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Associations of the 'weekend warrior' physical activity pattern with all-cause, cardiovascular disease, and cancer mortality: the Mexico City Prospective Study

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3 **Associations of the ‘weekend warrior’ physical activity pattern with all-cause, cardiovascular**
4 **disease, and cancer mortality: the Mexico City Prospective Study**
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Abstract

Objectives: The objective was to investigate the benefits of the 'weekend warrior' physical activity pattern in Latin America, where many people take part in high levels of non-exercise physical activity.

Methods: Participants in the Mexico City Prospective Study were surveyed from 1998-2004 and resurveyed from 2015-2019. Those who exercised up to once or twice per week were termed weekend warriors. Those who exercised more often were termed regularly active. Analyses were adjusted for potential confounders.

Results: The main analysis included 26,006 deaths in 154,882 adults (67% female) aged 52 ± 13 years followed for 18 ± 4 years (mean \pm SD). Compared with those who reported no exercise, the hazard ratio (95% confidence interval) was 0.88 (0.83, 0.93) in the weekend warriors, and 0.88 (0.84, 0.91) in the regularly active. Similar results were observed for cardiovascular disease and cancer mortality, but associations were weaker. Stratified analyses showed that substantial reductions in all-cause mortality risk only occurred when the duration of exercise sessions was at least 30-60 minutes. The repeated-measures analysis included 843 deaths in 10,023 adults followed for 20 ± 2 years. Compared with being inactive or becoming inactive, the hazard ratio was 0.86 (0.65, 1.12) when being a weekend warrior or becoming a weekend warrior, and 0.85 (0.70, 1.03) when being regularly active or becoming regularly active.

Conclusions: This is the first prospective study to investigate the benefits of the weekend warrior physical activity pattern in Latin America. The results suggest that even busy adults could benefit from taking part in one or two sessions of exercise per week.

Summary

What is already known on this topic

- The 'weekend warrior' takes part in one or two sessions of sport or exercise per week and studies in high-income countries in Europe and North America suggest that the benefits of exercising once or twice per week are similar to exercising more often.

What this study adds

- To the best of our knowledge, the Mexico City Prospective Study is the largest cohort study in Mexico or elsewhere in Latin America.
- The study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders.
- In this analysis of more than 150,000 cohort members, all-cause mortality risk was reduced by approximately 15% in the 'weekend warriors' who exercised once or twice per week and in the 'regularly active' who exercised more often.
- For both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes.
- In the repeated measures analysis, we found some evidence that being a weekend warrior or becoming a weekend warrior was associated with reduced risk of mortality.

How this study might affect research, practice or policy

- The weekend warrior physical activity pattern may be a more convenient option for busy people.
- There are high levels of non-exercise physical activity in many cities in Latin America and this study is important because it suggests that even busy people could benefit from taking part in one or two sessions of sport and exercise per week.

Introduction

Physical activity is regarded as one of the leading modifiable risk factors for morbidity and mortality worldwide.^{1,2} The promotion of physical activity is also thought to be beneficial to meeting 15 of the 17 United Nations Sustainable Development Goals.³ Nonetheless, relatively little is known about the benefits of physical activity in low- and middle-income countries in Latin America, where participation in large amounts of physical activity is a necessity, not a choice.³⁻⁸ Indeed, poverty, crime, informal work, and the cost of car ownership make walking for transport inevitable.⁴⁻⁶ Roughly 30% to 45% of all journeys are made on foot in low-income groups in cities in Latin America, compared with around 20% of journeys in higher-income groups.⁴ Furthermore, around 20% to 25% of residents in large cities in Latin America meet prevailing physical activity guidelines just by walking for transport.⁹ Participation in sport and exercise may be more beneficial to health than participation in occupational physical activity and other types of physical activity.^{10,11} Therefore, it is important to investigate the benefits of taking part in sport and exercise.

The 'weekend warrior' takes part in one or two sessions of sport or exercise per week and studies in high-income countries in Europe and North America suggest that the benefits of exercising once or twice per week are much the same as exercising more often.¹²⁻¹⁴ The weekend warrior physical activity pattern may be more convenient^{15,16} and it may be particularly important to investigate the benefits of different physical activity patterns in low- and middle-income countries in Latin America because lack of time is a major barrier to physical activity in the region.^{15,17,18} It may be particularly advantageous to investigate the benefits of the weekend warrior physical activity pattern in Latin America because the region is home to a weekly physical activity intervention known as the Ciclovía Recreativa.¹⁹ The Ciclovía Recreativa is a remarkably simple intervention in which main roads are closed to motor vehicles and are opened exclusively for people to enjoy a safe, free space to exercise.¹⁹ Millions of people across Latin America take part in the Ciclovía Recreativa every weekend¹⁹⁻²¹ and most participants say they would not exercise if it were not for the Ciclovía Recreativa.^{22,23} The health and economic impacts of the Ciclovía Recreativa in 15 cities in Latin America have been conservatively estimated to include the prevention of around 360 premature deaths per year and the associated cost saving of around US\$ 200 million per year.²⁰

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3 Consistency of association is one of the fundamental considerations when inferring
4 causality²⁴ and it is important to gather evidence from settings other than high-income
5 countries in Europe and North America. Mexico is an upper-middle-income country in Latin
6 America²⁵ and the Mexico City Prospective Study is a large cohort study that includes
7 measures of physical activity, mortality, and potential confounders.²⁶ The main objective of
8 the present analysis was to investigate associations of the weekend warrior physical
9 activity pattern with all-cause, cardiovascular disease (CVD), and cancer mortality in the
10 Mexico City Prospective Study. Participation in sport and exercise may change over the
11 life course,²⁷ yet few cohort studies include repeated measures of physical activity.²⁸⁻³¹
12 Participants in the Mexico City Prospective Study were assessed at baseline and after
13 around 16 years and the secondary objective of the present analysis was to investigate
14 associations of physical activity patterns with mortality using repeated measures of
15 physical activity and potential confounders.
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Methods

Participants

The Mexico City Prospective Study is described in detail elsewhere.²⁶ Briefly, door-to-door interviews were conducted from 1995 to 1997 to compile a record of all households in the neighboring districts of Coyoacán and Iztapalapa in Mexico City in Mexico.²⁶ Recruitment teams then visited households and at least one participant aged 35 years or older was recruited from 94% of eligible households.²⁶ The resulting sample was deemed to be broadly representative of the population aged 35 years or older in Mexico City.²⁶ Trained nurses collected data in the participant's household and the baseline survey took place from 1998 to 2004 and the resurvey took place from 2015 to 2019.²⁶ The study was approved by the Mexican Ministry of Health, the Mexican National Council of Science and Technology (approval number 0595 P-M), and the Central Oxford Research Ethics Committee (C99.260). All participants provided written informed consent. The data used in the current report were obtained through an open-access data request made to the Mexico City Prospective Study principal investigators.

Defining physical activity, exercise and sport

In the broadest sense, physical activity is defined as any volitional movement of skeletal muscle that results in energy expenditure.³² Exercise is a form of leisure time physical activity that is planned, structured, and repetitive. Exercise training is purposeful and is performed with specific external goals, including the improvement or maintenance of physical fitness, physical performance or health.^{32,33} Sport is a form of physical activity that includes rules and is usually competitive. The true sense of sport is broad: "Sport means all forms of physical activity, which, through casual or organised participation, aim at expressing or improving physical fitness and mental wellbeing, forming social relationships or obtaining results in competition at all levels".³⁴ The terms 'sport' and 'exercise' can have negative connotations in Europe and North America,³⁵ but asking someone what sport they like in Latin America is as innocent a question as asking them what music they like.¹⁸

Exposure

The exposure was leisure time physical activity. During the baseline survey, participants were asked whether they exercised or played sports (yes or no). Those who said yes, were then asked how many times per week they exercised (less than once per week; once or twice per week; or, three or more times per week). And, they were asked how many minutes they spent exercising per session (less than 30; from 30 to 60; or, more than 60). Similar questions were asked 16 years later at resurvey and we created three exposure groups. The 'no sport or exercise' group included those who said they did not exercise or play sports. The 'weekend warrior' group included those who said they exercised or played sports up to once or twice per week. The 'regularly active' group included those who said they exercised or played sports three or more times per week. Simple physical activity assessment tools like the one used in the present study have been validated against multiple-item physical activity assessment tools³⁶ and against cardiorespiratory fitness.³⁷

Outcomes

The registration of deaths in Mexico is thorough, with almost all deaths certified medically and with few deaths attributed to unknown causes.³⁸ The outcomes were all-cause mortality, CVD mortality, and cancer mortality. Mortality was tracked to 31st December 2020 through probabilistic linkage to the national death register based on the participant's name, age, and sex. Diseases listed on the death certificates were coded according to the International Classification of Diseases, 10th Revision (ICD-10).³⁹

