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Association of the "Weekend Warrior" and Other Leisure-time Physical Activity Patterns With All-Cause and Cause-Specific Mortality
A Nationwide Cohort Study

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IMPORTANCE It is unclear whether the weekly recommended amount of moderate to vigorous physical activity (MVPA) has the same benefits for mortality risk when activity sessions are spread throughout the week vs concentrated in fewer days.

OBJECTIVE To examine the association of weekend warrior and other patterns of leisure-time physical activity with all-cause and cause-specific mortality.

DESIGN, SETTING, AND PARTICIPANTS This large nationwide prospective cohort study included 350 978 adults who self-reported physical activity to the US National Health Interview Survey from 1997 to 2013. Participant data were linked to the National Death Index through December 31, 2015.

EXPOSURES Participants were grouped by self-reported activity level: physically inactive (<150 minutes per week [min/wk] of MVPA) or physically active (≥150 min/wk of moderate or ≥75 min/wk of vigorous activity). The active group was further classified by pattern: weekend warrior (1-2 sessions/wk) or regularly active (≥3 session/wk); and then, by frequency, duration/session, and intensity of activity.

MAIN OUTCOMES AND MEASURES All-cause, cardiovascular disease (CVD), and cancer mortality. Statistical analyses were performed in April 2022.

RESULTS A total of 350 978 participants (mean [SD] age, 41.4 [15.2] years; 192 432 [50.8%] women; 209 432 [67.8%] Non-Hispanic White) were followed during a median of 10.4 years (3.6 million person-years). There were 21 898 deaths documented, including 4130 from CVD and 6034 from cancer. Compared with physically inactive participants, hazard ratios (HR) for all-cause mortality were 0.92 (95% CI, 0.83-1.02) for weekend warrior and 0.85 (95% CI, 0.83-0.88) for regularly active participants; findings for cause-specific mortality were similar. Given the same amount of total MVPA, weekend warrior participants had similar all-cause and cause-specific mortality rates as regularly active participants. The HRs for weekend warrior vs regularly active participants were 1.08 (95% CI, 0.97-1.20) for all-cause mortality; 1.14 (95% CI, 0.85-1.53) for CVD mortality; and 1.07 (95% CI, 0.87-1.31) for cancer mortality.

CONCLUSIONS AND RELEVANCE The findings of this large prospective cohort study suggest that individuals who engage in active patterns of physical activity, whether weekend warrior or regularly active, experience lower all-cause and cause-specific mortality rates than inactive individuals. Significant differences were not observed for all-cause or cause-specific mortality between weekend warriors and regularly active participants after accounting for total amount of MVPA; therefore, individuals who engage in the recommended levels of physical activity may experience the same benefit whether the sessions are performed throughout the week or concentrated into fewer days.

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Supplemental content

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Physical activity is associated with a lower risk of noncommunicable diseases and mortality.[1,2] The 2020 World Health Organization (WHO) guidelines for physical activity and sedentary behaviors recommend that adults perform from 150 to 300 minutes per week (min/wk) of moderate-intensity aerobic physical activity, 75 to 150 min/wk of vigorous-intensity aerobic physical activity, or an equivalent combination of both intensities.[3] However, it is unclear whether the same amount of physical activity spread over more days or concentrated into fewer days provides the same benefits or differs in terms of mortality risk. Given that performing leisure-time physical activity during the weekend may be a more convenient option for many people, the answer to this question is important for achieving the recommended levels of physical activity.[4]

The findings of a meta-analysis of epidemiologic studies of physical activity[5] suggest that both moderate- and vigorous-intensity activity may offer similar benefits on all-cause mortality, although vigorous intensity is advocated by exercise professionals to induce larger gains in physical fitness. The minimum frequency of weekly physical activity associated with lower all-cause mortality is unknown.[3] In fact, few studies have investigated whether the same amount of physical activity concentrated in 1 or 2 sessions per week (ie, *weekend warrior* pattern) or spread over multiple sessions during the week (ie, *regularly active* pattern) differ in regard to all-cause and cause-specific mortality rates. In the Harvard Alumni Health Study,[6] men who followed a regularly active physical activity pattern had a 36% lower all-cause mortality compared with physically inactive participants. The relative risk for all-cause mortality among weekend warrior vs physically inactive participants was 0.85 (95% CI, 0.65-1.11); of note, 580 participants performed weekend warrior physical activity and 73 deaths were ascertained in 1988 to 1997. In a pooled study of 11 cohorts with more than 60 000 participants,[7] weekend warrior activity patterns were associated with a 30% lower risk of all-cause mortality, a 41% lower risk of cardiovascular disease (CVD) mortality, and a 13% lower risk of cancer mortality compared with participants reporting no moderate to vigorous physical activity (MVPA). However, it remains unclear whether the associations of weekend warrior and regularly active patterns vs physically inactive pattern with mortality differ by duration and/or intensity of the activity sessions. In addition, few studies compared mortality outcomes between weekend warrior and regularly active participants. The present comparison may provide important information on whether spreading the same amount of physical activity over more days or concentrating it into fewer days makes a difference in its associations with mortality outcomes.

