigorous activity. Among those with the least moderate-to-vigorous activity (≤50.8 AC x 1000), greater amounts of light PA were associated with 30% to 40% less mortality risk. In contrast, among those with the least light activity (≤61.8 AC x 1000), greater moderate-to-vigorous PA was associated with a 60% to 90% less mortality risk; however, CI were wide for the most active group (Table 3). In general, the greatest reductions in risk were associated with a greater volume of both light- and moderate-to-vigorous PA. This suggests that the total volume of PA (light and moderate-to-vigorous) was important for risk reduction. In sensitivity analyses of Table 3, the HR remained similar after excluding the first 1 and 2 years of follow-up. With these exclusions, the associations were attenuated by 5% to 8% and CI widened (Table S4).

To better understand the interrelations between light and moderate-to-vigorous PA and total activity volume, we plotted...
the 16 hazard ratios in Table 3 by mean TAC and described the proportion of TAC accumulated in each intensity category (Figure). Addition of information about total activity volume demonstrates the strong influence of total activity on mortality risk, and the relative contributions of light and moderate-to-vigorous PA for increasing total activity in these data.

**Discussion**

In this prospective study conducted in a representative sample of US adults using device-measured PA, we found the volume of both light and moderate-to-vigorous intensity PA to be associated with less mortality after mutual adjustments. However, at similar volumes of PA, moderate-to-vigorous activity was more strongly associated with mortality risk reduction than light-intensity PA (46% versus 31% lower risk). This finding suggests an added benefit of greater-intensity PA (moderate-to-vigorous) over light activity. Our exploration of the joint associations of light- and moderate-to-vigorous activity volume on mortality showed that greater light activity had a stronger influence among those doing the least moderate-to-vigorous intensity activity, but there was only limited evidence of an influence of light activity at greater levels of moderate-to-vigorous intensity activity.

Our findings extend previous accelerometer-based studies of the duration of light and moderate-to-vigorous PA and mortality that may be confounded in part by not considering differences in PA volume associated with intensity. Previous studies examining this question have focused only on the duration of PA (minutes of intensity-specific activity). While the duration of an activity is more easily measured and interpretable, inferences about intensity-specific effects are limited by the lack of control over the total volume of exposure. In these studies, moderate-to-vigorous PA appeared to have substantially greater mortality benefits than did light PA (≈0–30% for light PA and 40–80% for moderate-to-vigorous PA).7–11 The large difference in risk reduction is consistent with our supplemental analyses (Figure S1). Our study extends previous studies by estimating the volume of intensity-specific PA, using total activity counts—which reflect both the duration and intensity of activity—to estimate PA volume. We found that greater intensity activity appeared to have greater mortality benefits, although the differences we observed (0–24%) were not as large as in previous duration studies, or when compared with our replicated analysis using PA duration (Figure versus Figure S1).

Examination of the relative contributions of light or moderate-to-vigorous PA volume to mortality was challenging. One critical challenge was the limited overlap among the distributions of light and moderate-to-vigorous PA volume. It appears that few individuals accumulate their total PA at relatively similar contributions of light and moderate-to-vigorous PA. For example, the joint quartile 2,2 light–moderate-to-vigorous PA was one of a few that had similar contributions of light and moderate-to-vigorous intensity volume to total (71.9 versus 77.7 AC for a total of 149.6 AC x 1000; Table S2). The stratified approach described in Figure provides a good illustration of this issue. The jointly classified categories were associated with wide ranges of TAC; and the upper quartiles of moderate-to-vigorous had much greater total volumes of activity compared with those for light-intensity activity. Thus, while contributing substantially to total activity duration (Figure S1), light-intensity activity was much less of a driver of total activity volume.

