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Leisure-Time Physical Activity, Falls, and Fall Injuries in Middle-Aged Adults

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Introduction: Although exercise and strength training have been shown to be protective against falls in older adults (aged 65 years and older), evidence for the role of leisure-time physical activity (LTPA) in the prevention of falls and resulting injuries in middle-aged adults (aged 45–64 years) is lacking. In the present study, we investigate the association between self-reported engagement in LTPA and the frequency of falls and fall-related injuries among middle-aged and older adults, while controlling for key sociodemographic and health characteristics.

Methods: Nationally representative data from the 2010 U.S. Behavioral Risk Factor Surveillance Survey were analyzed in April 2014 to examine the number of adults aged ≥ 45 years who self-reported their fall experience in the previous 3 months and any injuries that resulted from those falls. We then evaluated the association between LTPA and self-reported falls and injuries across three age strata (45–54, 55–64, and ≥ 65 years). The two main self-reported outcome measures were (1) frequency of falls in the 3 months prior to the survey interview date and (2) the number of injuries resulting from these falls. Prevalence ratios (PRs) and 95% CIs were calculated using Poisson regression models with robust SEs.

Results: Of 340,680 survey participants aged ≥ 45 years, 70.7% reported engaging in LTPA, and 17% reported one or more falls. Among those reporting a fall within 3 months, 25.6% experienced one injurious fall (fall resulting in an injury) and 8.4% reported two or more injurious falls. Controlling for sociodemographic and health characteristics, among adults aged 45–54 years, those who engaged in LTPA were significantly less likely to report one fall (PR=0.90, 95% CI=0.81, 0.99); two or more falls (PR=0.84, 95% CI=0.77, 0.93); one injurious fall (PR=0.88, 95% CI=0.78, 0.99); and two or more injurious falls (PR=0.69, 95% CI=0.58, 0.83) than those who did not exercise. A similar protective effect of LTPA on reporting falls and injuries was noted for adults aged 55–64 and ≥ 65 years.

Conclusions: Similar to older adults, middle-aged adults who engage in LTPA report fewer falls and fall-related injuries. Upon further confirmation of the relationship between LTPA and falls among middle-aged adults, fall prevention interventions could be developed for this population.

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Introduction

In the U.S., falls are the leading cause of non-fatal injuries treated in hospital emergency departments in every age stratum except 15–24 years.¹ Falls are also the third leading cause of unintentional injury deaths among those aged 45–64 years.^{2,3} Secular trends suggest an increasing burden of injuries from falls leading to emergency room visits, hospitalizations, and deaths.^{4–7} For example, the 2010 Global Burden of Disease report indicated a marked rise in the rate of falls among adults.^{8,9} The report also showed that annually, falls result in losses of more than 1.16 million disability-adjusted life-years (DALYs) among all U.S. adults, including 422,000 DALYs lost for middle-aged adults, aged 45–64 years, and 606,000 DALYs for adults aged above 65 years.^{8,9} In addition to life-years lost due to an injury and subsequent disability, these events are costly. One U.S. study examining unintentional injuries that occur in the home estimated the total societal costs of these injuries to be approximately U.S. \$217 billion. Falls accounted for the largest proportion (42%) of the total cost of these injuries.¹⁰ These data support the notion that falls are not only an issue for older adults but also that there is a need to identify fall prevention strategies that target middle-aged adults to have an overall impact on fall-related injuries and disability.

Current evidence suggests that among older adults (aged 65 years and older), progressive exercise programs focusing on moderate- to high-intensity exercise at a minimum dose of 50 hours over a period of 3 months are among the most effective interventions to prevent falls.¹¹ Exercise and regular physical activity have also been suggested to be as potentially effective at improving health conditions as drug interventions are for patients with chronic health conditions.^{12–16} However, there has been limited investigation of the association between leisure-time physical activity (LTPA) and falls among middle-aged adults (aged 45–64 years). It is well documented that exercise has a protective effect against falls among older adults.^{11,15,17,18} However, it is not known if this effect is similar in middle-aged adults.