Using data from a large cohort of 350 978 US adults, we examined the association of weekend warriors and regularly active leisure-time physical activity patterns with all-cause, CVD and cancer mortality. In addition, weekend warriors and regularly active participants were granularly classified by frequency, duration, and intensity of physical activities. Lastly, we compared mortality outcomes between weekend warriors and regularly active participants, independent of total MVPA.

Key Points

Question Does performing the recommended levels of weekly physical activity in 1 to 2 sessions (weekend warrior) vs 3 or more sessions (regularly active) influence mortality?

Findings This large prospective cohort study of 350 978 adults in the US did not find any significant difference in mortality rates between weekend warriors and regularly active participants. Compared with physically inactive participants, active participants (both weekend warrior and regularly active) had lower all-cause and cause-specific mortality rates.

Meaning Adults who perform 150 minutes or more of moderate to vigorous physical activity (or 75 minutes of vigorous activity) per week may experience similar health benefits whether the sessions are spread throughout the week or concentrated in a weekend.

Methods

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines. This large prospective cohort study was based on secondary analyses of publicly available and deidentified data from the US National Health Interview Survey (NHIS); therefore, no additional institutional review board approval or informed consent was needed.

Study Design and Population

The NHIS is a nationally representative survey of civilian, noninstitutionalized participants in the US, conducted annually by the Centers for Disease Control and Prevention's National Center for Health Statistics. The National Center for Health Statistics Disclosure Review Board reviews and approves the NHIS (additional information on ethics approvals and procedures for informed consent are available from the National Center for Health Statistics[8]). Details on the NHIS design, methodology, and weighting have been published elsewhere.[9,10] In brief, the NHIS conducted in 1997 to 2013 used a stratified, complex multistage sampling design to select households from random clusters. From these households, a sample of adults (≥18 years) was randomly selected to respond to a questionnaire on health status, health services, lifestyle risk factors, prevalent diseases, and other health-related issues.[9,10] Trained investigators collected data through personal interviews.

This study used a total of 481 566 adults (18-84 years old) with data from the 1997 to 2013 NHIS and linked their records to the National Death Index records through December 31, 2015.[9,10] We excluded participants who had been diagnosed with cancer, chronic bronchitis, emphysema, heart disease, and stroke at baseline (n = 104 345); with missing data for physical activity (n = 11 694); with limitations on their instrumental and other activities of daily living (n = 8345); or who were unable to perform moderate or vigorous physical activity (n = 3362). Of note, the rationale for excluding participants with chronic conditions at baseline was based on previous studies suggesting the influence of reverse causation bias (confounding by preexisting diseases) in cohort studies assessing the association between physical activity and mortality.[11-14] Lastly, we excluded the first 2 years of follow-up to further mitigate the influence of reverse causation bias, producing a final analytical sample of 350 978 participants.

Assessment of Physical Activity

Information on weekly frequency, duration of sessions, and intensity of leisure-time physical activities was measured through 4 questions: (1) How often do you engage in physical activities of vigorous intensity for at least 10 minutes? (20 min for participants of the NHIS 1997); (2) How long do you do these vigorous leisure-time physical activities each time? (3) How often do you engage in physical activities of light-to-moderate intensity for at least 10 minutes? (20 min for participants of the NHIS 1997); and (4) How long do you do these light-to-moderate intensity leisure-time physical activities each time? *Intensity* was exemplified through sweating, breathing, and heart rate references (eg, vigorous physical activity being those that produce heavy sweating and large increases in breathing and heart rate). We calculated the total amount of MVPA (in min/wk) by multiplying frequency and duration of sessions. Total (weighted) MVPA was obtained by summing the duration (in min) of moderate intensity plus vigorous intensity and multiplying by 2 (to account for intensity).[11]