Potential confounders

Potential confounders that may influence the relationships between physical activity and mortality include age, sex, education, income, smoking, diet, and alcohol.⁴⁰⁻⁴² Body mass index, hypertension, diabetes, and other such variables might be regarded as biological intermediates, not confounding factors.^{2,43} Trained nurses recorded age and sex. Participants were asked about education at baseline and resurvey and we created five groups (none; at least some elementary; at least some high-school; at least some college; and, at least some university). Participants were asked about income at baseline and resurvey and we created three groups (tertile 1, tertile 2, and tertile 3). The trained nurses

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3 asked about smoking at baseline and resurvey and we created three categories (never,
4 former, and current). Participants were also asked about alcohol drinking frequency and
5 we created four categories (never; occasionally; at least once per week; and, daily).
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7 Finally, diet quality at baseline and resurvey was expressed as fruit and vegetable intake
8 (never; one or two days per week; three or four days per week; five or more days per
9 week).
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14 *Statistical analyses*

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17 Participants' characteristics at baseline were described according to physical activity
18 patterns. Associations of physical activity patterns with mortality were investigated using
19 Cox models. The proportional hazards assumption was checked graphically for the
20 discrete physical activity patterns and no violations were observed. In the main analysis,
21 we used a single-measure design. We investigated associations of physical activity
22 patterns at baseline with mortality. We also investigated associations stratified by length of
23 time spent exercising at each session. The simple physical activity questionnaire allowed
24 us to investigate three strata: less than 30 minutes per session; from 30 to 60 minutes per
25 session; and, more than 60 minutes per session. Analyses were adjusted for age, sex,
26 education, income, smoking, fruit and vegetable intake, and alcohol. In a sensitivity
27 analysis, associations of physical activity patterns at baseline with all-cause mortality were
28 further adjusted for self-reported illnesses at baseline, including diabetes, hypertension,
29 heart attack, stroke, and cancer.
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39 In the secondary analyses, we used a repeated-measures design. We investigated
40 associations of physical activity patterns with mortality using repeated measures of
41 physical activity and potential confounders. The analysis included baseline measures of
42 age and sex as well as baseline and resurvey measures of physical activity, education,
43 income, smoking, and alcohol. Physical activity, education, income, smoking, fruit and
44 vegetable intake, and alcohol were treated as time-varying variables. The analysis
45 included all the available data for each variable, whether the data were available at
46 baseline, resurvey, or both. Robust estimates of variance were used to obtain the
47 confidence intervals in the repeated-measures analysis because conventional estimates of
48 variance are not appropriate when observations are dependent. Participants who died
49 during the first two years of follow-up were removed from all analyses to minimize the
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3 possibility of reverse causation. All analyses were performed using Stata SE version 17.0
4 for Mac (StataCorp, Texas, USA).
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8 *Patient and public involvement*
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11 Patients and other members of the public were not involved in the design or conduct of this
12 study.
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16 *Equity, diversity and inclusion*
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19 In the Mexico City Prospective Study, door-to-door interviews were conducted in the
20 neighboring districts of Coyoacán and Iztapalapa, at least one person was recruited from
21 94% of eligible households, and the final sample was broadly representative of the
22 population aged 35 years or older in Mexico City. The author team includes six men and
23 three women. Five of the authors live and work in Latin America and one author spends
24 their time in both Europe and Latin America. Physical activity levels are reported according
25 to age, sex, education, and income and associations between physical activity and health
26 are adjusted for these important confounders. In the Discussion, we explain why the
27 magnitude of the association between leisure time physical activity and mortality may be
28 different in Latin America and in high-income countries in Europe and North America.
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Results

Figure S1 in the online supplement shows the flow of participants through the study. Data from 154,882 of 159,517 (97%) cohort members were included in the main analysis, after excluding 2,530 people who died during the first two years of follow-up and 2,105 with missing values for the exposures or the outcomes. Table 1 shows participants' characteristics at baseline according to physical activity patterns. Age was around 52 years in those who reported no sport or exercise and was similar in the weekend warriors and the regularly active. The proportion of women was 70% in those who reported no sport or exercise and was lower in the other groups. The proportion with no education was 15% in those who reported no sport or exercise and was only 7% in the weekend warriors and the regularly active. The proportion in the lowest income tertile was approximately 50% in those who reported no sport or exercise, 31% in the weekend warriors, and 43% in the regularly active. The proportion who had never smoked was around 50% in those who reported no sport or exercise and was lower in the other groups. The proportion who currently smoked was highest in the weekend warriors. The proportion who had never drank alcohol was around 21% in those who reported no sport or exercise and was lower in the other groups. The proportion who drank at least once a week was highest in the weekend warriors. The frequency of fruit and vegetable intake tended to be higher in the weekend warriors, and higher still in the regularly active.

Table 2 shows associations of physical activity patterns at baseline with mortality risks. Participants were followed for 17.6 ± 4.0 years (mean \pm SD) and there was a total of 26,006 deaths from all causes during 2,721,235 person-years of follow-up. Compared with the group that reported no sport or exercise, the hazard ratio (95% confidence interval) was 0.88 (0.84, 0.93) in the weekend warrior group, and 0.88 (0.85, 0.91) in the regularly active group after adjustment for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. There was a total of 8,750 deaths from CVD. Compared with the group that reported no sport or exercise, the fully-adjusted hazard ratio was 0.94 (0.86, 1.03) in the weekend warrior group, and 0.93 (0.87, 0.99) in the regularly active group. Finally, there was a total of 3,409 deaths from cancer. Compared with the group that reported no sport or exercise, the fully-adjusted hazard ratio was 0.82 (0.71, 0.95) in the weekend warrior group, and 0.94 (0.86, 1.04) in the regularly active groups. Table S1 in the online supplement shows the results of the sensitivity analysis. Associations of

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3 physical activity patterns with all-cause mortality were similar after further adjustment for
4 diabetes, hypertension, heart attack, stroke, and cancer.
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8 Table 3 shows associations of physical activity patterns at baseline with all-cause mortality
9 risk stratified by length of time spent exercising at each session. The first stratum was less
10 than 30 minutes per session. Compared with the group that reported no sport or exercise,
11 the hazard ratio (95% confidence interval) was 1.03 (0.94, 1.14) in the weekend warrior
12 group, and 0.95 (0.89, 1.01) in the regularly active group after adjustment for age, sex,
13 education, income, smoking, fruit and vegetable intake, and alcohol. The second stratum
14 was 30 to 60 minutes per session. Compared with the group that reported no sport or
15 exercise, the fully-adjusted hazard ratio was 0.84 (0.78, 0.91) in the weekend warrior
16 group, and 0.88 (0.84, 0.93) in the regularly active group. The third stratum was more than
17 60 minutes per session. Compared with the group that reported no sport or exercise, the
18 fully-adjusted hazard ratio was 0.80 (0.75, 0.89) in the weekend warrior group, and 0.81
19 (0.75, 0.86) in the regularly active group.
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28 Table 4 shows physical activity patterns at baseline and resurvey. The present study
29 included 10,023 of 10,143 (99%) cohort members who were resurveyed after 19.7 ± 1.9
30 years. Among those who reported no sport or exercise at baseline, 6,688 (84%) reported
31 being inactive at resurvey, 318 (4%) reported being weekend warriors at resurvey, and
32 930 (12%) reported being regularly active at resurvey. Among those who reported being
33 weekend warriors at baseline, 474 (65%) reported being inactive at resurvey, 100 (14%)
34 reported being weekend warriors at resurvey, and 152 (21%) reported being regularly
35 active at resurvey. Among those who reported being regularly active at baseline, 847
36 (62%) reported being inactive at resurvey, 85 (6%) reported being weekend warriors at
37 resurvey, and 432 (32%) reported being regularly active at resurvey.
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46 Table 5 shows associations of physical activity patterns with all-cause mortality risk using
47 repeated measures of physical activity and potential confounders. Participants were
48 followed for 19.7 ± 1.9 years and there was a total of 843 deaths during 195,580 person-
49 years of follow-up. Compared with being inactive or becoming inactive, the hazard ratio
50 (95% confidence interval) was 0.86 (0.65, 1.12) when being a weekend warrior or
51 becoming a weekend warrior, and 0.85 (0.70, 1.03) when being regularly active or
52 becoming regularly active.
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Discussion

The main objective of this study was to investigate associations of the weekend warrior physical activity pattern with mortality in adults in Mexico City. We found that the weekend warrior physical activity pattern and the regularly active physical activity pattern were associated with similar reductions in mortality risks. In what are novel findings, we also found that, for both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes. The secondary objective was to investigate associations of physical activity patterns with mortality using repeated measures of physical activity and potential confounders. We found that physical activity patterns changed considerably over time. In what are also novel findings, we found some evidence that being a weekend warrior or becoming a weekend warrior and being regularly active or becoming regularly active were associated with reduced risk of mortality.