In the present study, we used nationally representative U.S. survey data to investigate the association between self-reported engagement in LTPA and the frequency of falls and fall-related injuries among middle-aged adults (grouped into two age strata, 45–54 and 55–64 years) and older adults (aged 65 years and older), while controlling for key sociodemographic and health characteristics. We hypothesized that middle-aged adults who engaged in LTPA would be less likely to report a fall, as well as injuries resulting from a fall, when compared with middle-aged adults who did not engage in LTPA.

Older adults are included in the study to compare the results with middle-aged adults and prior published studies.

Methods

Data Source

Since 1984, the Centers for Disease Control and Prevention have coordinated the Behavioral Risk Factor Surveillance System (BRFSS)—a state-based system of health surveys designed to collect standardized information on risk factors for morbidity and mortality, including questions on falls, injuries, and physical activity.¹⁹ This cross-sectional survey is conducted annually among non-institutionalized adults, aged ≥ 18 years, in all 50 states and U.S. territories. Measures related to physical activity and injury risk are notably of high reliability and validity in the BRFSS.^{20,21} The calculated 2010 BRFSS response rates across states ranged from 39.1% to 68.8% with a median response rate of 54.6%.²²

Information on falls and injuries resulting from falls are assessed from all survey participants aged ≥ 45 years. In the present study, we analyzed in April 2014 the association between self-reported LTPA, falls, and injuries resulting from falls by major age groups (45–54, 55–64, and ≥ 65 years) among participants of the 2010 BRFSS (N=340,680).

Measures

The two ordinal outcome variables in the present study were (1) self-reported number of falls and (2) injuries resulting from the falls. Specifically, participants were asked for the first outcome variable, *In the past 3 months, how many times have you fallen?* Response options included the number of times a person fell in the past 3 months, *none*, or *don't know*. For the second outcome variable, participants were asked, *How many of these falls caused an injury? By an injury, we mean the fall caused you to limit your regular activities for at least a day to go see a doctor.* Response options included the numeric value of falls resulting in injury (injurious falls), *none*, or *don't know*.

The primary exposure of interest in the study was LTPA, which was derived from the question *During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?* Question response items were dichotomized into either those survey respondents who engaged in LTPA or those who did not.

Additional covariates included age, gender, race/ethnicity, educational attainment, marital status, household income, BMI (categorized as neither overweight nor obese [< 25 kg/m²], overweight [25–29.9 kg/m²], or obese [≥ 30 kg/m²])²³; heavy alcohol use (categorized as a dichotomous yes/no for adult men having more than two drinks per day and adult women having more than one drink per day)²⁴; diabetes status (dichotomously categorized as affirmative by those who reported being told by a doctor they had diabetes)²⁵; cardiovascular disease category (dichotomously categorized as affirmative by those who reported being told by a doctor they had either a heart attack, coronary heart disease, or stroke)²⁶; and health status (dichotomized into excellent to good or fair to poor in response to the question *Would you say that in general your health is—excellent, very good, good, fair or poor?*)²⁷.

Statistical Analysis

We performed analyses stratified by three age groups (45–54, 55–64, and ≥ 65 years) among individuals participating in the 2010 BRFSS who self-reported on their LPTA, falls, and those falls resulting in injuries. Descriptive statistics of the sociodemographic and health characteristics by fall and injury experience are presented in [Table 1](#). Univariate and multivariate Poisson regression models with empirical SEs were used to test the associations between LPTA, falls, and falls with injuries and estimate prevalence ratios (PRs) and 95% CIs.²⁸ An alpha level of 0.05 was considered statistically significant. All potential confounders were selected a priori and were included in the multivariable model regardless of the significance level. All analyses were performed using SAS, version 9.2, with adjustments for sample weights and survey design. We also calculated the proportion of adults by 2-year age groups who self-reported two or more falls (recurrent fallers) and one or more injuries from falls ([Figure 1A](#) and [1B](#), respectively) in the previous 3 months stratified by their engagement in exercise. The study was approved as exempt by the IRBs of the Liberty Mutual Research Institute for Safety and the Harvard T.H. Chan School of Public Health.

Results

The sample characteristics of survey respondents and their fall experience in the previous 3 months are shown in [Table 1](#). Overall, 17% of participants experienced one or more falls in the previous 3 months, and 34% of the participants with one or more falls reported one or more injuries from falling. The proportion of participants reporting no fall in the previous 3 months was similar among participants aged 45–54, 55–64, and 75–84 years. This proportion was slightly higher for those aged 65–74 years and lower for those aged ≥ 85 years.