Strengths of this study include evaluation of a nationally representative cohort of US adults with device-measured PA. We examined the associations between PA and mortality while adjusting for various confounders, including age, comorbidities, and mobility limitations. Information on these confounders is not always readily available for consideration in etiologic studies examining the benefits of PA; however, despite these adjustments, we cannot rule out possible larger effects among older individuals at higher risk for mobility complications. Our method to estimate intensity-specific activity volume is also novel and a strength of this study. The application of device-based measures of PA is evolving17; our estimates of light and moderate-to-vigorous intensity activity duration have been evaluated and found to be reasonably accurate in comparison to a range of criterion

### Table 3. Joint Associations for Quartiles of Accumulated Light and Moderate-to-Vigorous Intensity AC

| Moderate-to-Vigorous PA | Light PA | | | |
|-------------------------|----------|----------|----------|----------|
|                         | AC ≤61.8 | 61.8<AC≤80.5 | 80.5<AC≤98.5 | AC >98.5 |
|                         | HR (95% CI) | HR (95% CI) | HR (95% CI) | HR (95% CI) |
| AC ≤50.8                | 1.00 (REF) | 0.69 (0.46, 1.04) | 0.64 (0.41, 0.98) | 0.59 (0.23, 1.52) |
| 50.8–AC≤110.2           | 0.40 (0.22, 0.73) | 0.43 (0.31, 0.60) | 0.40 (0.27, 0.62) | 0.42 (0.23, 0.76) |
| 110.2<AC≤187.9          | 0.48 (0.24, 0.95) | 0.17 (0.09, 0.34) | 0.24 (0.14, 0.40) | 0.15 (0.07, 0.32) |
| AC >187.9               | 0.10 (0.02, 0.43) | 0.16 (0.06, 0.42) | 0.25 (0.13, 0.48) | 0.21 (0.09, 0.50) |

AC indicates activity counts; CI, confidence interval; HR, hazard ratio; PA, physical activity; REF, referent group.
To determine the volume of PA, we estimated intensity-specific activity counts—a metric demonstrated to be a good proxy for total volume of PA. We also chose a widely accepted threshold to distinguish sedentary behavior from PA (100 AC) and a light/moderate-to-vigorous threshold designed to capture a broader range of lifestyle and ambulatory activities in adults (760 AC). There are a variety of published cut points, and NHANES studies have commonly used 2020 counts/min, which is based on ambulatory calibrations, to define moderate-to-vigorous PA. The choice of a cut point calibrated to capture a broader range of moderate-to-vigorous activity or one calibrated to capture only walking and running to distinguish light from moderate-to-vigorous PA has important implications when classifying activity. Although we recognize there may be a wide range of opinions about the best method, we believe potential misclassification with our approach will provide a more conservative estimate of the association between mortality for each PA intensity. Thus, if the 760 count/min threshold overestimates moderate PA, light-intensity activity would be classified as moderate activity, potentially diluting the strength of the observed moderate-intensity associations. In contrast, if ambulatory cut points underestimate moderate PA, moderate-intensity activity would be classified as light activity, potentially overestimating the strength of the light-intensity associations. A potential limitation of our approach is that the accuracy of our estimates of light and moderate-to-vigorous PA volume has not been fully explored; it may be that measurement error is greater for our estimates of light intensity. This limitation also relates to a general limitation of device-based monitors that are not able to capture nonambulatory activities (eg, bicycling or activities while standing). There were also a relatively small number of deaths. This limited our ability to match activity volumes by

Figure. Hazard ratios* for jointly classified quartiles of light, moderate-to-vigorous physical activity (PA) from Table 3 for each category: by total activity counts (TAC, per 1000). *HR 1, 1 is for quartile 1 for both types of activity, while HR 4, 1 is for quartile 4 of light PA and quartile 1 of moderate-to-vigorous PA, etc. The amount of moderate-to-vigorous PA (MVPA) as a proportion of total activity counts (TAC) is reflected by color (least MVPA bright yellow, most MVPA dark red). For example, quartiles 2, 2 accumulated on average 150 counts (per 1000) in total activity and ≈50% of the TAC was accumulated in moderate-to-vigorous PA intensity. The remaining 50% were accumulated in light PA intensity. Joint quartiles filled with orange indicate joint distributions with relatively similar contributions of moderate-to-vigorous and light PA to total physical activity.
intensity and to create finer gradations of volumes to study combined-intensity effects. Furthermore, although we controlled for many relevant confounding factors and several chronic conditions, and our sensitivity analysis did not reveal consistent evidence of reverse causality, we cannot completely rule out the influence of reverse-causality bias.