Participants were classified according to the level and pattern of their physical activity. First, we classified participants into 2 groups: physically active (MVPA ≥150 min/wk) and inactive (MVPA <150 min) per WHO guidelines for physical activity and sedentary behaviors.[3] The physically active group was further classified according to the frequency of MVPA sessions per week: weekend warrior (≤2 sessions/wk) or regularly active (≥3 sessions/wk). Lastly, the weekend warrior and regularly active subgroups were granularly classified by each session duration (≤20 min, >20-30 min, >30-60 min, or >60 min/session) and intensity (calculated as the proportion of total MVPA that was vigorous [VPA]). The MVPA intensity scale was defined as: 0% (all min at moderate intensity), 1% to 24%, 25% to 49%, 50% to 74%, 75% to 99%, and 100% (all min at vigorous intensity).[11] For example, a participant performing 25 min/wk of VPA (ie, 50 min/wk [VPA duration multiplied by 2 to account for intensity]) and 100 min of moderate physical activity (MPA) had a total of 150 min/wk of MVPA, with 33% of VPA to total MVPA (VPA proportion calculated as 25 × 2 / 100 + [25 × 2]).

Ascertainment of Death

The NHIS records of study participants were linked to the National Death Index through December 31, 2015. Data linkage was performed with a combination of name, social security number, and date of birth, and had a success rate (range) of approximately 96% (91%-98%) across survey years. Details on the NHIS data linking with the National Death Index have been published elsewhere.[15] The mortality outcomes were based on the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)* codes recorded as the underlying cause of death. The following mortality outcomes were considered: all-cause, CVD (I00-09, I11, I13, and I20-51, I60-69), and cancer (C00-97) mortality.

Covariates

The covariates included were age, sex, race and ethnicity (Hispanic, non-Hispanic Black, non-Hispanic White, and other), marital status (married/living with partner; divorced/separated/widowed; never married; or missing/unknown), income and educational attainment. Income was classified according to the federal poverty income ratio (PIR) as high (≥4), middle (<4 to >1), and low (≤1). Educational attainment was classified as less than high school degree, a high school degree, more than a high school degree, or missing data. The lifestyle behaviors we considered included smoking status (defined as never, former, current smokers, or missing data) and alcohol consumption (defined as abstainer, former drinker, current drinker, or missing data). We also included body mass index (BMI), calculated as weight in kilograms divided by height in meters squared. To create a comorbidities score, we used data the participants' self-reported medical diagnosis of asthma, diabetes, hypertension, liver conditions, and/or weak or failing kidney function. In addition, we considered self-rated health (rated as excellent, very good, good, fair, or poor), mobility difficulties (not at all difficult/only a little; somewhat difficult to walk one-quarter of a mile [approximately 3 city blocks]; somewhat difficult to ascend 10 steps without resting), and psychological distress based on the Kessler 6 scale.[16,17]

Statistical Analysis

Person-years were counted from the baseline survey date to the date of death or to the end of the study period (December 31, 2015), whichever came first. Multivariable Cox proportional hazards regression models using quarter-years after the interview as the time variable were performed to examine the association of physical activity patterns with all-cause and cause-specific mortality rates and were adjusted for age at baseline (as a continuous variable), sex, race and ethnicity, marital status, income, educational attainment, smoking, alcohol intake, comorbidities score, self-rated health, psychological distress, and mobility. In addition, the first 2 years of follow-up were excluded to limit reverse causation bias. Given the small amount of missing data (≤3% for each covariate; eTable 1 in the Supplement), we used the missing data indicator to maximize statistical power rather than deleting participants with missing values or performing multiple imputation methods. Of note, previous studies using NHIS data have used a similar approach.[11,18,19] Multiple comparisons may have increased the potential for type I error; therefore, findings should be interpreted carefully. We used adjusted Wald test to assess interaction by including the cross-terms of physical activity patterns and sex. Considering that we found no evidence of interaction by sex, results were presented for all participants (men and women combined).

We performed 4 sensitivity analyses. First, we included BMI in the primary model. We also included the total amount of MVPA into the model, when we investigated whether, for the same amount of total MVPA, weekly frequency, duration of sessions, and intensity of physical activity were associated with mortality. We also excluded the first 5 years of follow-up to investigate the influence of confounding by preexisting diseases.[12] In our final sensitivity analysis, we also excluded participants with ≥600 min/wk of physical activity and ≥780 min/wk of physical activity were conducted to account for different exposure variability and to increase comparability between weekend warriors and regularly active participants (ie, relatively few weekend warriors exceeded this level). For statistically significant results in the main analysis, we calculated the *E* value to estimate the strength of the associations, on the risk ratio scale, of an unmeasured confounder with both exposure and outcome needed to explain away the observed associations.[20]

Adjusted weights, primary sampling units, and strata were used in all analysis to account for complex multistage sampling design (using the *svy* prefix) to obtain hazard ratio (HR) estimates for the association between weekend warrior and other leisure-time physical activity patterns with mortality in a representative sample of adults in the US. In addition, incorporating sample weights provided on the 2015 linked mortality data aimed to prevent biased mortality estimates.[21] Final statistical analysis was performed in April 2022. All data management and analyses were conducted using Stata, version 15.0 (StataCorp LLC). Statistical tests were 2-tailed and *P* values < .05 were considered statistically significant.