Novelty and importance

To the best of our knowledge, this is the first study of the associations of the weekend warrior physical activity pattern with mortality in Mexico or any other low- to middle-income country in Latin America. The Mexico City Prospective Study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders.²⁸⁻³⁰ In 2004, Lee and colleagues first investigated the benefits of the weekend warrior physical activity pattern in a relatively small study in the United States.⁴⁴ More recently, O'Donovan and colleagues investigated associations of physical activity patterns with mortality in more than 63,000 adults in England and Scotland.¹³ They found that all-cause mortality risk was around 30% lower in weekend warriors and in the regularly active, whether or not they met prevailing physical activity guidelines.¹³ More recently still, Inoue and colleagues investigated associations of daily step patterns with mortality in more than 3,000 adults in the United States.⁴⁵ They found that all-cause mortality risk was lower in those accumulated at least 8000 steps on one or two days per week compared with those who never took 8000 steps per day.⁴⁵ The present study is important because findings from high-income countries in Europe and North America may not be generalizable to low- to middle-income countries in Latin America.

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3 The present study suggests that all-cause mortality risk is around 15% lower in exercisers
4 than non-exercisers. In contrast, large studies in high-income countries in Europe and
5 North America suggest that all-cause mortality risk is around 30% lower in exercisers than
6 non-exercisers.⁴⁶ These differences in risk may be explained by the high amounts of non-
7 exercise physical activity that are part of everyday life in many cities in Latin America^{4-6,8,9}
8 and other low- and middle-income regions.⁷ For example, if the non-exercise group were
9 to take part in large amounts of walking for transport in Latin America, then the difference
10 in risk between the exercise and non-exercise groups would not be as great as in high-
11 income countries. Indeed, Lear and colleagues found that moderate and high levels of
12 exercise were associated with reduced risk of mortality and major CVD events in high-
13 income and upper-middle-income countries, but not in lower-middle-income and low-
14 income countries where people took part in high amounts of non-exercise physical
15 activity.⁴² The present study also suggests that there is a substantial reduction in cancer
16 mortality risk in weekend warriors and little or no reduction in the regularly active. These
17 results should be interpreted with caution because of the relatively low number of cancer
18 deaths and because other large studies suggest that different physical activity patterns are
19 associated with reduced risk of cancer mortality.^{12,13,41,46}

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31 Very few cohort studies include repeated measures of physical activity.²⁸⁻³¹ The present
32 study suggests that people in Latin America can become more active. Large studies in
33 high-income countries in Europe and North America also suggest that physical activity is
34 amenable to change.^{29,31} For example, Breidablik and colleagues investigated changes in
35 physical activity across four waves of the HUNT Study in Norway.³¹ When physical activity
36 was defined as 60 minutes per week, 8% of participants were persistently inactive, 15%
37 were persistently active, and 77% had a mixed pattern.³¹ When physical activity was
38 defined as 150 minutes per week, 32% were persistently inactive, 2% were persistently
39 active, and 65% had a mixed pattern.³¹ Breidablik and colleagues also found that mortality
40 risk was reduced in those who became active, whether physical activity was defined as 60
41 or 150 minutes per week.³¹ To the best of our knowledge, the present study is the first
42 study to provide some evidence that becoming a weekend warrior is associated with
43 reduced risk of mortality. Leisure time physical activity volume was not assessed in the
44 present study, but studies in high-income countries in Europe and North America suggest
45 that the dose-response relationship between leisure time physical activity and mortality is
46 curvilinear, where performing any level of activity is associated with a 20% lower risk of
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3 mortality and performing 3 to 10 times the recommended level is associated with a
4 threshold of 39% lower risk of mortality.⁴⁶ More research is required to determine the
5 nature of the dose-response relationship between leisure time physical activity volume and
6 mortality in Latin America.
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10 *Policy implications*

14 The present study has important implications for policy and practice. Lack of time is
15 probably the major barrier to participation in sport and exercise in Latin America^{15,17,18} and
16 as many as eight out of ten adults in the region say they would like to do more sport.¹⁸
17 Twice as many participants were weekend warriors in the present study compared with
18 large studies in high-income countries in Europe and North America (8% vs 3-4%)^{12,13} and
19 it is reasonable to suggest that more people in Latin America would exercise if they knew
20 that taking part in one or two sessions per week was associated with considerable health
21 benefits. Latin America is home to the Ciclovía Recreativa,^{19,47} which is the best large-
22 scale physical activity intervention that we know of. Every Sunday, roads are closed to
23 motor vehicles in dozens of cities in Latin America and the streets fill with walkers,
24 runners, and cyclists.^{19,47} In Mexico City, for example, more than 50 kilometers of roads
25 are closed to motor vehicles on Sundays and around 80,000 people enjoy being physically
26 active in a safe and free-of-charge environment.^{23,48} In Bogotá in Colombia, more than 120
27 kilometers of roads are closed every Sunday and public holiday and more than one million
28 people take part in the Ciclovía Recreativa.⁴⁹ Surveys in Mexico City²³ and Bogotá²²
29 suggest that most of these weekend warriors would not exercise if it were not for the
30 Ciclovía Recreativa. Men were more likely to be weekend warriors in the present study
31 and surveys suggest that males are more likely to take part in the Ciclovía Recreativa than
32 females;^{20,21} however, the proportion of female participants can be increased by offering
33 complementary aerobics classes and dance classes in nearby parks and public spaces.⁵⁰
34 People in the highest income tertile were more likely to be weekend warriors in the present
35 study and surveys suggest that people in middle and high socioeconomic groups are more
36 likely to take part in the Ciclovía Recreativa than people in low socioeconomic groups;²¹
37 however, the proportion of low socioeconomic participants can be increased by including
38 different neighbourhoods in the route.²¹ For example, the Ciclovía Recreativa in the city of
39 Santiago in Chile takes place in high socioeconomic neighbourhoods and less than 10% of
40 participants are of low socioeconomic status.²¹ In contrast, the interventions in the cities of
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3 Bogotá and Cali in Colombia take place in low, middle, and high socioeconomic
4 neighbourhoods and more than 20% of participants are of low socioeconomic status.²¹
5 Sophisticated studies in high-income countries in Europe suggest that taking part in two or
6 three one- or two-minute bouts of physical activity per day is sufficient to reduce mortality
7 risk.⁵¹ However, more research is required to determine the benefits of non-exercise
8 activity in Latin America, where levels of non-exercise activity are much higher.^{6,7}
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14 *Limitations*

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17 This study has strengths and limitations. The Mexico City Prospective Study is broadly
18 representative of the population aged 35 years or older in Mexico City.²⁶ The present
19 investigation included more than 150,000 cohort members and the analyses were adjusted
20 for major confounders.⁴⁰⁻⁴² Analyses were not adjusted for the dose of leisure time physical
21 activity (where the dose is the product of frequency x intensity x duration), but the available
22 evidence suggests that the benefits of a given amount of physical activity are much the
23 same whether performed on the weekend or spread over the week.¹² For example, dos
24 Santos and colleagues investigated more than 350,000 adults in the United States and
25 found that the hazard ratios for all-cause mortality, CVD mortality, and cancer mortality
26 were similar in weekend warriors and the regularly active after adjusting for the dose of
27 leisure time physical activity.¹² Participants who died during the first two years of follow-up
28 were removed to minimize the possibility of reverse causation. Physical activity and
29 potential confounders were assessed at baseline and, unusually, after around 16 years in
30 a sub-sample of more than 10,000 adults. The sample size in the main analysis was large
31 enough to give precise estimates of the associations between physical activity and
32 mortality, as indicated by the relatively narrow confidence intervals. The sample size in the
33 repeated-measures analysis was not large enough to give precise estimates of the
34 associations between changes in physical activity and mortality, as indicated by the
35 relatively wide confidence intervals. Physical activity and other variables were self-
36 reported, which may introduce recall bias, social desirability bias, and other biases.
37 Questionnaires were used to assess physical activity, but it is preferable that both
38 questionnaires and accelerometers be used to assess physical activity in cohort studies
39 because each method has advantages and disadvantages.⁵²⁻⁵⁴ Three simple questions
40 were used to assess physical activity in the present study, but such simple assessment
41 tools have been validated against multiple-item physical activity assessment tools³⁶ and
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3 against cardiorespiratory fitness.³⁷ The assessment of diet quality was relatively simple,
4 but relatively sophisticated assessments suggest that the benefits of physical activity are
5 largely independent of the confounding effects of diet quality.⁴² This study provides clear
6 evidence that the weekend warrior physical activity pattern and the regularly active
7 physical activity pattern are beneficial to health in adults in Mexico. However, it is
8 important to gather evidence from other countries in Latin America because there are
9 great differences in income,⁵⁵ health,⁵⁶ and healthcare⁵⁷ in the region.
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Conclusions

To the best of our knowledge, the Mexico City Prospective Study is the largest cohort study in Mexico or elsewhere in Latin America. The study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders. Participants who died during the first two years of follow-up were removed to minimize the possibility of reverse causation. The analyses were adjusted for major confounders and the main results were robust to further adjustment for diabetes, hypertension, heart attack, stroke, and cancer. The present analysis provides clear evidence that participation in sport and exercise is associated with health benefits in adults in Mexico. Both the weekend warrior physical activity pattern and the regularly active physical activity pattern were associated with reduced risk of mortality. In what are novel findings, we found that, for both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes. In what are also novel findings, in the repeated measures analysis, we found some evidence that being a weekend warrior or becoming a weekend warrior was associated with reduced risk of mortality. There are high levels of non-exercise physical activity in many cities in Latin America and this study is important because it suggests that even the busy people of Mexico City could benefit from taking part in one or two sessions of sport and exercise per week.