When modeling falls using univariate Poisson regression, we found that adults aged 45–54 years who engaged in LTPA were significantly less likely to report one fall incident (unadjusted PR [UPR]=0.80, 95% CI=0.74, 0.88), and two or more falls (UPR=0.49, 95% CI=0.45, 0.54) when compared with adults in the same age group who did not engage in LTPA. A similar association was noted among adults aged 55–64 and ≥ 65 years who engaged in LTPA, as they were significantly less likely to report one fall (UPR=0.85, 95% CI=0.79, 0.91, and UPR=0.79, 95% CI=0.75, 0.83, respectively) and two or more falls (UPR=0.46, 95% CI=0.43, 0.50, and UPR=0.51, 95% CI=0.47, 0.54, respectively) when compared with those age groups who did not engage in LTPA.

Univariate Poisson regression analyses for fall-related injuries showed that adults aged 45–54 years who engaged in LTPA were significantly less likely to report one injurious fall (UPR=0.73, 95% CI=0.66, 0.81) and two or more injurious falls (UPR=0.38, 95% CI=0.32, 0.44) relative to those aged 45–54 years who did not

engage in LTPA. A similar association was noted among the older age groups (55–64 and ≥ 65 years) in being less likely to report one injurious fall (UPR=0.82, 95% CI=0.75, 0.90 and UPR=0.86, 95% CI=0.81, 0.92, respectively) and two or more injurious falls (UPR=0.48, 95% CI=0.41, 0.56 and UPR=0.54, 95% CI=0.46, 0.65, respectively) relative to those who did not engage in LTPA.

Based on multivariable Poisson regression models, adults aged 45–54 years who engaged in LTPA were significantly less likely to report one fall (adjusted PR [APR]=0.90, 95% CI=0.81, 0.99) and two or more falls (APR=0.84, 95% CI=0.77, 0.93) relative to those adults who did not engage in LTPA ([Table 2](#)). Similarly, adults aged 55–64 and ≥ 65 years who engaged in LTPA were also significantly less likely to report one fall and two or more falls than those aged 55–64 and adults ≥ 65 years who did not engage in LTPA.

Many other factors associated with self-reported falls were comparable in middle-aged adults and older age groups. Female gender in all three age groups was significantly associated with a higher proportion of one self-reported fall but not two or more falls ([Table 2](#)). Other demographic factors associated with higher self-reported falls were some college and college graduate education (versus less than high school diploma); Non-Hispanic white and multiracial non-Hispanic race; divorced, widowed, or separated status (versus married and unmarried couple); and household income $< \$15,000$. Among health-related factors, obesity, cardiovascular disease, alcohol consumption, and fair/poor self-reported health were associated with a higher prevalence of self-reported falls.

When modeling falls resulting in injury using multivariable Poisson regression, adults aged 45–54 years who engaged in LTPA were significantly less likely to report one injurious fall (APR=0.88, 95% CI=0.78, 0.99) ([Table 3](#)). However, this association was not statistically significant for respondents aged 55–64 and ≥ 65 years. Prevalence of two or more injurious falls among those who engaged in LTPA was significantly lower as compared with those who did not engage in LTPA in all three age groups.

Female gender was associated with a higher prevalence of fall-related injuries among all the three age groups. Among other demographic variables, only household income $< \$15,000$ was significantly associated with higher reports of fall-related injuries. Cardiovascular disease and fair/poor self-reported health were the only health-related factors significantly associated with a higher prevalence of self-reported fall injuries.