Results

The study population comprised 350 978 participants (mean [SD] age, 41.4 [15.2] years; 192 432 [50.8%] women; 69 152 [14.5%] Hispanic, 52 620 [12.1%] non-Hispanic Black, and 209 432 [67.8%] non-Hispanic White individuals). During a median of 10.4 years of follow-up (3.6 million person-years), 21 898 deaths were ascertained, including 4130 from CVD and 6034 from cancer. Baseline characteristics of the 350 978 participants by physical activity groups are displayed in **Table 1**. Compared with physically inactive participants, regularly active participants were younger and more likely to be men, leaner, never or former smokers, and current drinkers and to have a higher education level and income, lower comorbidities score, and better self-rated health (excellent/very good). Weekend warriors were younger, more likely to be men, Hispanic, current smokers, have overweight or obesity, and have lower educational attainment and income compared with regularly active participants. Median physical activity was 240 min/wk in the weekend warrior group vs 420 min/wk in the regularly active group.

Weekend Warrior and Regularly Active vs Inactive Participants

Compared with physically inactive participants, multivariable-adjusted HRs for all-cause mortality were 0.92 (95% CI, 0.83-1.02) for weekend warrior and 0.85 (95% CI, 0.83-0.88) for regularly active participants; likewise, HRs for CVD mortality were 0.87 (95% CI, 0.66-1.15) for weekend warrior and 0.77 (95% CI, 0.71-0.84) for regularly active participants. The HRs for cancer mortality were 0.94 (95% CI, 0.77-1.15) for weekend warrior and 0.88 (95% CI, 0.83-0.94) for regularly active participants. All results remained similar after adding BMI into the models (**Table 2**).

Regularly active participants with longer durations of sessions and intensity of physical activity had lower all-cause and cause-specific mortality rates compared with inactive participants (**Table 3**). Longer session duration was associated with lower all-cause mortality. We found HRs of 1.02 (95% CI, 0.86-1.21) for the those with sessions of 20 min or less to 0.83 (95% CI, 0.79-0.87) for those performing session of more than 60 min compared with inactive participants. Some VPA in addition to MVPA was associated with lower mortality vs MPA only. These association of session duration and intensity of activity remained after adding total MVPA to the model (eTable 2 in the Supplement). Similar results were observed for CVD and cancer mortality (Table 3), and after adding BMI into the model (eTable 3 in the Supplement). When comparing weekend warrior with inactive participants, higher frequency (2 vs 1 session/wk) and intensity of physical activity were not associated with lower mortality (**Table 4**).

Weekend Warrior vs Regularly Active Participants

After adjusting for the amount of total MVPA, weekend warrior participants had similar all-cause and cause-specific mortality rates compared with regularly active participants (**Table 5**). The HRs for weekend warrior vs regularly active participants (reference) were 1.08 (95% CI, 0.97-1.20) for all-cause mortality, 1.14 (95% CI, 0.85-1.53) for CVD mortality, and 1.07 (95% CI, 0.87-1.31) for cancer mortality. Null associations were consistently observed independent of weekly frequency and intensity of activity performed by weekend warrior participants (Table 5).

Sensitivity Analysis

In the sensitivity analyses excluding the first 5 years of follow-up and participants who reported 600 min/wk or more of physical activity, results did not change substantially; that is, null associations with all mortality outcomes were observed when comparing weekend warrior with regularly active participants (eTables 4-6 in the Supplement).

Discussion

This study examined the association of leisure-time physical activity patterns with all-cause and cause-specific mortality in a large cohort of 350 978 adults in the US. Compared with physically inactive participants, regularly active participants had lower all-cause and cause-specific mortality rates, after adjusting for potential confounders and excluding the first 2 years of follow-up. Regarding mortality, we observed nonstatistically significant associations between weekend warrior vs inactive participants. However, we found that weekend warrior and regularly active participants had similar all-cause and cause-specific mortality, suggesting that when performing the same amount of physical activity, spreading it over more days or concentrating it into fewer days may not influence mortality outcomes.

