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Original article

The impact of weather on summer and winter exercise behaviors

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Abstract

Background: Outdoor exercise is an enjoyable way for individuals to improve fitness, but it is dependent on weather conditions. This study examines the association between weather conditions and outdoor exercise after adjustment for age, sex, race, and socioeconomic status.
Methods: We used data representative of American adults from the University of Michigan/Thomson Reuters June 2013 surveys of consumers (core and supplement) to investigate self-reported exercise behavior in summer and winter. Multivariate multinomial logistic regression models estimated the odds of delayed or indoor exercise compared with outdoor exercise.
Results: Of the 502 respondents, 16.3% did not regularly exercise outdoors (i.e., at least once a week), and many would delay exercise both in summer (51.8%) and winter (43.9%). Individuals listing rain as the predominant adverse weather condition had 3.33 times higher odds of exercising indoors (95% confidence interval (CI): 1.34–8.28) and 3.49 times higher odds of delaying exercise (95%CI: 1.69–7.21) compared with those mentioning heat as the predominant adverse condition. Individuals for whom ice or snow was an adverse winter weather condition were more likely to delay exercise (odds ratio (OR) = 3.34; 95%CI: 1.19–9.36), compared with those concerned with cold.
Conclusion: This study found that race, age, and education exacerbate the negative effects of adverse weather conditions on the decision to exercise outdoors. Accordingly, any recommendation for an individual to exercise outdoors should be combined with an evaluation of the individual's outdoor environment along with strategies for the individual to continue exercising, indoors or outdoors, when adverse weather is present.

Keywords: Outdoor exercise; Physical activity; Rain; Seasons; Snow; Survey

1. Introduction

Participation in physical activity (PA) is an integral part of a healthy lifestyle and leads to a decrease in all-cause mortality, improved immune and psychological function, and numerous physical and mental health benefits.[1,2] Such PA-related benefits can accrue if exercise continues across an individual's lifetime, and PA can prevent age-related cognitive decline and neurodegenerative diseases.[3]

Participation in PA is more likely to be continued if the activity is low or moderate in intensity and if the activity is viewed as enjoyable.[1] Research has shown that outdoor PA is more enjoyable than indoor PA. In a study of 319 fitness club members in Zurich, Switzerland, outdoor PA was considered more "restorative", meaning that individuals could more easily distance themselves from the physically demanding aspects of the exercise through an interaction with the natural environment.[4] In a narrative synthesis of 11 randomized and non-randomized controlled trials, which included a total of 833 adults, participants in outdoor activities had greater feelings of enjoyment and satisfaction and were more likely to intend to continue exercising in the future, compared with participants in indoor activities.[5]

Promotion of regular outdoor PAs rather than indoor activities may therefore be a more effective approach to increasing PA, particularly given that few individuals are meeting PA guidelines.[6] Regular outdoor exercise can also be beneficial for other reasons, such as preventing vitamin D deficiency.[7] However, participation in outdoor PAs can be affected by a number of factors that are difficult or impossible for an individual to control, including built environment,[8,9] changing seasons,[10,11] day length,[8] and weather patterns[8–10,12] such as temperature,[8,12,13] wind intensity,[12,13] and precipitation.[8,12] These factors, which may interact with each other, are postulated to affect PA by influencing an

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individual's perception of the safety of being outdoors, the comfort in exercising, and the suitability of the neighborhood environment to exercising. It follows that individuals may be more capable of adapting to weather depending on their demographic or socioeconomic status (SES).[11,14,15] Outdoor PA in vulnerable groups, such as racial minorities and older adults, may be disproportionately affected by weather. For example, studies in Toronto, Canada,[16] and Detroit, Michigan[17] have shown that older adults (those over 60 years of age) reduce their outdoor exercise during the winter months when expecting slippery road conditions or when afraid of falling on ice. Yet there has been little research to examine how the impact of day-to-day weather on decisions to exercise outdoors differs across the lifespan or between people of different racial or SES groups, even though cultural, situational, and personal factors can moderate an individual's thermal comfort and response to weather.[18,19] Identification of risk factors for exercise delay in adverse weather conditions (be it summer or winter) is important to target appropriate interventions to promote outdoor exercises and to promote alternative indoor exercise activities.