To our knowledge, this is the first study to explore the differences in volume accumulated through light and moderate-to-vigorous PA and their associations with all-cause mortality. We found moderate-to-vigorous PA to provide greater benefits than light PA; however, the difference in benefits because of intensity was less than that associated with PA duration (Figure versus Figure S1). Future studies should explore these associations using data from other cohorts, with longer follow-up periods, and more sophisticated methods of activity intensity classification. A better understanding of the interplay between light PA and moderate-to-vigorous PA for mortality risk reduction is critical and can have important implications for clinical practice and public health recommendations. The current US PA guidelines reinforce the importance of volume by allowing for various combinations of moderate and vigorous intensity activities to achieve the recommended amounts of PA per week. The examination of the relative contribution of light PA to total PA volume can clarify whether lower-intensity activities can be factored into these recommendations. As demonstrated in our study, the benefit ratio between light and moderate is hard to disentangle. While our findings suggest that light PA has benefits, participation in moderate-to-vigorous PA is needed to obtain maximal health benefits. The consideration of light-intensity activities to achieve benefits for health is particularly important among inactive individuals, who are at higher risk for comorbidities and are less likely to engage in physically active behaviors.

Disclosures

None.

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SUPPLEMENTAL MATERIAL
Table S1. Weighted means (Standard Error) for physical activity variables by quartiles of light and moderate-to-vigorous physical activity.

|                      | Light PA                          |                      | Moderate-to-Vigorous PA |
|----------------------|-----------------------------------|----------------------|-------------------------|
|                      | Q1 (n = 1159)                     | Q2 (n = 1215)        | Q3 (n = 1236)           | Q4 (n = 1230)          |
|                      | % (SE)                            | % (SE)               | % (SE)                  | % (SE)                 |
| **Physical Activity**| **(counts)**                      |                      |                         |                        |
| Sedentary (AC<100)   | 7.7 (0.1)                         | 8.3 (0.1)            | 8.7 (0.1)               | 8.6 (0.1)              |
| Light (100≥AC<760)   | 47.7 (0.4)                        | 71.6 (0.2)           | 89.1 (0.2)              | 115.1 (0.6)            |
| Moderate-to-vigorous (AC≥760) | 85.2 (4.4)            | 141.8 (4.8)          | 167.8 (4.3)             | 198.3 (0.6)            |
| **Total (AC≥100)**   | 133.0 (4.6)                       | 213.4 (4.8)          | 256.9 (4.3)             | 313.5 (4.8)            |
| **Physical Activity**| **(minutes)**                     |                      |                         |                        |
| Sedentary (AC<100)   | 582.0 (4.3)                       | 519.2 (3.9)          | 474.2 (4.3)             | 417.7 (3.3)            |
| Light (100≥AC<760)   | 163.4 (1.2)                       | 224.2 (0.9)          | 270.5 (0.7)             | 336.5 (1.6)            |
| Moderate-to-vigorous (AC≥760) | 49.6 (2.1)             | 86.9 (2.1)           | 110.2 (2.1)             | 137.1 (2.4)            |
| **Total (AC≥100)**   | 352.9 (2.3)                       | 212.9 (2.6)          | 380.7 (2.3)             | 473.6 (2.7)            |
| **Wear Time (minutes)** | 794.9 (4.2)                     | 830.3 (4.8)          | 854.9 (4.4)             | 891.3 (4.8)            |
| **Number of Valid Days** | 5.1 (0.1)                   | 5.7 (0.1)            | 5.8 (0.1)               | 5.9 (0.1)              |

AC – Activity counts
PA – Physical activity
Light PA Quartiles: Q1- 1st Quartile (AC ≤61.8); Q2 – 2nd Quartile (61.8< AC ≤80.5); Q3 – 3rd Quartile (80.5< AC ≤98.5); Q4 – 4th Quartile (AC > 98.5)
Moderate-to-Vigorous PA Quartiles: Q1- 1st Quartile (AC ≤13.7); Q2 – 2nd Quartile (13.7< AC ≤49.1); Q3 – 3rd Quartile (49.1< AC ≤113.6); Q4 – 4th Quartile (AC > 113.6)