Table 1. Baseline Characteristics of Participants According to Leisure-time Physical Activity Pattern, National Health Interview Survey, 1997 to 2013

	Pattern of physical activity, No. (%)[a]			
Variable	Inactive	Weekend warrior	Regularly active	Overall
Total	190 080 (52.5)	9992 (3.0)	150 906 (44.5)	350 978 (100.0)
Age, y				
18-44	104 883 (56.8)	6502 (65.8)	94 750 (63.8)	206 135 (60.2)
45-64	61 134 (32.9)	2745 (27.8)	43 596 (29.4)	107 475 (31.2)
65-84	24 063 (10.4)	745 (6.4)	12 560 (6.8)	37 368 (8.7)
Sex				
Men	77 684 (45.2)	6521 (69.1)	74 341 (52.7)	158 546 (49.3)
Women	112 396 (54.8)	3471 (31.0)	76 565 (47.3)	192 432 (50.8)
Race and ethnicity				
Hispanic	44 261 (17.2)	1996 (15.4)	22 895 (11.2)	69 152 (14.5)
Non-Hispanic Black	32 396 (13.9)	1344 (11.6)	18 880 (10.1)	52 620 (12.1)
Non-Hispanic White	102 711 (63.0)	5964 (66.8)	100 757 (73.6)	209 432 (67.8)
Other[b]	10 712 (5.9)	688 (6.3)	8374 (5.1)	19 774 (5.6)
Education level				
<High school degree	42 522 (19.2)	1340 (12.1)	14 930 (9.1)	58 792 (14.5)
High school degree	59 043 (32.1)	2746 (28.1)	33 479 (22.7)	95 268 (27.8)
>High school degree	87 263 (48.1)	5876 (59.6)	102 094 (68.0)	195 233 (57.3)
Income[c]				
Low	35 289 (14.2)	1198 (9.3)	18 284 (9.2)	54 771 (11.8)
Middle	101 402 (52.6)	4901 (47.2)	67 685 (42.9)	173 988 (48.1)
High	53 389 (33.2)	3893 (43.5)	64 937 (48.0)	122 219 (40.1)
Marital status				
Married/living with partner	104 170 (64.8)	5419 (63.3)	79 805 (62.3)	189 394 (63.6)
Widowed/divorced/separated	43 090 (14.8)	1747 (10.7)	27 521 (11.5)	72 358 (13.2)
Never married	42 277 (20.2)	2815 (26.0)	43 288 (26.1)	88 380 (23.0)
BMI				
≤18.4	3439 (1.9)	144 (1.3)	2187 (1.5)	5770 (1.7)
18.5-24.9	66 258 (35.1)	3753 (36.9)	63 025 (41.8)	133 036 (38.1)
25-29.9	63 646 (33.4)	3715 (37.7)	53 229 (35.3)	120 590 (34.4)
≥30	49 335 (25.8)	2195 (22.2)	29 299 (19.4)	80 829 (22.9)
Cigarette smoking status				
Never	114 015 (59.5)	5539 (56.0)	92 305 (61.6)	211 859 (60.3)
Former	31 972 (17.2)	1857 (18.6)	30 249 (20.1)	64 078 (18.5)
Current	43 436 (23.0)	2580 (25.1)	28 145 (18.2)	74 161 (20.9)
Alcohol intake				
Lifetime abstainer	53 900 (27.0)	1504 (15.4)	23 825 (15.8)	79 229 (21.7)
Former drinker	25 889 (13.2)	1015 (10.1)	15 227 (9.6)	42 131 (11.5)
Current drinker	107 569 (58.3)	7409 (73.9)	110 841 (74.0)	225 819 (65.8)
Psychological distress				
No	182 933 (96.5)	9749 (97.7)	147 505 (98.0)	340 187 (97.2)
Yes	5057 (2.4	163 (1.4	2336 (1.4	7556 (1.9
Chronic condition, No.				
0	129 620 (69.2)	7390 (74.3)	109 655 (73.2)	246 665 (71.1)
1	47 911 (24.7)	2184 (21.7)	34 741 (22.7)	84 836 (23.7)
≥2	12 060 (5.9)	409 (3.9)	6271 (4.0)	18 740 (5.0)
Self-rated health				
Excellent	51 979 (28.9)	3504 (36.3)	62 162 (42.9)	117 645 (35.3)
Very good	64 405 (34.4)	3654 (36.9)	53 762 (35.4)	121 821 (34.9)
Good	54 824 (28.0)	2363 (22.6)	29 233 (18.5)	86 420 (23.6)
Fair/poor	18 798 (8.8)	468 (4.1)	5705 (3.3)	24 971 (6.2)
Mobility difficulty				
None/little	171 434 (91.1)	9678 (97.1)	146 783 (97.6)	327 895 (94.2)
Difficult/very difficult/unable	16 271 (7.7)	267 (2.5)	3666 (2.1)	20 204 (5.1)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] A multistage area probability sampling design was used by the survey. Analyses of percent values were conducted using the adjusted weights. Variable categories may not sum to 100% because of missing data. More details are available in the statistical analysis section of the Methods.