Lastly, when age was categorized by 2-year age groups, the protective effect of LTPA on two or more

Table 1. Estimated Incidence of Falls and Injury-Related Falls by Socio-Demographic and Health Characteristics of Adults (Age ≥ 45 Years Old) Participating in the 2010 Behavioral Risk Factor Surveillance Survey

Sociodemographic characteristics	Total n (%) ^a	Falls			Falls resulting in injury		
		No falls n (%)	One fall n (%)	Two or more falls n (%)	No injurious fall n (%)	One injurious fall n (%)	Two or more injurious falls n (%)
Total	340,680 (100.0)	274,200 (82.8)	34,404 (10.1)	22,711 (6.9)	37,475 (66.1) ^b	14,504 (25.6) ^b	4,754 (8.4) ^b
LTPA							
45–54-year-olds							
Yes, LTPA	64,319 (74.8)	52,659 (84.0)	6,129 (9.8)	3,869 (6.2)	6,792 (68.3)	2,382 (24.0)	772 (7.8)
No, LTPA	21,666 (25.2)	16,234 (77.5)	2,290 (10.9)	2,431 (11.6)	2,566 (55.0)	1,316 (28.2)	781 (16.8)
55–64-year-olds							
Yes, LTPA	74,213 (72.5)	60,995 (84.2)	7,289 (10.1)	4,133 (5.7)	7,772 (68.4)	2,767 (24.3)	831 (7.3)
No, LTPA	28,181 (27.5)	21,256 (77.5)	3,012 (11.0)	3,146 (11.5)	3,577 (58.6)	1,642 (26.9)	888 (14.5)
65 and older							
Yes, LTPA	102,091 (67.3)	84,672 (85.2)	9,948 (10.0)	4,816 (4.8)	10,447 (71.1)	3,566 (24.3)	676 (4.6)
No, LTPA	49,687 (32.7)	38,022 (79.3)	5,676 (11.84)	4,256 (8.9)	6253 (63.5)	2802 (28.5)	790 (8.0)
Age (years)							
45–54	86,077 (25.3)	68,949 (82.4)	8,430 (10.1)	6,321 (7.6)	9,373 (64.0)	3,706 (25.3)	1,560 (10.7)
55–64	102,507 (30.1)	82,324 (82.4)	10,314 (10.3)	7,294 (7.3)	11,368 (64.9)	4,413 (25.2)	1,722 (9.8)
65–74	82,854 (24.3)	68,282 (84.6)	7,963 (9.9)	4,471 (5.5)	8,509 (68.8)	3,068 (24.8)	792 (6.4)
75–84	52,819 (15.5)	42,292 (82.6)	5,615 (11.0)	3,266 (6.4)	5,957 (67.6)	2,372 (26.9)	484 (5.5)
≥ 85	16,423 (4.8)	12,353 (78.2)	2,082 (13.2)	1,359 (8.6)	2,268 (66.5)	945 (27.7)	196 (5.7)
Gender							
Male	128,088 (37.6)	103,402 (83.3)	11,643 (9.4)	9,064 (7.3)	14,793 (71.9)	4,280 (20.8)	1,497 (7.3)
Female	212,592 (62.4)	170,798 (82.4)	22,761 (11.0)	13,647 (6.6)	22,682 (62.7)	10,224 (28.3)	3,257 (9.0)
Educational attainment							
Less than high school	33,875 (10.0)	25,629 (78.9)	3,357 (10.3)	3,490 (10.7)	3,990 (59.1)	1,899 (28.1)	866 (12.8)
High school diploma	106,199 (31.3)	85,649 (83.1)	10,121 (9.8)	7,297 (7.1)	11,324 (65.5)	4,470 (25.9)	1,497 (8.7)
Some college	89,264 (26.3)	71,678 (82.2)	92,76 (10.6)	6,199 (7.1)	9,919 (64.5)	4,056 (26.4)	1,406 (9.1)

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Table 1. Estimated Incidence of Falls and Injury-Related Falls by Socio-Demographic and Health Characteristics of Adults (Age ≥45 Years Old) Participating in the 2010 Behavioral Risk Factor Surveillance Survey (continued)