Weighted mean (Standard Error) age for quartiles 1 through 4 of Light PA were 62.5 (0.6), 57.1 (0.4), 55.3 (0.6), and 53.6 (0.2) yrs, respectively;
Weighted mean (Standard Error) age for quartiles 1 through 4 of Moderate-to-Vigorous PA were 69.9 (0.6), 58.0 (0.5), 54.2 (0.4), and 50.6 (0.4) yrs, respectively.
Table S2. U.S. population weighted means (Standard Error) for physical activity counts and minutes across joint classifications of light and moderate-to-vigorous physical activity quartiles.

| Light PA | Moderate-to-vigorous PA | AC ≤61.8 | 61.8< AC ≤80.5 | 80.5< AC ≤98.5 | AC >98.5 |
|----------|-------------------------|----------|----------------|----------------|---------|
|          | Physical activity (counts) | N | Mean (SE) | N | Mean (SE) | N | Mean (SE) | N | Mean (SE) |
| Sédentary (≤100) | AC ≤50.8 | 717 | 7.8 (0.1) | 288 | 8.4 (0.2) | 115 | 9.2 (0.3) | 54 | 10.2 (0.5) |
|           | 50.8< AC ≤110.2 | 228 | 7.4 (0.1) | 375 | 8.4 (0.1) | 371 | 9.2 (0.2) | 243 | 9.2 (0.1) |
|           | 110.2< AC ≤187.9 | 122 | 7.7 (0.3) | 302 | 8.4 (0.2) | 387 | 8.7 (0.1) | 418 | 8.7 (0.1) |
|           | AC >187.9 | 92 | 7.4 (0.2) | 250 | 7.9 (0.1) | 363 | 8.1 (0.1) | 515 | 8.1 (0.1) |

| Light PA (100≥AC<760) | AC ≤50.8 | 717 | 43.0 (0.6) | 288 | 69.7 (0.5) | 115 | 88.1 (0.6) | 54 | 108.4 (1.6) |
|                       | 50.8< AC ≤110.2 | 228 | 51.6 (0.7) | 375 | 71.9 (0.4) | 371 | 88.2 (0.4) | 243 | 113.0 (1.1) |
|                       | 110.2< AC ≤187.9 | 122 | 53.0 (0.8) | 302 | 72.3 (0.4) | 387 | 89.3 (0.3) | 418 | 115.6 (1.1) |
|                       | AC >187.9 | 92 | 54.0 (0.6) | 250 | 71.9 (0.4) | 363 | 89.9 (0.3) | 515 | 116.1 (0.7) |

| Moderate-vigorous PA (AC≥760) | AC ≤50.8 | 717 | 22.2 (0.6) | 288 | 31.9 (0.7) | 115 | 36.1 (1.0) | 54 | 38.7 (1.4) |
|                               | 50.8< AC ≤110.2 | 228 | 77.9 (1.3) | 375 | 77.7 (1.0) | 371 | 80.9 (1.0) | 243 | 85.7 (1.5) |
|                               | 110.2< AC ≤187.9 | 122 | 148.1 (2.1) | 302 | 142.3 (1.4) | 387 | 144.3 (1.4) | 418 | 148.3 (1.6) |
|                               | AC >187.9 | 92 | 292.5 (12.3) | 250 | 283.1 (6.7) | 363 | 287.7 (5.6) | 515 | 290.8 (5.9) |

| Total (AC≥100) | AC ≤50.8 | 717 | 65.2 (1.0) | 288 | 101.6 (0.9) | 115 | 124.2 (1.2) | 54 | 147.1 (2.4) |
|                | 50.8< AC ≤110.2 | 228 | 129.5 (1.7) | 375 | 149.6 (1.1) | 371 | 169.0 (1.1) | 243 | 198.6 (1.4) |
|                | 110.2< AC ≤187.9 | 122 | 201.1 (2.2) | 302 | 214.6 (1.3) | 387 | 233.9 (1.7) | 418 | 263.9 (2.0) |
|                | AC >187.9 | 92 | 346.5 (12.0) | 250 | 355.1 (6.8) | 363 | 377.6 (5.6) | 515 | 406.9 (6.0) |