[b] This category included American Indian or Alaska Native; Native Hawaiian or other Pacific Islander; Asian; Hispanic or Latino; mixed races; refused to respond; or race unknown.

[c] Classified according to the federal poverty income scale as high (≥4), middle (<4 to >1), and low (≤1).

To our knowledge, only a few prospective studies have examined the association of weekend warrior physical activity pattern with mortality. A pooled study of 11 cohorts of 63 591 respondents to the Health Survey for England and Scottish Health Survey with prospective linkage to mortality records[7] found that the weekend warrior physical activity

Table 2. Association of Physical Activity Pattern With All-Cause and Cause-Specific Mortality

Outcomes	Deaths	Participants	HR (95% CI) Model 1[a]	Model 2[b]	Model 3[c]	*E* value[d]
All-cause mortality						
Inactive	14 943	190 080	1 [Reference]	1 [Reference]	1 [Reference]	
Weekend warrior	512	9992	0.92 (0.83-1.02)	0.92 (0.83-1.02)	0.92 (0.83-1.02)	NA
Regularly active	6443	150 906	0.85 (0.83-0.88)	0.85 (0.82-0.88)	0.85 (0.82-0.88)	1.63
CVD mortality						
Inactive	2961	190 080	1 [Reference]	1 [Reference]	1 [Reference]	
Weekend warrior	89	9992	0.87 (0.66-1.15)	0.87 (0.66-1.15)	0.87 (0.65-1.14)	NA
Regularly active	1080	150 906	0.77 (0.71-0.84)	0.77 (0.71-0.84)	0.76 (0.69-0.84)	1.92
Cancer mortality						
Inactive	3962	190 080	1 [Reference]	1 [Reference]	1 [Reference]	
Weekend warrior	143	9992	0.94 (0.77-1.15)	0.94 (0.77-1.15)	0.94 (0.77-1.14)	NA
Regularly active	1929	150 906	0.88 (0.83-0.94)	0.89 (0.83-0.95)	0.88 (0.82-0.94)	1.53

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; NA, not applicable/calculated.

[a] Adjusted for age, sex, race and ethnicity, education, income, marital status, smoking, alcohol intake, self-rated health, psychological distress, number of comorbidities, and mobility.

[b] Model 1 + body mass index (calculated as weight in kilograms divided by height in meters squared).

[c] Model 1 + total volume of physical activity.

[d] The *E* value is the minimum strength of association, on the risk ratio scale, that an unmeasured confounder would need to have with both the treatment and outcome, conditional on the measured covariates, to explain away a treatment-outcome association.

Table 3. Association of Regularly Active Physical Activity Pattern With All-Cause and Cause-Specific Mortality, by Frequency, Duration, and Intensity of Activity

Dimension	Mortality, HR (95% CI)[a] All-cause	CVD	Cancer
Physical activity pattern			
Inactive	1 [Reference]	1 [Reference]	1 [Reference]
Regularly active	0.85 (0.83-0.88)	0.77 (0.71-0.84)	0.88 (0.83-0.94)
Frequency, sessions/wk			
3-4	0.81 (0.76-0.86)	0.81 (0.68-0.97)	0.83 (0.73-0.93)
≥5	0.87 (0.83-0.90)	0.76 (0.70-0.83)	0.90 (0.84-0.96)
Duration of session, min			
≤20	1.02 (0.86-1.21)	0.85 (0.56-1.31)	1.11 (0.84-1.47)
>20-≤30	0.92 (0.85-0.99)	0.75 (0.62-0.90)	0.98 (0.86-1.11)
>30-≤60	0.85 (0.80-0.89)	0.77 (0.68-0.87)	0.87 (0.80-0.96)
>60	0.83 (0.79-0.87)	0.77 (0.69-0.87)	0.85 (0.77-0.93)
Intensity (VPA/MVPA), %			
0	0.91 (0.86-0.95)	0.74 (0.65-0.85)	0.93 (0.84-1.03)
1-25	0.80 (0.71-0.91)	0.88 (0.67-1.16)	0.75 (0.60-0.94)
26-50	0.94 (0.86-1.03)	0.89 (0.71-1.13)	1.01 (0.86-1.18)
51-75	0.80 (0.75-0.85)	0.73 (0.62-0.87)	0.76 (0.67-0.86)
76-99	0.81 (0.75-0.88)	0.64 (0.51-0.80)	0.90 (0.78-1.05)
100	0.83 (0.76-0.90)	0.92 (0.77-1.09)	0.94 (0.82-1.08)

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; MVPA, moderate to vigorous physical activity; VPA, vigorous physical activity.