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Conflicts of interest

None

Data availability

Mexico City Prospective Study data are available for open-access data requests. The data access policy is described online: <http://www.ctsu.ox.ac.uk/research/mcps>

Table 1. Participants' characteristics at baseline according to physical activity patterns

	Physical activity pattern		
	No sport or exercise	Weekend Warrior	Regularly Active
Number (%)	120,325 (77.69)	11,981 (7.74)	22,576 (14.58)
Age, years, mean±SD	52.3±13.1	49.9±12.1	53.3±12.8
Sex			
Male, n (%)	35,579 (29.57)	6,595 (55.05)	8,563 (37.93)
Female, n (%)	84,746 (70.43)	5,386 (44.95)	14,013 (62.07)
Education			
None, n (%)	17,899 (14.88)	820 (6.85)	1,473 (6.53)
At least some elementary, n (%)	59,384 (49.37)	4,451 (37.16)	8,714 (38.61)
At least some high-school, n (%)	27,816 (23.13)	3,627 (30.28)	6,509 (28.84)
At least some college, n (%)	6,731 (5.60)	1,240 (10.35)	2,111 (9.35)
At least some university, n (%)	8,442 (7.02)	1,840 (15.36)	3,764 (16.68)
Income			
Tertile 1 (lowest), n (%)	59,480 (49.43)	3,729 (31.12)	9,746 (43.17)
Tertile 2, n (%)	25,204 (20.95)	2,102 (17.54)	4,115 (18.23)
Tertile 3 (highest), n (%)	35,641 (29.62)	6,150 (51.33)	8,715 (38.60)

Table 1 (continued). Participants' characteristics at baseline according to physical activity patterns

	Physical activity pattern		
	No sport or exercise	Weekend Warrior	Regularly active
Smoking			
Never, n (%)	61,036 (50.76)	4,684 (39.13)	10,055 (44.57)
Former, n (%)	22,356 (18.59)	2,647 (22.11)	5,615 (24.89)
Current, n (%)	36,843 (30.64)	4,640 (38.76)	6,892 (30.55)
Alcohol			
Never, n (%)	25,780 (21.43)	1,566 (13.08)	3,511 (15.56)
Occasionally, n (%)	87,836 (73.02)	9,052 (75.58)	17,314 (76.72)
At least once per week, n (%)	5,353 (4.45)	1,217 (10.16)	1,473 (6.53)
Daily, n (%)	1,325 (1.10)	142 (1.19)	269 (1.19)
Fruit and vegetable intake			
Never, n (%)	1,430 (1.19)	103 (0.86)	119 (0.53)
One or two days per week, n (%)	22,394 (18.62)	1,842 (15.38)	1,928 (8.54)
Three or four days per week, n (%)	35,276 (29.32)	3,275 (27.34)	4,610 (20.42)
Five or more days per week, n (%)	61,198 (50.87)	6,758 (56.42)	15,917 (70.51)

Table 2. Associations of physical activity patterns at baseline with mortality risks*

Physical activity pattern	N	Deaths	Adjusted for age and sex	Fully-adjusted
<i>All-cause mortality</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	1,583	0.84 (0.80, 0.88)	0.88 (0.84, 0.93)
Regularly active	22,576	3,632	0.83 (0.80, 0.86)	0.88 (0.85, 0.91)
<i>CVD mortality</i>				
No sport or exercise	120,325	6,921	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	533	0.91 (0.84, 1.00)	0.94 (0.86, 1.03)
Regularly active	22,576	1,296	0.90 (0.85, 0.95)	0.93 (0.87, 0.99)
<i>Cancer mortality</i>				
No sport or exercise	120,325	2,673	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	207	0.82 (0.71, 0.95)	0.82 (0.71, 0.95)
Regularly active	22,576	529	0.97 (0.88, 1.06)	0.94 (0.86, 1.04)

*Fully-adjusted model was adjusted for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. Participants who died during the first two years of follow-up were removed. Values are hazard ratio (95% confidence interval).

Table 3. Associations of physical activity patterns at baseline with all-cause mortality risk, stratified by length of time spent exercising at each session*

Physical activity pattern	N	Deaths	Adjusted for age and sex	Fully-adjusted
<i><30 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	2,212	422	1.01 (0.92, 1.12)	1.03 (0.94, 1.14)
Regularly active	5,307	1,120	0.91 (0.86, 0.97)	0.95 (0.89, 1.01)
<i>30-60 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	4,977	640	0.80 (0.74, 0.87)	0.84 (0.78, 0.91)
Regularly active	10,360	1,586	0.84 (0.79, 0.88)	0.88 (0.84, 0.93)
<i>>60 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	4,794	521	0.76 (0.70, 0.83)	0.82 (0.75, 0.89)
Regularly active	6,925	932	0.76 (0.71, 0.81)	0.80 (0.75, 0.86)

*Fully-adjusted model was adjusted for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. Participants who died during the first two years of follow-up were removed. Values are hazard ratio (95% confidence interval).

Table 4. Physical activity patterns at baseline and resurvey

Baseline		Resurvey			Total
		No sport or exercise	Weekend Warrior	Regularly Active	
No sport or exercise		6,688	318	930	7,936
Weekend Warrior		474	100	152	726
Regularly active		847	85	432	1,364
Total		8,009	503	1,514	10,026

Table 5. Associations of physical activity patterns with all-cause mortality risk using repeated measures of physical activity and potential confounders*

Physical activity pattern	N	Deaths	Hazard ratio (95% confidence interval)
No sport or exercise	8,008	685	1.00 (Reference)
Weekend warrior	502	51	0.86 (0.65, 1.12)
Regularly active	1,513	107	0.85 (0.70, 1.03)

*This analysis only included participants who were resurveyed. The analysis included baseline measures of age and sex as well as baseline and resurvey measures of physical activity, education, income, smoking, fruit and vegetable intake, and alcohol. The analysis included all the available data for each variable, whether the data were available at baseline, resurvey, or both. Robust estimates of variance were used to obtain the confidence intervals.

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3 **Associations of the ‘weekend warrior’ physical activity pattern with all-cause, cardiovascular**
4 **disease, and cancer mortality: the Mexico City Prospective Study**
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Abstract

Objectives: The objective was to investigate the benefits of the 'weekend warrior' physical activity pattern in Latin America, where many people take part in high levels of non-exercise physical activity.

Methods: Participants in the Mexico City Prospective Study were surveyed from 1998-2004 and resurveyed from 2015-2019. Those who exercised up to once or twice per week were termed weekend warriors. Those who exercised more often were termed regularly active. Analyses were adjusted for potential confounders.

Results: The main analysis included 26,006 deaths in 154,882 adults (67% female) aged 52±13 years followed for 18±4 years (mean±SD). Compared with those who reported no exercise, the hazard ratio (95% confidence interval) was 0.88 (0.83, 0.93) in the weekend warriors, and 0.88 (0.84, 0.91) in the regularly active. Similar results were observed for cardiovascular disease and cancer mortality, but associations were weaker. Stratified analyses showed that substantial reductions in all-cause mortality risk only occurred when the duration of exercise sessions was at least 30-60 minutes. The repeated-measures analysis included 843 deaths in 10,023 adults followed for 20±2 years. Compared with being inactive or becoming inactive, the hazard ratio was 0.86 (0.65, 1.12) when being a weekend warrior or becoming a weekend warrior, and 0.85 (0.70, 1.03) when being regularly active or becoming regularly active.

Conclusions: This is the first prospective study to investigate the benefits of the weekend warrior physical activity pattern in Latin America. The results suggest that even busy adults could benefit from taking part in one or two sessions of exercise per week.

Summary

What is already known on this topic

- The 'weekend warrior' takes part in one or two sessions of sport or exercise per week and studies in high-income countries in Europe and North America suggest that the benefits of exercising once or twice per week are similar to exercising more often.

What this study adds

- To the best of our knowledge, the Mexico City Prospective Study is the largest cohort study in Mexico or elsewhere in Latin America.
- The study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders.
- In this analysis of more than 150,000 cohort members, all-cause mortality risk was reduced by approximately 15% in the 'weekend warriors' who exercised once or twice per week and in the 'regularly active' who exercised more often.
- For both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes.
- In the repeated measures analysis, we found some evidence that being a weekend warrior or becoming a weekend warrior was associated with reduced risk of mortality.