In this study, we group a nationally representative sample of American adults into 4 exercise behaviors based on their self-reported exercise behavior when faced with challenging weather conditions: they (1) continue to exercise outdoors, (2) exercise indoors, (3) delay exercising, or (4) do not regularly exercise outdoors regardless of the weather. We broadly compare the demographic characteristics of Americans who do and do not regularly exercise outdoors and examine the association between weather conditions and exercise behaviors among those who do regularly exercise outdoors, adjusting for age, sex, race, and SES characteristics.

2. Methods

2.1. Participant selection

Data used in the study came from the University of Michigan/Thomson Reuters surveys of consumers (SCA) June 2013 (core and supplement) on weather and mobility. The SCA is a nationally representative, monthly telephone survey of approximately 500 noninstitutionalized adults in the contiguous United States. In this cross-sectional probability sample, approximately 300 of these participants were selected through a list-assisted random-digit dialing frame using the GENESYS Sampling System (Marketing Systems Group, Horsham, PA, USA), and 200 of them were recontacts from the survey 6 months prior.[20] According to guidelines from the American Association for Public Opinion Research,[21] this survey's response rate (response rate 1) was 27%, which is better than or comparable to the response rate from other national telephone surveys.[22]

This study was approved by the Institutional Review Board at the University of Michigan. All the participants gave their written informed consent before participating in the survey.

2.2. Derived variables

Questions in the SCA supplement arose from a literature review[9,10,19] and 2 focus groups; the focus groups included 14 individuals who were asked questions about the impact of weather on their typical outdoor activities. The primary independent variable, that is, weather condition, was based on the question, "Which of the following weather conditions is most likely to change the way you go about day-to-day activities?" It was asked separately for summer and winter. For summer, the participant could respond with heat (hot temperature), humidity, poor air quality, rain/thunderstorms, tornados, or hurricanes; in the analysis, these were grouped into 3 categories based on prevalence: heat, rain/thunderstorms, and other. For winter, the response options were cold temperatures, snow, ice, rain, fog, and wind; we combined these into 3 categories based on frequency: cold temperatures, snow and ice, and other.

The dependent variable, that is, outdoor exercise behavior, was also specific to summer and winter. The 4 possible responses were derived from 2 questions. First, participants were asked if they regularly go outdoors at least once a week for exercise such as walking or walking the dog, running, biking, playing sports, or any other type of outdoor exercise. If they answered no, they were categorized as not exercising outdoors. If they had a positive response, they were later asked how they exercised in the summer or winter weather condition that they were previously asked about. If the respondents answered that they skipped exercise under such conditions or waited for the weather to change, this was coded as a delay in exercise; otherwise, they could mention that they would exercise indoors or exercise as planned outdoors.

Those who did regularly exercise outdoors were also asked, "What kind of outdoor exercise do you do most often?" According to World Health Organization standards,[23] responses were dichotomized into vigorous intensity (running, biking, playing sports, or hiking) and moderate intensity (walking, playing with kids, or yard work/gardening) activities. This is a simplified categorization reflecting self-report of activity, and it does not reflect length of time or metabolic equivalents (METs) spent on the PA. Nonetheless, we supposed the activities designated as vigorous intensity to be associated with >6 METs and moderate-intensity activities with $3-6$ METs.[24]

Sex, age, race, and the SES factors (income and education) were simplified from categories in the SCA core questionnaire. Sex was coded as male or female, and individuals were divided into 2 age groups based on whether they were younger or older than 65 years. Race/ethnicity was dichotomized into non-Hispanic white *vs.* other. Income was categorized into tertiles based on participants' responses about their family's total income. The education variable had 2 categories: less than college (for those whose educational attainment was a high school diploma or lower) and at least some college (for those who had some college or a bachelor's or other college degree).

2.3. Statistical analysis

For the multivariate analysis, we first used a logistic regression model to compute the adjusted odds ratio (OR), with 95% confidence intervals (CIs), comparing those with no regular outdoor exercise to all those who do regularly exercise outdoors. Subsequently, we did a subpopulation analysis only among those who did exercise outdoors. Using a multivariate

multinomial logistic regression model, adjusted ORs were computed for delayed *vs.* outdoor exercise and for indoor *vs.* outdoor exercise. The study did include information about which of the 9 census regions the participant resided in, but this variable was not included in the analysis because it was overly broad and did not account for the important climatic variation that would affect PA at an individual level. Additionally, we did test for interaction between weather condition and other independent variables. However, these analyses yielded interaction terms that either were not significant or were exaggerated (e.g., OR > 50) owing to small cell sizes.