| Physical activity (minutes) |
|-----------------------------|
| AC ≤50.8 | 717 | 65.2 (1.0) | 288 | 101.6 (0.9) | 115 | 124.2 (1.2) | 54 | 147.1 (2.4) |
| 50.8< AC ≤110.2 | 228 | 129.5 (1.7) | 375 | 149.6 (1.1) | 371 | 169.0 (1.1) | 243 | 198.6 (1.4) |
| 110.2< AC ≤187.9 | 122 | 201.1 (2.2) | 302 | 214.6 (1.3) | 387 | 233.9 (1.7) | 418 | 263.9 (2.0) |
| AC >187.9 | 92 | 346.5 (12.0) | 250 | 355.1 (6.8) | 363 | 377.6 (5.6) | 515 | 406.9 (6.0) |
| Activity Level          | AC ≤50.8 | 50.8< AC ≤110.2 | 110.2< AC ≤187.9 | AC >187.9 |
|------------------------|----------|-----------------|-------------------|-----------|
| **Sedentary (<100)**   |          |                 |                   |           |
| AC ≤50.8               | 717      | 228             | 122               | 92        |
| 50.8< AC ≤110.2        | 604.6 (6.1) | 571.9 (4.8)   | 565.8 (10.6)     | 525.3 (11.9) |
| 110.2< AC ≤187.9       | 288      | 375             | 302               | 250       |
| AC >187.9              | 542.2 (7.3) | 537.7 (5.3) | 519.0 (6.8)     | 484.1 (7.1) |
| Total                  | 115      | 371             | 387               | 363       |
| PA                     | 519.1 (14.0) | 511.2 (6.3) | 481.3 (6.1)     | 428.4 (5.6) |
|                          | 54       | 243             | 418               | 515       |
| AC                     | 492.9 (18.5) | 453.3 (8.7) | 430.9 (5.4)     | 388.5 (5.3) |
| **Light (100≥AC<760)** |          |                 |                   |           |
| AC ≤50.8               | 717      | 228             | 122               | 92        |
| 50.8< AC ≤110.2        | 158.2 (1.8) | 168.0 (2.3)   | 167.8 (2.9)     | 171.0 (2.0) |
| 110.2< AC ≤187.9       | 288      | 375             | 302               | 250       |
| AC >187.9              | 233.3 (1.8) | 226.1 (1.4) | 223.4 (1.4)    | 217.1 (1.7) |
| Total                  | 115      | 371             | 387               | 363       |
| PA                     | 289.9 (2.9) | 275.8 (1.7) | 268.9 (1.3)     | 263.7 (1.1) |
|                          | 54       | 243             | 418               | 515       |
| AC                     | 349.6 (6.0) | 343.8 (2.9) | 339.5 (3.0)     | 330.4 (1.7) |
| **Moderate-vigorous (AC≥760)** |          |                 |                   |           |
| AC ≤50.8               | 717      | 228             | 122               | 92        |
| 50.8< AC ≤110.2        | 17.8 (0.5) | 54.2 (1.2)     | 167.8 (2.9)     | 130.5 (7.8) |
| 110.2< AC ≤187.9       | 288      | 375             | 302               | 250       |
| AC >187.9              | 27.3 (0.6) | 59.3 (0.6)    | 94.7 (1.0)      | 147.6 (2.8) |
| Total                  | 115      | 371             | 387               | 363       |
| PA                     | 31.7 (0.9) | 64.6 (0.8)   | 102.2 (1.3)     | 171.1 (2.6) |
|                          | 54       | 243             | 418               | 515       |
| AC                     | 35.0 (1.2) | 70.4 (1.1)   | 111.7 (1.0)     | 189.3 (3.3) |
| **Total (AC≥100)**     |          |                 |                   |           |
| AC ≤50.8               | 717      | 228             | 122               | 92        |
| 50.8< AC ≤110.2        | 176.0 (2.1) | 222.1 (2.8)   | 255.1 (3.6)     | 301.5 (7.9) |
| 110.2< AC ≤187.9       | 288      | 375             | 302               | 250       |
| AC >187.9              | 260.6 (1.8) | 285.4 (1.7) | 318.1 (1.7)    | 364.7 (3.0) |
| Total                  | 115      | 371             | 387               | 363       |
| PA                     | 321.6 (2.7) | 340.3 (1.6) | 371.1 (1.5)     | 434.9 (2.8) |
|                          | 54       | 243             | 418               | 515       |
| AC                     | 384.6 (6.1) | 414.6 (2.8) | 451.3 (3.1)     | 519.7 (3.3) |