How this study might affect research, practice or policy

- The weekend warrior physical activity pattern may be a more convenient option for busy people.
- There are high levels of non-exercise physical activity in many cities in Latin America and this study is important because it suggests that even busy people could benefit from taking part in one or two sessions of sport and exercise per week.

Introduction

Physical activity is regarded as one of the leading modifiable risk factors for morbidity and mortality worldwide.^{1,2} The promotion of physical activity is also thought to be beneficial to meeting 15 of the 17 United Nations Sustainable Development Goals.³ Nonetheless, relatively little is known about the benefits of physical activity in low- and middle-income countries in Latin America, where participation in large amounts of physical activity is a necessity, not a choice.³⁻⁸ Indeed, poverty, crime, informal work, and the cost of car ownership make walking for transport inevitable.⁴⁻⁶ Roughly 30% to 45% of all journeys are made on foot in low-income groups in cities in Latin America, compared with around 20% of journeys in higher-income groups.⁴ Furthermore, around 20% to 25% of residents in large cities in Latin America meet prevailing physical activity guidelines just by walking for transport.⁹ Participation in sport and exercise may be more beneficial to health than participation in occupational physical activity and other types of physical activity.^{10,11} Therefore, it is important to investigate the benefits of taking part in sport and exercise.

The 'weekend warrior' takes part in one or two sessions of sport or exercise per week and studies in high-income countries in Europe and North America suggest that the benefits of exercising once or twice per week are much the same as exercising more often.¹²⁻¹⁴ The weekend warrior physical activity pattern may be more convenient^{15,16} and it may be particularly important to investigate the benefits of different physical activity patterns in low- and middle-income countries in Latin America because lack of time is a major barrier to physical activity in the region.^{15,17,18} It may be particularly advantageous to investigate the benefits of the weekend warrior physical activity pattern in Latin America because the region is home to a weekly physical activity intervention known as the Ciclovía Recreativa.¹⁹ The Ciclovía Recreativa is a remarkably simple intervention in which main roads are closed to motor vehicles and are opened exclusively for people to enjoy a safe, free space to exercise.¹⁹ Millions of people across Latin America take part in the Ciclovía Recreativa every weekend¹⁹⁻²¹ and most participants say they would not exercise if it were not for the Ciclovía Recreativa.^{22,23} The health and economic impacts of the Ciclovía Recreativa in 15 cities in Latin America have been conservatively estimated to include the prevention of around 360 premature deaths per year and the associated cost saving of around US\$ 200 million per year.²⁰

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3 Consistency of association is one of the fundamental considerations when inferring
4 causality²⁴ and it is important to gather evidence from settings other than high-income
5 countries in Europe and North America. Mexico is an upper-middle-income country in Latin
6 America²⁵ and the Mexico City Prospective Study is a large cohort study that includes
7 measures of physical activity, mortality, and potential confounders.²⁶ The main objective of
8 the present analysis was to investigate associations of the weekend warrior physical
9 activity pattern with all-cause, cardiovascular disease (CVD), and cancer mortality in the
10 Mexico City Prospective Study. Participation in sport and exercise may change over the
11 life course,²⁷ yet few cohort studies include repeated measures of physical activity.²⁸⁻³¹
12 Participants in the Mexico City Prospective Study were assessed at baseline and after
13 around 16 years and the secondary objective of the present analysis was to investigate
14 associations of physical activity patterns with mortality using repeated measures of
15 physical activity and potential confounders.
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Methods

Participants

The Mexico City Prospective Study is described in detail elsewhere.²⁶ Briefly, door-to-door interviews were conducted from 1995 to 1997 to compile a record of all households in the neighboring districts of Coyoacán and Iztapalapa in Mexico City in Mexico.²⁶ Recruitment teams then visited households and at least one participant aged 35 years or older was recruited from 94% of eligible households.²⁶ The resulting sample was deemed to be broadly representative of the population aged 35 years or older in Mexico City.²⁶ Trained nurses collected data in the participant's household and the baseline survey took place from 1998 to 2004 and the resurvey took place from 2015 to 2019.²⁶ The study was approved by the Mexican Ministry of Health, the Mexican National Council of Science and Technology (approval number 0595 P-M), and the Central Oxford Research Ethics Committee (C99.260). All participants provided written informed consent. The data used in the current report were obtained through an open-access data request made to the Mexico City Prospective Study principal investigators.

Defining physical activity, exercise and sport

In the broadest sense, physical activity is defined as any volitional movement of skeletal muscle that results in energy expenditure.³² Exercise is a form of leisure time physical activity that is planned, structured, and repetitive. Exercise training is purposeful and is performed with specific external goals, including the improvement or maintenance of physical fitness, physical performance or health.^{32,33} Sport is a form of physical activity that includes rules and is usually competitive. The true sense of sport is broad: "Sport means all forms of physical activity, which, through casual or organised participation, aim at expressing or improving physical fitness and mental wellbeing, forming social relationships or obtaining results in competition at all levels".³⁴ The terms 'sport' and 'exercise' can have negative connotations in **Europe and North America**,³⁵ but asking someone what sport they like in Latin America is as innocent a question as asking them what music they like.¹⁸

Exposure

The exposure was leisure time physical activity. During the baseline survey, participants were asked whether they exercised or played sports (yes or no). Those who said yes, were then asked how many times per week they exercised (less than once per week; once or twice per week; or, three or more times per week). And, they were asked how many minutes they spent exercising per session (less than 30; from 30 to 60; or, more than 60). Similar questions were asked 16 years later at resurvey and we created three exposure groups. The 'no sport or exercise' group included those who said they did not exercise or play sports. The 'weekend warrior' group included those who said they exercised or played sports up to once or twice per week. The 'regularly active' group included those who said they exercised or played sports three or more times per week. Simple physical activity assessment tools like the one used in the present study have been validated against multiple-item physical activity assessment tools³⁶ and against cardiorespiratory fitness.³⁷

Outcomes

The registration of deaths in Mexico is thorough, with almost all deaths certified medically and with few deaths attributed to unknown causes.³⁸ The outcomes were all-cause mortality, CVD mortality, and cancer mortality. Mortality was tracked to 31st December 2020 through probabilistic linkage to the national death register based on the participant's name, age, and sex. Diseases listed on the death certificates were coded according to the International Classification of Diseases, 10th Revision (ICD-10).³⁹

Potential confounders

Potential confounders that may influence the relationships between physical activity and mortality include age, sex, education, income, smoking, diet, and alcohol.⁴⁰⁻⁴² Body mass index, hypertension, diabetes, and other such variables might be regarded as biological intermediates, not confounding factors.^{2,43} Trained nurses recorded age and sex. Participants were asked about education at baseline and resurvey and we created five groups (none; at least some elementary; at least some high-school; at least some college; and, at least some university). Participants were asked about income at baseline and resurvey and we created three groups (tertile 1, tertile 2, and tertile 3). The trained nurses

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3 asked about smoking at baseline and resurvey and we created three categories (never,
4 former, and current). Participants were also asked about alcohol drinking frequency and
5 we created four categories (never; occasionally; at least once per week; and, daily).
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7 Finally, diet quality at baseline and resurvey was expressed as fruit and vegetable intake
8 (never; one or two days per week; three or four days per week; five or more days per
9 week).
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14 *Statistical analyses*

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17 Participants' characteristics at baseline were described according to physical activity
18 patterns. Associations of physical activity patterns with mortality were investigated using
19 Cox models. The proportional hazards assumption was checked graphically for the
20 discrete physical activity patterns and no violations were observed. In the main analysis,
21 we used a single-measure design. We investigated associations of physical activity
22 patterns at baseline with mortality. We also investigated associations stratified by length of
23 time spent exercising at each session. The simple physical activity questionnaire allowed
24 us to investigate three strata: less than 30 minutes per session; from 30 to 60 minutes per
25 session; and, more than 60 minutes per session. Analyses were adjusted for age, sex,
26 education, income, smoking, fruit and vegetable intake, and alcohol. In a sensitivity
27 analysis, associations of physical activity patterns at baseline with all-cause mortality were
28 further adjusted for self-reported illnesses at baseline, including diabetes, hypertension,
29 heart attack, stroke, and cancer.
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39 In the secondary analyses, we used a repeated-measures design. We investigated
40 associations of physical activity patterns with mortality using repeated measures of
41 physical activity and potential confounders. The analysis included baseline measures of
42 age and sex as well as baseline and resurvey measures of physical activity, education,
43 income, smoking, and alcohol. Physical activity, education, income, smoking, fruit and
44 vegetable intake, and alcohol were treated as time-varying variables. The analysis
45 included all the available data for each variable, whether the data were available at
46 baseline, resurvey, or both. Robust estimates of variance were used to obtain the
47 confidence intervals in the repeated-measures analysis because conventional estimates of
48 variance are not appropriate when observations are dependent. Participants who died
49 during the first two years of follow-up were removed from all analyses to minimize the
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3 possibility of reverse causation. All analyses were performed using Stata SE version 17.0
4 for Mac (StataCorp, Texas, USA).
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8 *Patient and public involvement*
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11 Patients and other members of the public were not involved in the design or conduct of this
12 study.
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16 *Equity, diversity and inclusion*
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19 In the Mexico City Prospective Study, door-to-door interviews were conducted in the
20 neighboring districts of Coyoacán and Iztapalapa, at least one person was recruited from
21 94% of eligible households, and the final sample was broadly representative of the
22 population aged 35 years or older in Mexico City. The author team includes six men and
23 three women. Five of the authors live and work in Latin America and one author spends
24 their time in both Europe and Latin America. Physical activity levels are reported according
25 to age, sex, education, and income and associations between physical activity and health
26 are adjusted for these important confounders. In the Discussion, we explain why the
27 magnitude of the association between leisure time physical activity and mortality may be
28 different in Latin America and in **high-income countries in Europe and North America**.
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Results