All analyses used Taylor series variance estimation and an adult sampling weight, which was provided by the SCA to make the statistics representative of all United States adults living in private households. The weight adjusts for telephone ownership, survey nonresponse, panel attrition, age, and income.[20] All tests for significance were 2-sided and used an α level of 0.05. Missing values in the analysis were treated as not being missing completely at random, and nonmissing values were analyzed as a domain for variance estimation purposes. The analysis were conducted using the statistical software program SAS Version 9.3 (SAS Institute, Inc., Cary, NC, USA).

3. Results

A total of 502 participants completed the questionnaire. Most individuals (68.7%) were younger than 65 years of age, and 79.3% were white. Few (6.9%) did not have a high school diploma; 24.3% had a high school diploma, 29.5% had some college education, 26.9% had completed a bachelor's degree, and 12.3% had a graduate degree (Table 1).

The vast majority of these Americans (83.7%) indicated that they exercised outdoors regularly. The most popular type of exercise was walking (69.5% of those who exercised outdoors regularly); the other exercises categorized as moderate intensity were yard work (6.5%) and playing with kids (0.6%). The most popular exercise categorized as having vigorous intensity was running (8.1%), followed by playing sports (7.0%), biking (5.4%), hiking (1.7%), and swimming (1.2%).

The predominant weather condition identified as being most likely to change the way in which individuals went about their day-to-day activities was rain in the summer (mentioned by 53.2%) and ice or snow in the winter (mentioned by 66.2%). Heat (21.8%) and cold (11.4%) were also subjects of concern from the participants. Faced with challenging weather conditions, many Americans said that they would delay exercise both in the summer (51.8%) and in the winter (43.9%) (Table 1).

Table 2 shows results of a comparison between Americans who do and do not regularly exercise outdoors. The odds of not regularly exercising outdoors were more than 2 times greater among nonwhite Americans (OR = 2.04, 95%CI: 1.03−4.04; $p = 0.04$) and among those with less than a college education (OR = 2.30, 95%CI: 1.19−4.45; $p = 0.01$) compared with their white and college-educated counterparts, respectively. There was no statistically significant relationship by sex, income tertile, or age in regular outdoor exercise.

Table 1
Distribution of demographic characteristics and exercise behaviors: U.S. Survey of Consumers, June 2013 (unweighted $n = 502$).

	Count	Weighted proportion (%, 95%CI)
Sex		
Male	231	45.3 (40.6−49.9)
Female	271	54.7 (50.1−59.4)
Age		
<65 years	320	68.7 (64.5−72.9)
≥65 years	180	31.3 (27.1−35.5)
Missing values	2	
Race		
White	401	79.3 (75.3−83.2)
Nonwhite	88	20.7 (16.8−24.7)
Missing values	13	
Income		
Lower tertile (USD 5000−USD 35,000)	148	33.8 (29.1−38.4)
Middle tertile (USD 36,000−USD 77,500)	162	32.0 (27.6−36.4)
Upper tertile (USD 80,000−USD 650,000)	161	34.2 (29.7−38.8)
Missing values	31	
Education		
<College education	155	31.2 (26.9−35.6)
College education	345	68.7 (64.4−73.1)
Missing values	2	
Summer exercise patterns		
No exercise	78	16.3 (12.8−19.9)
Delayed exercise	250	51.8 (47.0−56.5)
Indoor exercise	86	17.9 (14.2−21.5)
Outdoor exercise	69	14.0 (10.7−17.3)
Missing values	19	
Winter exercise patterns		
No exercise	78	16.3 (12.8−19.9)
Delayed exercise	210	43.9 (39.2−48.7)
Indoor exercise	143	29.8 (25.5−34.2)
Outdoor exercise	51	9.9 (7.1−12.7)
Missing values	20	
Exercise intensity[a]		
Moderate intensity	338	76.7 (72.3−81.2)
Vigorous intensity	86	23.3 (18.8−27.7)
Summer weather condition		
Rain	266	53.2 (48.6−57.9)
Heat	112	21.8 (18.0−25.6)
Other	124	25.0 (20.9−29.0)
Winter weather condition		
Ice or snow	334	66.2 (61.8−70.6)
Cold	55	11.4 (8.4−14.4)
Other	113	22.4 (18.5−26.3)

[a] Only asked for those who did regularly exercise.
Abbreviation: CI = confidence interval.