Sociodemographic characteristics	Total n (%) ^a	Falls			Falls resulting in injury		
		No falls n (%)	One fall n (%)	Two or more falls n (%)	No injurious fall n (%)	One injurious fall n (%)	Two or more injurious falls n (%)
College graduate	110,252 (32.5)	90,712 (84.0)	11,606 (10.7)	5,683 (5.3)	12,188 (70.8)	4,058 (23.6)	977 (5.7)
Race/ethnicity							
White, non-Hispanic	276,709 (82.4)	223,145 (82.7)	28,725 (10.6)	18,063 (6.7)	31,426 (67.5)	11,548 (24.8)	3,549 (7.6)
Black, non-Hispanic	25,063 (7.5)	20,483 (84.4)	2,082 (8.6)	1,594 (6.6)	2,191 (60.3)	1,053 (29.0)	390 (10.7)
Other, non-Hispanic	10,532 (3.1)	8,387 (82.9)	926 (9.2)	802 (7.9)	1,017 (59.4)	462 (27.0)	232 (13.6)
Multiracial, non-Hispanic	5,334 (1.6)	3,961 (76.2)	629 (12.1)	608 (11.7)	678 (55.3)	357 (29.1)	192 (15.6)
Hispanic	18,325 (5.5)	14,675 (83.8)	1,601 (9.1)	1,244 (7.1)	1,634 (58.1)	871 (31.0)	309 (11.0)
Obesity status (BMI)							
Healthy/normal weight	109,546 (33.6)	89,841 (84.2)	10,486 (9.8)	6,399 (6.0)	11,144 (66.5)	4,358 (26.0)	1,264 (7.5)
Overweight	122,961 (37.7)	100,443 (83.7)	12,058 (10.1)	7,472 (6.2)	13,356 (68.8)	4,683 (24.1)	1,379 (7.1)
Obese	93,409 (28.7)	72,861 (79.6)	10,598 (11.6)	8,081 (8.8)	11,743 (63.3)	4,889 (26.3)	1,925 (10.4)
Marital status							
Married/unmarried couple	189,718 (55.9)	156,339 (84.5)	18,018 (9.7)	10,573 (5.7)	19,737 (69.3)	6,820 (24.0)	1,906 (6.7)
Divorced, widow, or separated	124,979 (36.8)	97,585 (80.4)	13,719 (11.3)	10,141 (8.4)	14,756 (62.4)	6,494 (27.5)	2,407 (10.2)
Single	24,654 (7.3)	19,408 (81.2)	2,562 (10.7)	1,925 (8.1)	2,873 (64.7)	1,142 (25.7)	425 (9.6)
Household income total (\$)							
<15,000	37,178 (12.8)	26,695 (74.0)	4,312 (12.0)	5,044 (14.0)	4,931 (53.3)	2,792 (30.2)	1,523 (16.5)
15,000 to <25,000	55,675 (19.2)	43,280 (79.9)	5,883 (10.9)	4,997 (9.2)	6,785 (62.8)	2,806 (26.0)	1,208 (11.2)
25,000 to <35,000	37,027 (12.8)	29,974 (82.7)	3,851 (10.6)	2,441 (6.7)	4,227 (67.4)	1,585 (25.3)	457 (7.5)
35,000 to <50,000	44,832 (15.5)	37,022 (84.2)	4,526 (10.3)	2,427 (5.5)	4,895 (70.6)	1,673 (24.1)	362 (5.2)
≥50,000	115,332 (39.8)	97,242 (85.8)	11,150 (9.8)	4,922 (4.3)	11,753 (73.3)	3,650 (22.8)	629 (3.9)
Diabetes status							
Yes, diabetic	53,396 (15.7)	40,297 (77.6)	6,172 (11.9)	5,439 (10.5)	6,928 (60.1)	3,249 (28.2)	1,344 (11.7)

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Table 1. Estimated Incidence of Falls and Injury-Related Falls by Socio-Demographic and Health Characteristics of Adults (Age ≥45 Years Old) Participating in the 2010 Behavioral Risk Factor Surveillance Survey (continued)

Sociodemographic characteristics	Total n (%) ^a	Falls			Falls resulting in injury		
		No falls n (%)	One fall n (%)	Two or more falls n (%)	No injurious fall n (%)	One injurious fall n (%)	Two or more injurious falls n (%)
No diabetes	286,920 (84.3)	233,633 (83.7)	28,199 (10.1)	17,243 (6.2)	30,512 (67.6)	11,239 (24.9)	3,403 (7.5)
CVD status							
Yes, CVD (MI, CHD, or stroke)	53,762 (15.8)	39,043 (74.8)	6,456 (12.4)	6,707 (12.8)	7,679 (58.9)	3,584 (27.5)	1,773 (13.6)
No CVD	286,918 (84.2)	235,157 (84.3)	27,948 (10.0)	16,004 (5.7)	29,796 (68.2)	10,920 (25.0)	2,981 (6.8)
Alcohol consumption							
Not heavy drinker	315,739 (95.5)	257,089 (82.7)	32,203 (10.4)	21,504 (6.9)	35,147 (65.9)	13,699 (25.6)	4,549 (8.5)
Heavy drinker	14,797 (4.5)	12,041 (82.6)	1,667 (11.4)	863 (5.9)	1,762 (69.8)	622 (24.6)	141 (5.6)
Health status							
Excellent to good	260,759 (76.9)	218,939 (86.2)	24,443 (9.6)	10,750 (4.2)	25,466 (72.6)	8,220 (23.4)	1,372 (3.9)
Fair/poor	78,373 (23.1)	54,110 (71.4)	9,796 (12.9)	11,834 (15.6)	11,820 (55.3)	6,208 (29.0)	3,359 (15.7)