Figure S1 in the online supplement shows the flow of participants through the study. Data from 154,882 of 159,517 (97%) cohort members were included in the main analysis, after excluding 2,530 people who died during the first two years of follow-up and 2,105 with missing values for the exposures or the outcomes. Table 1 shows participants' characteristics at baseline according to physical activity patterns. Age was around 52 years in those who reported no sport or exercise and was similar in the weekend warriors and the regularly active. The proportion of women was 70% in those who reported no sport or exercise and was lower in the other groups. The proportion with no education was 15% in those who reported no sport or exercise and was only 7% in the weekend warriors and the regularly active. The proportion in the lowest income tertile was approximately 50% in those who reported no sport or exercise, 31% in the weekend warriors, and 43% in the regularly active. The proportion who had never smoked was around 50% in those who reported no sport or exercise and was lower in the other groups. The proportion who currently smoked was highest in the weekend warriors. The proportion who had never drank alcohol was around 21% in those who reported no sport or exercise and was lower in the other groups. The proportion who drank at least once a week was highest in the weekend warriors. The frequency of fruit and vegetable intake tended to be higher in the weekend warriors, and higher still in the regularly active.

Table 2 shows associations of physical activity patterns at baseline with mortality risks. Participants were followed for 17.6 ± 4.0 years (mean \pm SD) and there was a total of 26,006 deaths from all causes during 2,721,235 person-years of follow-up. Compared with the group that reported no sport or exercise, the hazard ratio (95% confidence interval) was 0.88 (0.84, 0.93) in the weekend warrior group, and 0.88 (0.85, 0.91) in the regularly active group after adjustment for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. There was a total of 8,750 deaths from CVD. Compared with the group that reported no sport or exercise, the fully-adjusted hazard ratio was 0.94 (0.86, 1.03) in the weekend warrior group, and 0.93 (0.87, 0.99) in the regularly active group. Finally, there was a total of 3,409 deaths from cancer. Compared with the group that reported no sport or exercise, the fully-adjusted hazard ratio was 0.82 (0.71, 0.95) in the weekend warrior group, and 0.94 (0.86, 1.04) in the regularly active groups. Table S1 in the online supplement shows the results of the sensitivity analysis. Associations of

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3 physical activity patterns with all-cause mortality were similar after further adjustment for
4 diabetes, hypertension, heart attack, stroke, and cancer.
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8 Table 3 shows associations of physical activity patterns at baseline with all-cause mortality
9 risk stratified by length of time spent exercising at each session. The first stratum was less
10 than 30 minutes per session. Compared with the group that reported no sport or exercise,
11 the hazard ratio (95% confidence interval) was 1.03 (0.94, 1.14) in the weekend warrior
12 group, and 0.95 (0.89, 1.01) in the regularly active group after adjustment for age, sex,
13 education, income, smoking, fruit and vegetable intake, and alcohol. The second stratum
14 was 30 to 60 minutes per session. Compared with the group that reported no sport or
15 exercise, the fully-adjusted hazard ratio was 0.84 (0.78, 0.91) in the weekend warrior
16 group, and 0.88 (0.84, 0.93) in the regularly active group. The third stratum was more than
17 60 minutes per session. Compared with the group that reported no sport or exercise, the
18 fully-adjusted hazard ratio was 0.80 (0.75, 0.89) in the weekend warrior group, and 0.81
19 (0.75, 0.86) in the regularly active group.
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28 Table 4 shows physical activity patterns at baseline and resurvey. The present study
29 included 10,023 of 10,143 (99%) cohort members who were resurveyed after 19.7 ± 1.9
30 years. Among those who reported no sport or exercise at baseline, 6,688 (84%) reported
31 being inactive at resurvey, 318 (4%) reported being weekend warriors at resurvey, and
32 930 (12%) reported being regularly active at resurvey. Among those who reported being
33 weekend warriors at baseline, 474 (65%) reported being inactive at resurvey, 100 (14%)
34 reported being weekend warriors at resurvey, and 152 (21%) reported being regularly
35 active at resurvey. Among those who reported being regularly active at baseline, 847
36 (62%) reported being inactive at resurvey, 85 (6%) reported being weekend warriors at
37 resurvey, and 432 (32%) reported being regularly active at resurvey.
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46 Table 5 shows associations of physical activity patterns with all-cause mortality risk using
47 repeated measures of physical activity and potential confounders. Participants were
48 followed for 19.7 ± 1.9 years and there was a total of 843 deaths during 195,580 person-
49 years of follow-up. Compared with being inactive or becoming inactive, the hazard ratio
50 (95% confidence interval) was 0.86 (0.65, 1.12) when being a weekend warrior or
51 becoming a weekend warrior, and 0.85 (0.70, 1.03) when being regularly active or
52 becoming regularly active.
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Discussion

The main objective of this study was to investigate associations of the weekend warrior physical activity pattern with mortality in adults in Mexico City. We found that the weekend warrior physical activity pattern and the regularly active physical activity pattern were associated with similar reductions in mortality risks. In what are novel findings, we also found that, for both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes. The secondary objective was to investigate associations of physical activity patterns with mortality using repeated measures of physical activity and potential confounders. We found that physical activity patterns changed considerably over time. In what are also novel findings, we found some evidence that being a weekend warrior or becoming a weekend warrior and being regularly active or becoming regularly active were associated with reduced risk of mortality.

Novelty and importance

To the best of our knowledge, this is the first study of the associations of the weekend warrior physical activity pattern with mortality in Mexico or any other low- to middle-income country in Latin America. The Mexico City Prospective Study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders.²⁸⁻³⁰ In 2004, Lee and colleagues first investigated the benefits of the weekend warrior physical activity pattern in a relatively small study in the United States.⁴⁴ More recently, O'Donovan and colleagues investigated associations of physical activity patterns with mortality in more than 63,000 adults in England and Scotland.¹³ They found that all-cause mortality risk was around 30% lower in weekend warriors and in the regularly active, whether or not they met prevailing physical activity guidelines.¹³ More recently still, Inoue and colleagues investigated associations of daily step patterns with mortality in more than 3,000 adults in the United States.⁴⁵ They found that all-cause mortality risk was lower in those accumulated at least 8000 steps on one or two days per week compared with those who never took 8000 steps per day.⁴⁵ The present study is important because findings from high-income countries in **Europe and North America** may not be generalizable to low- to middle-income countries in Latin America.

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3 The present study suggests that all-cause mortality risk is around 15% lower in exercisers
4 than non-exercisers. In contrast, large studies in **high-income countries in Europe and**
5 **North America** suggest that all-cause mortality risk is around 30% lower in exercisers than
6 non-exercisers.⁴⁶ These differences in risk may be explained by the high amounts of non-
7 exercise physical activity that are part of everyday life in many cities in Latin America^{4-6,8,9}
8 and other low- and middle-income regions.⁷ For example, if the non-exercise group were
9 to take part in large amounts of walking for transport in Latin America, then the difference
10 in risk between the exercise and non-exercise groups would not be as great as in **high-**
11 **income** countries. Indeed, Lear and colleagues found that moderate and high levels of
12 exercise were associated with reduced risk of mortality and major CVD events in high-
13 income and upper-middle-income countries, but not in lower-middle-income and low-
14 income countries where people took part in high amounts of non-exercise physical
15 activity.⁴² The present study also suggests that there is a substantial reduction in cancer
16 mortality risk in weekend warriors and little or no reduction in the regularly active. These
17 results should be interpreted with caution because of the relatively low number of cancer
18 deaths and because other large studies suggest that different physical activity patterns are
19 associated with reduced risk of cancer mortality.^{12,13,41,46}