Results of exercise behaviors under summer and winter weather conditions are shown in Table 3. Compared with younger adults, those ≥65 years had 3 times greater odds (OR = 3.00, 95%CI: 1.24−7.29; $p = 0.02$) of choosing to exercise indoors instead of outdoors when faced with adverse weather conditions. Nonwhite Americans had greater odds of delaying exercise instead of continuing to exercise outdoors (OR = 3.13, 95%CI: 1.08−9.08; $p = 0.04$) compared with white Americans. Individuals listing rain as the predominant adverse weather condition had over 3 times higher odds of exercising indoors (OR = 3.33, 95%CI: 1.34−8.28; $p < 0.01$) and 3.49 times higher odds of delaying exercise (OR = 3.49, 95%CI: 1.69−7.21; $p < 0.01$) compared with those mentioning heat in summer.

Table 2
Results from a logistic regression comparing no regular outdoor exercise to regular outdoor exercise. U.S. Survey of Consumers, June 2013 ($n = 459$).

	OR (95%CI)	p^a
Female *vs.* male	0.91 (0.50−1.66)	0.77
≥65 years *vs.* <65 years	1.37 (0.73−2.57)	0.33
Nonwhite *vs.* white	2.04 (1.03−4.04)	0.04
Income tertiles		0.22
Bottom *vs.* top	1.72 (0.72−4.12)	
Middle *vs.* top	0.91 (0.40−2.05)	
No college *vs.* college	2.30 (1.19−4.45)	0.01

[a] Wald χ^2 type 3 analysis of effects.
Bottom income: USD 5000−USD 35,000; middle income: USD 36,000−USD 77,500; top income: USD 80,000−USD 650,000.
Abbreviations: CI = confidence interval; OR = odds ratio.

In the winter, choosing to exercise indoors instead of outdoors was more common for females than males (OR = 2.49, 95%CI: 1.13−5.51; $p = 0.02$) and for nonwhite Americans compared with white Americans (OR = 3.51, 95%CI: 1.01−12.14; $p = 0.04$). Participants in vigorous-intensity exercise had more than 4 times greater odds of exercising indoors than outdoors (OR = 4.19, 95%CI: 1.38−12.70; $p = 0.01$) compared with individuals who participated in moderate-intensity exercises. Americans who identified ice or snow as the most challenging winter weather condition had greater odds of delaying exercise (OR = 3.34, 95%CI: 1.19−9.36; $p = 0.03$) or exercising indoors (OR = 3.13, 95%CI: 1.09−9.03; $p = 0.01$) compared with those who identified cold temperatures as the most challenging factor.

4. Discussion

Exercising outdoors can be a satisfying means of attaining PA goals, but adverse weather conditions can curtail the decision to exercise. In this analysis of data from the June 2013 SCA (core and supplement) on weather and mobility, which is a nationally representative sample of the USA, a large proportion of American adults delayed exercise in the summer and in the winter when faced with adverse weather conditions. Previous research corroborates this finding; in their systematic review, Tucker and Gilliland[10] found 4 journal articles in which participants mentioned that bad weather was a barrier to physical exercise. However, in some studies, only a few individuals have indicated that weather impedes exercise. For example, in a study of community-dwelling adults over 74 years of age, only 10.9% mentioned bad weather as a barrier to exercise or walking.[25] Nonetheless, outdoor exercise is an extremely important part of most American's routine of PA: depending on the month, it is estimated that Americans are 2 to 3 times more likely to exercise outdoors than indoors.[26] Therefore, any perturbation in the convenience or enjoyability of outside exercise can have an appreciable impact on the overall amount of exercise that Americans do.

We were able to estimate how likely it would be for weather occurrences, such as rain or ice, to result in individuals' delaying exercise. In summer, rain was associated with individuals both exercising indoors and delaying exercise more often than was heat. Compared with cold temperatures, ice or snow in winter similarly had a substantive impact on individuals switching to exercising indoors or delaying exercise. After matching exercise behaviors in the Behavioral Risk Factor Surveillance System to weather records, Eisenberg and Okeke[26] found precipitation and temperature to both be associated with exercise: at temperatures below 60˚F (15.6˚C), decreases in temperature were associated with less exercise, and at temperatures above 80˚F (26.7˚C), increases in temperature were associated with less exercise. Additionally, they found that more precipitation was associated with less

Table 3
Results from 2 multinomial logistic regression models for exercise behaviors in summer and winter weather. U.S. Survey of Consumers, June 2013.