[a] Adjusted for age, sex, race and ethnicity, education, income, marital status, smoking, alcohol intake, self-rated health, psychological distress, number of comorbidities, and mobility difficulty.

pattern was associated with 30% lower all-cause mortality (HR, 0.70; 95% CI, 0.60-0.82), 41% lower CVD mortality (HR, 0.59; 95% CI, 0.48-0.73), and 13% lower cancer mortality (HR, 0.79; 95% CI, 0.66-0.94) compared with inactive participants. In the Harvard Alumni Health Study,[6] weekend warrior physical activity pattern was associated with 15% lower all-cause mortality (risk ratio, 0.85; 95% CI, 0.65-1.11) compared with inactive participants. In a National Health and Nutrition Examination Survey, 2003-2005, accelerometer-based study, weekend warrior physical activity pattern was associated with 69% lower all-cause mortality (HR 0.31; 95% CI, 0.17-0.57) compared with physically inactive participants.[22] In our study, we found a nonstatistically significant association between weekend warrior physical activity with 8% lower all-cause mortality (HR 0.92; 95% CI, 0.83-1.02), 13% lower CVD mortality (HR 0.87; 95% CI, 0.66-1.15), and 6% lower cancer mortality (HR 0.94; 95% CI, 0.77-1.15). The overall evidence suggests that there

Table 4. Association of Weekend Warrior Physical Activity Pattern With All-Cause and Cause-Specific Mortality, by Frequency and Intensity of Activity

Dimension	Mortality, HR (95% CI)[a] All-Cause	CVD	Cancer
Physical activity pattern			
Inactive	1 [Reference]	1 [Reference]	1 [Reference]
Weekend warrior	0.92 (0.83-1.02)	0.87 (0.66-1.15)	0.94 (0.77-1.15)
Frequency, sessions/wk			
1	0.87 (0.71-1.06)	1.14 (0.71-1.83)	0.63 (0.40-1.00)
2	0.94 (0.83-1.05)	0.75 (0.55-1.02)	1.06 (0.85-1.32)
Intensity (VPA/MVPA), %			
0	0.98 (0.84-1.14)	0.97 (0.66-1.42)	1.12 (0.84-1.49)
1-25	0.63 (0.33-1.19)	0.45 (0.06-3.21)	0.84 (0.28-2.49)
26-50	0.88 (0.55-1.39)	NA	0.94 (0.36-2.49)
51-75	0.71 (0.46-1.10)	0.52 (0.19-1.41)	0.54 (0.26-1.11)
76-99	0.84 (0.57-1.26)	1.28 (0.63-2.62)	0.64 (0.26-1.56)
100	0.94 (0.80-1.11)	0.86 (0.53-1.40)	0.90 (0.65-1.26)

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; MVPA, moderate to vigorous physical activity; NA, not applicable/calculated; VPA, vigorous physical activity.

[a] Adjusted for age, sex, race and ethnicity, education, income, marital status, smoking, alcohol intake, self-rated health, psychological distress, number of comorbidities, and mobility difficulty.

Table 5. Association of Weekend Warrior Physical Activity Pattern With All-Cause and Cause-Specific Mortality, With Regularly Active Participants as the Reference Category

Dimension	Mortality, HR (95% CI)[a] All-cause	CVD	Cancer
Physical activity pattern			
Regularly active	1 [Reference]	1 [Reference]	1 [Reference]
Weekend warrior	1.08 (0.97-1.20)	1.14 (0.85-1.53)	1.07 (0.87-1.31)
Frequency, session/wk			
1	1.01 (0.82-1.24)	1.44 (0.89-2.32)	0.74 (0.47-1.17)
2	1.10 (0.97-1.24)	0.97 (0.71-1.33)	1.23 (0.98-1.54)
Intensity (VPA/MVPA), %			
0	1.16 (0.99-1.35)	1.22 (0.82-1.82)	1.29 (0.96-1.72)
1-25	0.74 (0.39-1.41)	0.58 (0.08-4.2)	0.97 (0.33-2.90)
26-50	1.04 (0.66-1.67)	NA	1.11 (0.42-2.94)
51-75	0.84 (0.55-1.30)	0.68 (0.25-1.85)	0.62 (0.30-1.29)
76-99	0.98 (0.65-1.46)	1.62 (0.78-3.35)	0.76 (0.31-1.87)
100	1.08 (0.92-1.27)	1.12 (0.69-1.81)	1.06 (0.76-1.47)

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; MVPA, moderate to vigorous physical activity; NA, not applicable/calculated; VPA, vigorous physical activity.