AC – Activity counts
PA – Physical activity
Table S3. Number of deaths occurrences across joint classifications of light and moderate-to-vigorous physical activity quartiles.

| Mortality Records (n) | Light PA                                      |                       |                       |                       |                       |
|-----------------------|------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                       | Moderate-to-vigorous PA                        | AC ≤61.8              | 61.8 < AC ≤80.5       | 80.5 < AC ≤98.5       | AC > 98.5             |
| AC ≤ 50.8             | N                                               | 717                   | 309                   | 288                   | 84                    |
|                       | Deaths                                          | 309                   | 84                    | 115                   | 27                    |
|                       | 50.8 < AC ≤ 110.2                              | 288                   | 84                    | 115                   | 27                    |
|                       | N                                               | 115                   | 27                    | 54                    | 9                     |
|                       | Deaths                                          | 371                   | 54                    | 243                   | 25                    |
|                       | 110.2 < AC ≤ 187.9                             | 302                   | 18                    | 387                   | 18                    |
|                       | AC > 187.9                                      | 363                   | 19                    | 515                   | 20                    |
|                       | 92                                               | 3                     | 8                     | 363                   | 19                    |
|                       | 13                                               | 3                     | 8                     | 363                   | 19                    |
Table S4. Joint associations for quartiles of accumulated light and moderate-to-vigorous intensity activity counts after excluding first 2 years of follow-up.

| Moderate-to-vigorous PA | AC ≤61.8 | 61.8< AC ≤80.5 | 80.5< AC ≤98.5 | AC >98.5 |
|-------------------------|----------|----------------|----------------|---------|
|                         | HR (95% CI) | HR (95% CI) | HR (95% CI) | HR (95% CI) |
| AC ≤50.8                | 1.00 (REF) | 0.73 (0.45, 1.17) | 0.72 (0.42, 1.26) | 0.61 (0.21, 1.75) |
| 50.8< AC ≤110.2         | 0.52 (0.28, 0.97) | 0.50 (0.33, 0.77) | 0.48 (0.31, 0.74) | 0.42 (0.23, 0.80) |
| 110.2< AC ≤187.9        | 0.45 (0.22, 0.94) | 0.15 (0.07, 0.31) | 0.29 (0.17, 0.48) | 0.18 (0.08, 0.39) |
| AC >187.9               | 0.06 (0.01, 0.45) | 0.17 (0.06, 0.47) | 0.26 (0.12, 0.58) | 0.28 (0.11, 0.72) |

AC – Activity counts
PA – Physical activity
HR – Hazard ratio
95% CI – 95% Confidence interval
Figure S1. Hazard ratios* for jointly classified quartiles of light, moderate-to-vigorous physical activity from Table 3 for each category: by Total activity duration (TAD).

*HR 1.1 is for quartile 1 for both type of activity, while HR 4.1 is for quartile 4 of light PA and quartile 1 of moderate-to-vigorous PA, etc.

The amount of moderate-to-vigorous PA (MVPA) as a proportion of total activity counts (TAC) is reflected by color (least MVPA bright yellow, most MVPA dark red). For example, quartiles 4,1 spent on average 400 minutes in total activity and approximately 10% of the total activity duration was spent on moderate-to-vigorous PA intensity. The remaining 90% were spent in light PA intensity. Joint quartiles filled with orange indicate joint distributions with relatively similar contributions of moderate-to-vigorous and light PA to total physical activity.