	Summer ($n = 376$)				Winter ($n = 375$)			
	Delayed *vs.* outdoor exercise OR (95%CI)	p^a	Indoor *vs.* outdoor exercise OR (95%CI)	p^a	Delayed *vs.* outdoor exercise OR (95%CI)	p^a	Indoor *vs.* outdoor exercise OR (95%CI)	p^a
Female *vs.* male	1.15 (0.62−2.12)	0.67	1.75 (0.83−3.70)	0.14	1.31 (0.63−2.75)	0.47	2.49 (1.13−5.51)	0.02
≥65 years *vs.* <65 years	1.36 (0.63−2.96)	0.43	3.00 (1.24−7.29)	0.02	0.79 (0.32−1.93)	0.60	1.43 (0.57−3.55)	0.45
Nonwhite *vs.* white	3.13 (1.08−9.08)	0.04	2.26 (0.65−7.86)	0.20	2.22 (0.67−7.42)	0.20	3.51 (1.01−12.14)	0.04
Income tertiles								
Bottom *vs.* top	0.68 (0.28−1.68)	0.60	0.37 (0.13−1.04)	0.10	1.89 (0.67−5.33)	0.27	1.25 (0.42−3.74)	0.74
Middle *vs.* top	0.71 (0.34−1.49)	0.65	0.63 (0.26−1.53)	0.94	1.27 (0.52−3.09)	0.85	1.13 (0.45−2.83)	0.98
No college *vs.* college	1.63 (0.76−3.50)	0.21	0.95 (0.36−2.54)	0.92	2.18 (0.81−5.85)	0.12	1.26 (0.44−3.57)	0.66
Vigorous *vs.* moderate intensity exercise	0.52 (0.24−1.14)	0.10	0.87 (0.35−2.17)	0.77	2.22 (0.75−6.52)	0.15	4.19 (1.38−12.70)	0.01
Summer weather								
Rain *vs.* heat	3.49 (1.69−7.21)	<0.01	3.33 (1.34−8.28)	<0.01				
Other *vs.* heat	1.08 (0.46−2.55)	0.15	1.46 (0.49−4.36)	0.63				
Winter weather								
Ice or snow *vs.* cold					3.34 (1.19−9.36)	0.03	3.13 (1.09−9.03)	0.01
Other *vs.* cold					2.09 (0.67−6.52)	0.76	1.26 (0.37−4.33)	0.50

[a] Maximum likelihood estimate *t* test.
Bottom income: USD 5000−USD 35,000; middle income: USD 36,000−USD 77,500; top income: USD 80,000−USD 650,000.
Abbreviations: CI = confidence interval; OR = odds ratio

adherence to exercise recommendations from the United States Centers for Disease Control and Prevention. A narrative review of scientific articles on weather and PA also found that precipitation was associated with decreased PA.[12] However, it is difficult to compare the association between weather and exercise behaviors across different countries or even within a country because of differing conceptions of exercise and familiarity with a range of weather conditions. Additionally, because high temperature and humidity can compromise thermoregulation during exercise,[13] the impact of weather on exercise in the summer is likely greater for heat than for rain. Our finding that rain contributed to delays in exercise more than heat may be due to participants' misunderstanding of the question or may be because participants were not familiar or experienced with heat-related illness during exercise.

Global climate change could change what individuals commonly experience in a given area. As the average temperature increases worldwide, and as other climate patterns change (humidity, precipitation, wind, and severe weather like tornadoes and hurricanes), which exercises are possible outdoors in a certain area may change, and preventive measures such as thorough hydration (before, during, and after PA), more breaks during exercise, and better clothing will need to be promoted.[13] These changes in weather may require communities to build systems to warn against severe weather events,[27] particularly for heat, which could save many lives.[28]

A concern when considering outside exercise behaviors is that individuals of lower SES are less able to cope with changing weather and as a result abandon exercise routines. We did find that nonwhites and individuals without a college education had greater odds of not exercising than their white and college-educated counterparts, and nonwhites were also much more likely to delay exercising in summer conditions instead of continuing to exercise outdoors. A survey of Illinois residents also found that those with higher education were more likely to walk and exercise outside.[29] Eisenberg and Okeke[26] found that less educated groups of people had exercise behaviors that were more affected by weather patterns than did better educated individuals. Exercise patterns in people of lower SES may be more affected by weather because they live in less walkable neighborhoods[30] or because they perceive themselves to have limited opportunities for recreational PAs.[31] Lower-income neighborhoods and neighborhoods with a higher proportion of racial minorities are less likely to have indoor recreational facilities;[32] even if racial minorities and people of lower SES do have access to these facilities, they may lack the disposable income to purchase memberships and may not have experience in using specialized exercise equipment (compared with outdoor activities like running or walking, which have a lower barrier to entry). Human response to weather is also mediated by personal or cultural situations (e.g., norms, experiences, and expectations),[19] which could differ across demographic and SES groups.