[a] Adjusted for age, sex, race and ethnicity, education, income, marital status, smoking, alcohol intake, self-rated health, psychological distress, number of comorbidities, mobility difficulty, and total volume of physical activity.

may be some benefit associated with weekend warrior physical activity pattern and lower mortality.

Differences between our findings and those of previous studies could be because of differences in our definition of the reference group. We defined physically inactive participants as those who were not reaching the WHO physical activity recommendation of at least 150 min/wk of MVPA. Of note, fewer minutes of MVPA per week (ie, less than the WHO guidelines) has been associated with lower mortality.[7] In a study by O'Donovan and colleagues,[7] weekend warriors were compared with participants who reported no MVPA. Although this comparison may provide a clearer contrast in terms of amount of MVPA, its reference group was more likely to have preexisting diseases or conditions at baseline (ie, having a disease/condition is often associated with low/no MVPA). Confounding may be another factor that led to difference between our study and prior work. O'Donovan and colleagues'[7] main findings were adjusted for age, sex, smoking, occupation, and long-standing illness. In our study, we excluded participants with major noncommunicable diseases and those unable to perform activities of daily living, and we adjusted for several potential confounders. However, unmeasured confounding may still exist. For example, we estimated that the magnitude of unmeasured confounding, on the risk ratio scale, needed to explain away the statistically significant associations between regularly active vs inactive participants was 1.63 for all-cause, 1.92 for CVD, and 1.53 for cancer mortality (Table 2).

Implications for Public Health

The foremost findings of this study, based on 3 mortality outcomes, reinforce the importance of reaching the recommended levels of physical activity for health. Compared with physically inactive participants, regularly active patterns of leisure-time physical activity were associated with lower all-cause and cause-specific mortality. For the same amount of physical activity, we did not observe differences in mortality outcomes between weekend warrior and regularly active participants. These findings could be useful for clinical or individual counseling and for public health policies and interventions. Observational epidemiologic evidence suggests that there may be some health benefits associated with weekend warrior physical activity pattern, supporting its inclusion in prevailing physical activity guidelines. This is good news considering that the weekend warrior physical activity pattern may be a more convenient option for many people striving to achieve the recommended levels of physical activity. Clinicians and practitioners involved in public health interventions may advise that the same amount of physical activity, whether it is spread over more days or concentrated in fewer days during a week, may provide similar health benefits.

Strengths and Limitations

There are a number of limitations that should be considered when interpreting the results of this study. First, the exposure of interest was assessed via questionnaire, a method more prone to measurement error than those using device-measured physical activity (eg, accelerometers). In addition, device-measured physical activity may capture all activity performed in a day, not just leisure-time physical activity.[22] However, there are advantages to questionnaires. They are a cost-effective method of collecting information on type, domains, and context (eg, with whom, where, when) of physical activity in large-scale populational studies.[23,24] However, the NHIS adult physical activity questionnaire included only information regarding frequency and duration of light or moderate to vigorous physical activity, which we acknowledge is not ideal given the present guidelines. Thus, we recommend that future cohort studies combined both self-reported and device-measured physical activity. Second, a single physical activity measurement was obtained at baseline. To our knowledge, no other study has compared the associations of long-term weekend warrior and regularly active physical activity patterns with mortality rates. Studies using repeated measures of physical activity are less prone to measurement error and tend to show stronger magnitude of associations with mortality compared with studies using a single-measure of physical activity over time.[14] Third, the low number of deaths in the weekend warrior group may explain part of the nonsignificant associations with mortality. Finally, the influence of residual confounding (eg, dietary intake) in our findings should be considered.

Nonetheless, this study has several strengths. Compared with previous epidemiologic studies of physical activity and mortality, this study analyzed data from a large, representative sample of adults in the US who were followed during an average of 10 years. Our main analysis excluded participants with preexisting chronic diseases and the first 2 years of follow-up, and the models were adjusted for several potential confounders.[13,14] We also provided granular comparisons between weekend warrior, regularly active, and physically inactive participants by frequency, duration of sessions. and intensity of activities.

Conclusions

The findings of this large prospective cohort study underscore that regular physical activity has been associated with lower risks of all-cause and cause-specific mortality compared with physical inactivity. Most importantly, these findings suggest that whether the recommended amount of moderate to vigorous physical activity is spread out during the week or concentrated into fewer days, there may be no significant difference in health benefits. For people with fewer opportunities for daily or regular physical activity during their work week, these findings are important.

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