^aDifferences in sub-total population sample due to item non-response or missing.

^bPercentage indicates the proportion of participants who experienced at least one fall.

CHD, coronary heart disease; CVD, cardiovascular disease; HS, high school; LTPA, leisure-time physical activity; MI, myocardial infarction; PR, prevalence ratio.

falls remained almost constant across all age groups (Figure 1A). The effect on one or more falls resulting in injury was also protective among almost all age groups (Figure 1B).

Discussion

Earlier studies have shown a protective effect of exercise on falls among older adults.^{11,15,17,18} In this first national study of U.S. middle-aged adults, we observed that middle-aged adults (age strata, 45–54 and 55–64 years) who engaged in LTPA were significantly less likely to report falls, as well as injuries from their falls, when compared with adults in the same age strata who did not engage in LTPA. We observed a similar association in older adults, where survey respondents aged 65 years and older who engaged in LTPA were less likely to report falls and injuries resulting from falls than those who did not engage in LTPA. To our knowledge, no previous studies have evaluated the association between LTPA and self-reported falls and fall-related injuries among middle-aged adults. The findings are consistent with earlier studies, suggesting that physical activity and exercise

are protective of falls and fall-related injuries among adults aged 65 years and older.^{29–32} Hence, we now document a similar association for middle-aged adults.

This study also documents that about 18% of participants aged 45–64 years reported falling at least once in the previous 3 months. Although prior studies have primarily investigated falls and injuries resulting from falls in older adult populations, none have focused on the effects of physical activity in the middle-aged strata of the working age adult life span (45–64 years) as in this report. More attention may need to be directed to the middle-aged adult population where approximately 21% in an earlier study (similar to our study findings) reported falling at least once in a 2-year period.³³

Given the trends toward increased sedentary behavior as worksites, homes, and public spaces have been evolving in ways that minimize human movement and muscular activity,³⁴ more investigation into the role of physical activity in protecting middle-aged adults from falls is needed. Regular physical activity may help reduce the prevalence of chronic diseases, such as cardiovascular disease, among middle-aged adults.^{35–37} In this study, we found cardiovascular disease and self-reported health

Table 2. Multivariate Poisson Regression With Robust SEs to Calculate Prevalence Ratios and Their 95% CIs for Falls Among Adults (45 and Older): 2010 Behavioral Risk Factor Surveillance Survey