Interestingly, we found that individuals who did vigorous-intensity exercises were more likely to exercise indoors instead of outdoors in the winter. This may be because weather conditions such as ice, snow, or severe cold would be more of an impediment for higher-intensity activities like running than for lower-intensity activities like walking. However, because being able to exercise outdoors is an important part of maintaining a healthy amount of PA over time,[5,33] any interventions to improve population-level PA should include incorporate contingencies for both lower-intensity exercise outdoors and readily accessible indoor exercise facilities.

By sampling throughout the 48 contiguous U.S. states, we were able to generalize results to all Americans, and we were able to study a number of different weather conditions that may be more prevalent in some areas than others. Another strength of the study was the rigor in creating the survey questions; the content of the questions arose from a literature review[9,10,19] and focus groups, and the content of questions was evaluated through cognitive interviews and pretesting. We acknowledge that the study also has some limitations. The small sample size may have resulted in a decreased precision of the results, and the categorization of age, race, education, and income may have ignored within-group variation. There were no questions on how often respondents exercised outdoors, and direct measurement of exertion using METs would be preferable to self-reporting of PA type.[34] Additionally, different categorizations of PA can lead to substantially different estimates of adherence to PA, making comparison between our study and others difficult.[6,35] We did not have access to information on chronic health conditions, body mass index, or built environment, including access to outdoor open spaces, walkability, or neighborhood connectivity. These factors are all plausible confounders for the variables studied in this article and plausibly have a large impact on outdoor PA. For example, the difference we see between whites and nonwhites in this study could be explained by nonwhites living in neighborhoods with an outside environment less suitable for walking and other PA. Lastly, social desirability may have affected respondents' answers in the telephone survey. No exercise or delays in exercise could have been underreported because regular exercise is considered a desirable behavior.

Future research could measure the duration and occurrence of PAs across a week, allowing us to categorize participants based on adherence to PA guidelines. Measurement of the built environment and the amount of leisure time that individuals have could be fruitful for future studies assessing outdoor exercise patterns. Specifically, walkability of the neighborhood, availability of parks and open spaces, and perceived safety of the neighborhood could reveal important predictors of undelayed outdoor PA. More details on geographic location could also provide information on day length, weather patterns, and other factors that have been shown to affect outdoor PA.[8,9] Additionally, future research could directly measure the weather conditions using meteorological tools, or, if participants are asked, more detailed choices could be ascertained (e.g., thunderstorms, tornados, hurricanes, ultraviolet rays, humidity, *etc.*) to pinpoint the exact weather conditions that are most related to changed outdoor exercise behaviors.[13] This will be especially important to disentangle heat, humidity, and precipitation, which often co-occur in the summer. Nevertheless, this study reveals important connections between individual subjective perceptions of weather and exercise behaviors.[36]

5. Conclusion

As the United States and much of the world struggles with increasing prevalence of obesity, a recommendation for individuals to exercise outdoors so that they attain PA goals could be seen as an easy and affordable prescription.[1,4,5] However, attaining these PA goals may be elusive to a large proportion of individuals, particularly for those who regularly encounter adverse weather conditions and who do not have the means to continue exercising, whether inside or outside. Using nationally representative data on American adults, this study identified individual factors such as race, age, and education that mitigate or exacerbate the negative effects of adverse weather conditions on the decision to exercise outdoors. Physicians and other professionals should be attuned to temperature or precipitation patterns in their community and be able to talk with patients about why they may not want to exercise when it is raining, snowing, or uncomfortably hot. Communities can work to create more weather-flexible and exercise-friendly neighborhoods with wider, cleaner sidewalks, well-maintained parks, and access to places for other activities like swimming and hiking that are appropriate for individuals from diverse subgroups of the population. Exploring how to limit exercise delays through the promotion of alternatives to outdoor exercise or by creating more exercise-friendly neighborhoods is an important target for future research.

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Authors' contributions

ALW analyzed and interpreted the data, and drafted the manuscript; FK contributed to study design and data interpretation, and revised the manuscript critically for intellectual content; TY contributed to study design and data interpretation, and revised the manuscript critically for intellectual content; PJC conceived of the study, contributed to data anlysis and data interpretation, and revised the manuscript critically for intellectual content. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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