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22 Very few cohort studies include repeated measures of physical activity.²⁸⁻³¹ The present
23 study suggests that people in Latin America can become more active. Large studies in
24 **high-income countries in Europe and North America** also suggest that physical activity is
25 amenable to change.^{29,31} For example, Breidablik and colleagues investigated changes in
26 physical activity across four waves of the HUNT Study in Norway.³¹ When physical activity
27 was defined as 60 minutes per week, 8% of participants were persistently inactive, 15%
28 were persistently active, and 77% had a mixed pattern.³¹ When physical activity was
29 defined as 150 minutes per week, 32% were persistently inactive, 2% were persistently
30 active, and 65% had a mixed pattern.³¹ Breidablik and colleagues also found that mortality
31 risk was reduced in those who became active, whether physical activity was defined as 60
32 or 150 minutes per week.³¹ To the best of our knowledge, the present study is the first
33 study to provide some evidence that becoming a weekend warrior is associated with
34 reduced risk of mortality. Leisure time physical activity volume was not assessed in the
35 present study, but studies in **high-income countries in Europe and North America** suggest
36 that the dose-response relationship between leisure time physical activity and mortality is
37 curvilinear, where performing any level of activity is associated with a 20% lower risk of

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3 mortality and performing 3 to 10 times the recommended level is associated with a
4 threshold of 39% lower risk of mortality.⁴⁶ More research is required to determine the
5 nature of the dose-response relationship between leisure time physical activity volume and
6 mortality in Latin America.
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10 *Policy implications*

14 The present study has important implications for policy and practice. Lack of time is
15 probably the major barrier to participation in sport and exercise in Latin America^{15,17,18} and
16 as many as eight out of ten adults in the region say they would like to do more sport.¹⁸
17 Twice as many participants were weekend warriors in the present study compared with
18 large studies in **high-income countries in Europe and North America** (8% vs 3-4%)^{12,13} and
19 it is reasonable to suggest that more people in Latin America would exercise if they knew
20 that taking part in one or two sessions per week was associated with considerable health
21 benefits. Latin America is home to the Ciclovía Recreativa,^{19,47} which is the best large-
22 scale physical activity intervention that we know of. Every Sunday, roads are closed to
23 motor vehicles in dozens of cities in Latin America and the streets fill with walkers,
24 runners, and cyclists.^{19,47} In Mexico City, for example, more than 50 kilometers of roads
25 are closed to motor vehicles on Sundays and around 80,000 people enjoy being physically
26 active in a safe and free-of-charge environment.^{23,48} In Bogotá in Colombia, more than 120
27 kilometers of roads are closed every Sunday and public holiday and more than one million
28 people take part in the Ciclovía Recreativa.⁴⁹ Surveys in Mexico City²³ and Bogotá²²
29 suggest that most of these weekend warriors would not exercise if it were not for the
30 Ciclovía Recreativa. Men were more likely to be weekend warriors in the present study
31 and surveys suggest that males are more likely to take part in the Ciclovía Recreativa than
32 females;^{20,21} however, the proportion of female participants can be increased by offering
33 complementary aerobics classes and dance classes in nearby parks and public spaces.⁵⁰
34 People in the highest income tertile were more likely to be weekend warriors in the present
35 study and surveys suggest that people in middle and high socioeconomic groups are more
36 likely to take part in the Ciclovía Recreativa than people in low socioeconomic groups;²¹
37 however, the proportion of low socioeconomic participants can be increased by including
38 different neighbourhoods in the route.²¹ For example, the Ciclovía Recreativa in the city of
39 Santiago in Chile takes place in high socioeconomic neighbourhoods and less than 10% of
40 participants are of low socioeconomic status.²¹ In contrast, the interventions in the cities of
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3 Bogotá and Cali in Colombia take place in low, middle, and high socioeconomic
4 neighbourhoods and more than 20% of participants are of low socioeconomic status.²¹
5 Sophisticated studies in **high-income countries in Europe** suggest that taking part in two or
6 three one- or two-minute bouts of physical activity per day is sufficient to reduce mortality
7 risk.⁵¹ However, more research is required to determine the benefits of non-exercise
8 activity in Latin America, where levels of non-exercise activity are much higher.^{6,7}
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14 *Limitations*

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17 This study has strengths and limitations. The Mexico City Prospective Study is broadly
18 representative of the population aged 35 years or older in Mexico City.²⁶ The present
19 investigation included more than 150,000 cohort members and the analyses were adjusted
20 for major confounders.⁴⁰⁻⁴² Analyses were not adjusted for the dose of leisure time physical
21 activity (where the dose is the product of frequency x intensity x duration), but the available
22 evidence suggests that the benefits of a given amount of physical activity are much the
23 same whether performed on the weekend or spread over the week.¹² For example, dos
24 Santos and colleagues investigated more than 350,000 adults in the United States and
25 found that the hazard ratios for all-cause mortality, CVD mortality, and cancer mortality
26 were similar in weekend warriors and the regularly active after adjusting for the dose of
27 leisure time physical activity.¹² Participants who died during the first two years of follow-up
28 were removed to minimize the possibility of reverse causation. Physical activity and
29 potential confounders were assessed at baseline and, unusually, after around 16 years in
30 a sub-sample of more than 10,000 adults. The sample size in the main analysis was large
31 enough to give precise estimates of the associations between physical activity and
32 mortality, as indicated by the relatively narrow confidence intervals. The sample size in the
33 repeated-measures analysis was not large enough to give precise estimates of the
34 associations between changes in physical activity and mortality, as indicated by the
35 relatively wide confidence intervals. Physical activity and other variables were self-
36 reported, which may introduce recall bias, social desirability bias, and other biases.
37
38 Questionnaires were used to assess physical activity, but it is preferable that both
39 questionnaires and accelerometers be used to assess physical activity in cohort studies
40 because each method has advantages and disadvantages.⁵²⁻⁵⁴ Three simple questions
41 were used to assess physical activity in the present study, but such simple assessment
42 tools have been validated against multiple-item physical activity assessment tools³⁶ and
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3 against cardiorespiratory fitness.³⁷ The assessment of diet quality was relatively simple,
4 but relatively sophisticated assessments suggest that the benefits of physical activity are
5 largely independent of the confounding effects of diet quality.⁴² This study provides clear
6 evidence that the weekend warrior physical activity pattern and the regularly active
7 physical activity pattern are beneficial to health in adults in Mexico. However, it is
8 important to gather evidence from other countries in Latin America because there are
9 great differences in income,⁵⁵ health,⁵⁶ and healthcare⁵⁷ in the region.
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Conclusions

To the best of our knowledge, the Mexico City Prospective Study is the largest cohort study in Mexico or elsewhere in Latin America. The study is also one of the few cohort studies anywhere in the world to include repeated measures of physical activity and potential confounders. Participants who died during the first two years of follow-up were removed to minimize the possibility of reverse causation. The analyses were adjusted for major confounders and the main results were robust to further adjustment for diabetes, hypertension, heart attack, stroke, and cancer. The present analysis provides clear evidence that participation in sport and exercise is associated with health benefits in adults in Mexico. Both the weekend warrior physical activity pattern and the regularly active physical activity pattern were associated with reduced risk of mortality. In what are novel findings, we found that, for both the weekend warrior pattern and the regularly active pattern, substantial reductions in risk only occurred when the duration of exercise sessions was at least 30 to 60 minutes. In what are also novel findings, in the repeated measures analysis, we found some evidence that being a weekend warrior or becoming a weekend warrior was associated with reduced risk of mortality. There are high levels of non-exercise physical activity in many cities in Latin America and this study is important because it suggests that even the busy people of Mexico City could benefit from taking part in one or two sessions of sport and exercise per week.

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Conflicts of interest

None

Data availability

Mexico City Prospective Study data are available for open-access data requests. The data access policy is described online: <http://www.ctsu.ox.ac.uk/research/mcps>

Table 1. Participants' characteristics at baseline according to physical activity patterns

	Physical activity pattern		
	No sport or exercise	Weekend Warrior	Regularly Active
Number (%)	120,325 (77.69)	11,981 (7.74)	22,576 (14.58)
Age, years, mean±SD	52.3±13.1	49.9±12.1	53.3±12.8
Sex			
Male, n (%)	35,579 (29.57)	6,595 (55.05)	8,563 (37.93)
Female, n (%)	84,746 (70.43)	5,386 (44.95)	14,013 (62.07)
Education			
None, n (%)	17,899 (14.88)	820 (6.85)	1,473 (6.53)
At least some elementary, n (%)	59,384 (49.37)	4,451 (37.16)	8,714 (38.61)
At least some high-school, n (%)	27,816 (23.13)	3,627 (30.28)	6,509 (28.84)
At least some college, n (%)	6,731 (5.60)	1,240 (10.35)	2,111 (9.35)
At least some university, n (%)	8,442 (7.02)	1,840 (15.36)	3,764 (16.68)
Income			
Tertile 1 (lowest), n (%)	59,480 (49.43)	3,729 (31.12)	9,746 (43.17)
Tertile 2, n (%)	25,204 (20.95)	2,102 (17.54)	4,115 (18.23)
Tertile 3 (highest), n (%)	35,641 (29.62)	6,150 (51.33)	8,715 (38.60)

Table 1 (continued). Participants' characteristics at baseline according to physical activity patterns

	Physical activity pattern		
	No sport or exercise	Weekend Warrior	Regularly active
Smoking			
Never, n (%)	61,036 (50.76)	4,684 (39.13)	10,055 (44.57)
Former, n (%)	22,356 (18.59)	2,647 (22.11)	5,615 (24.89)
Current, n (%)	36,843 (30.64)	4,640 (38.76)	6,892 (30.55)
Alcohol			
Never, n (%)	25,780 (21.43)	1,566 (13.08)	3,511 (15.56)
Occasionally, n (%)	87,836 (73.02)	9,052 (75.58)	17,314 (76.72)
At least once per week, n (%)	5,353 (4.45)	1,217 (10.16)	1,473 (6.53)
Daily, n (%)	1,325 (1.10)	142 (1.19)	269 (1.19)
Fruit and vegetable intake			
Never, n (%)	1,430 (1.19)	103 (0.86)	119 (0.53)
One or two days per week, n (%)	22,394 (18.62)	1,842 (15.38)	1,928 (8.54)
Three or four days per week, n (%)	35,276 (29.32)	3,275 (27.34)	4,610 (20.42)
Five or more days per week, n (%)	61,198 (50.87)	6,758 (56.42)	15,917 (70.51)

Table 2. Associations of physical activity patterns at baseline with mortality risks*

Physical activity pattern	N	Deaths	Adjusted for age and sex	Fully-adjusted
<i>All-cause mortality</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	1,583	0.84 (0.80, 0.88)	0.88 (0.84, 0.93)
Regularly active	22,576	3,632	0.83 (0.80, 0.86)	0.88 (0.85, 0.91)
<i>CVD mortality</i>				
No sport or exercise	120,325	6,921	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	533	0.91 (0.84, 1.00)	0.94 (0.86, 1.03)
Regularly active	22,576	1,296	0.90 (0.85, 0.95)	0.93 (0.87, 0.99)
<i>Cancer mortality</i>				
No sport or exercise	120,325	2,673	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	207	0.82 (0.71, 0.95)	0.82 (0.71, 0.95)
Regularly active	22,576	529	0.97 (0.88, 1.06)	0.94 (0.86, 1.04)

*Fully-adjusted model was adjusted for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. Participants who died during the first two years of follow-up were removed. Values are hazard ratio (95% confidence interval).

Table 3. Associations of physical activity patterns at baseline with all-cause mortality risk, stratified by length of time spent exercising at each session*

Physical activity pattern	N	Deaths	Adjusted for age and sex	Fully-adjusted
<i><30 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	2,212	422	1.01 (0.92, 1.12)	1.03 (0.94, 1.14)
Regularly active	5,307	1,120	0.91 (0.86, 0.97)	0.95 (0.89, 1.01)
<i>30-60 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	4,977	640	0.80 (0.74, 0.87)	0.84 (0.78, 0.91)
Regularly active	10,360	1,586	0.84 (0.79, 0.88)	0.88 (0.84, 0.93)
<i>>60 minutes per session of sport or exercise</i>				
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	4,794	521	0.76 (0.70, 0.83)	0.82 (0.75, 0.89)
Regularly active	6,925	932	0.76 (0.71, 0.81)	0.80 (0.75, 0.86)

*Fully-adjusted model was adjusted for age, sex, education, income, smoking, fruit and vegetable intake, and alcohol. Participants who died during the first two years of follow-up were removed. Values are hazard ratio (95% confidence interval).

Table 4. Physical activity patterns at baseline and resurvey

Baseline	Resurvey			Total
	No sport or exercise	Weekend Warrior	Regularly Active	
No sport or exercise	6,688	318	930	7,936
Weekend Warrior	474	100	152	726
Regularly active	847	85	432	1,364
Total	8,009	503	1,514	10,026

Table 5. Associations of physical activity patterns with all-cause mortality risk using repeated measures of physical activity and potential confounders*

Physical activity pattern	N	Deaths	Hazard ratio (95% confidence interval)
No sport or exercise	8,008	685	1.00 (Reference)
Weekend warrior	502	51	0.86 (0.65, 1.12)
Regularly active	1,513	107	0.85 (0.70, 1.03)

*This analysis only included participants who were resurveyed. The analysis included baseline measures of age and sex as well as baseline and resurvey measures of physical activity, education, income, smoking, fruit and vegetable intake, and alcohol. The analysis included all the available data for each variable, whether the data were available at baseline, resurvey, or both. Robust estimates of variance were used to obtain the confidence intervals.

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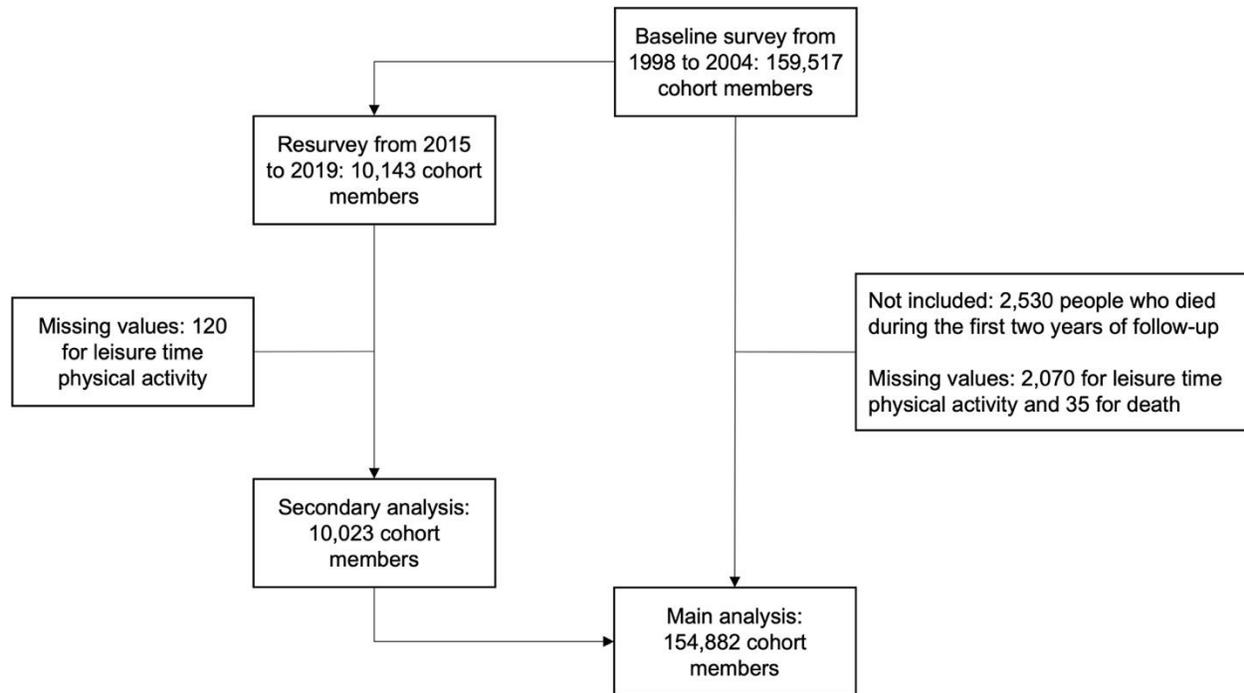
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3 **Associations of the ‘weekend warrior’ physical activity pattern with all-cause,**
4 **cardiovascular disease, and cancer mortality: the Mexico City Prospective Study**
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28 **Figure S1.** Flow of participants through the study. The main analysis was a single-measure
29 design and included 154,882 of 159,517 (97%) cohort members. The secondary analysis was a
30 repeated-measures design and included 10,023 of 10,143 (99%) cohort members who were
31 resurveyed. Mortality was tracked to December 2020. The duration of follow-up was 17.6±4.0
32 years (mean±SD) in the main analysis and 19.7±1.9 years in the secondary analysis.
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Table S1. Associations of physical activity patterns with all-cause mortality, with further adjustment for self-reported illnesses*

Physical activity pattern	N	Deaths	Adjusted for age and sex	Fully-adjusted
No sport or exercise	120,325	20,791	1.00 (Reference)	1.00 (Reference)
Weekend Warrior	11,981	1,583	0.84 (0.80, 0.88)	0.89 (0.85, 0.94)
Regularly active	22,576	3,632	0.83 (0.80, 0.86)	0.87 (0.84, 0.90)

*The fully-adjusted model was adjusted for age, sex, education, income, smoking, fruit and vegetable intake, alcohol, diabetes, hypertension, heart attack, stroke, and cancer. Participants who died during the first two years of follow-up were removed. Values are hazard ratio (95% confidence interval).