Predictors	45–54 years old (n=83,700) ^a		55–64 years old (n=99,932) ^a		65 and older (n=147,683) ^a	
	One	Two or more	One	Two or more	One	Two or more
	fall	falls	fall	falls	fall	falls
	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
LTPA (ref=no LTPA)						
Yes, LTPA	0.90 (0.81, 0.99)	0.84 (0.77, 0.93)	0.97 (0.89, 1.05)	0.76 (0.70, 0.83)	0.87 (0.82, 0.93)	0.70 (0.64, 0.76)
Gender (ref=males)						
Females	1.23 (1.13, 1.34)	0.96 (0.88, 1.05)	1.29 (1.20, 1.38)	1.01 (0.93, 1.11)	1.21 (1.13, 1.28)	0.89 (0.82, 0.97)
Educational attainment (ref= <HS diploma)						
HS diploma	1.08 (0.90, 1.3)	1.08 (0.93, 1.25)	1.03 (0.87, 1.22)	1.11 (0.95, 1.30)	0.96 (0.87, 1.06)	1.00 (0.89, 1.13)
Some college	1.28 (1.06, 1.55)	1.19 (1.02, 1.38)	1.15 (0.97, 1.35)	1.29 (1.11, 1.50)	1.09 (0.98, 1.21)	1.23 (1.09, 1.40)
College graduate	1.19 (0.99, 1.45)	1.21 (1.02, 1.43)	1.19 (1.00, 1.40)	1.32 (1.11, 1.57)	1.21 (1.08, 1.35)	1.19 (1.04, 1.36)
Race/ethnicity (ref=white, non-Hispanic)						
Black, non-Hispanic	0.69 (0.59, 0.81)	0.64 (0.53, 0.76)	0.79 (0.70, 0.91)	0.62 (0.53, 0.72)	0.72 (0.63, 0.83)	0.64 (0.54, 0.75)
Other, non-Hispanic	0.56 (0.42, 0.75)	0.57 (0.46, 0.71)	0.83 (0.64, 1.08)	0.74 (0.56, 0.97)	0.77 (0.62, 0.95)	1.07 (0.80, 1.43)
Multiracial, non-Hispanic	1.19 (0.94, 1.52)	1.41 (1.14, 1.73)	1.30 (1.04, 1.62)	1.29 (1.05, 1.58)	0.97 (0.77, 1.21)	1.34 (1.00, 1.80)
Hispanic	0.64 (0.52, 0.79)	0.47 (0.39, 0.57)	0.65 (0.55, 0.78)	0.47 (0.38, 0.59)	0.77 (0.66, 0.90)	0.74 (0.61, 0.89)
Obesity status (ref=healthy/normal weight)						
Overweight	1.12 (1.01, 1.23)	1.13 (1.00, 1.26)	1.07 (0.98, 1.18)	1.02 (0.91, 1.14)	1.03 (0.96, 1.10)	0.94 (0.86, 1.03)
Obese	1.28 (1.16, 1.42)	1.12 (1.00, 1.26)	1.18 (1.08, 1.30)	1.10 (0.98, 1.23)	1.11 (1.03, 1.19)	1.08 (0.98, 1.20)
Marital status (ref=married/unmarried couple)						
Divorced, widowed, or separated	1.11 (1.01, 1.22)	1.12 (1.01, 1.24)	1.07 (0.98, 1.16)	1.10 (1.00, 1.21)	1.15 (1.08, 1.23)	1.14 (1.05, 1.24)
Single	1.01 (0.89, 1.15)	0.83 (0.72, 0.96)	1.01 (0.89, 1.14)	1.00 (0.86, 1.17)	1.12 (0.98, 1.28)	1.09 (0.85, 1.40)
Household income total (\$, ref= <15,000)						
15,000 to <25,000	0.87 (0.73, 1.02)	0.71 (0.63, 0.81)	0.94 (0.82, 1.08)	0.84 (0.74, 0.94)	1.00 (0.91, 1.10)	0.86 (0.76, 0.96)
25,000 to <35,000	0.84 (0.70, 1.00)	0.56 (0.46, 0.67)	0.88 (0.76, 1.03)	0.58 (0.50, 0.67)	1.05 (0.95, 1.17)	0.81 (0.71, 0.93)

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Table 2. Multivariate Poisson Regression With Robust SEs to Calculate Prevalence Ratios and Their 95% CIs for Falls Among Adults (45 and Older): 2010 Behavioral Risk Factor Surveillance Survey (continued)

Predictors	45–54 years old (n=83,700) ^a		55–64 years old (n=99,932) ^a		65 and older (n=147,683) ^a	
	One	Two or more	One	Two or more	One	Two or more
	fall	falls	fall	falls	fall	falls
	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
35,000 to < 50,000	0.78 (0.66, 0.92)	0.54 (0.45, 0.65)	0.82 (0.71, 0.95)	0.50 (0.42, 0.59)	1.01 (0.90, 1.12)	0.70 (0.61, 0.81)
≥ 50,000	0.75 (0.64, 0.89)	0.38 (0.32, 0.44)	0.86 (0.75, 0.99)	0.39 (0.34, 0.46)	0.96 (0.86, 1.08)	0.65 (0.56, 0.77)
Diabetes status (ref=no diabetes)						
Yes, diabetic	1.08 (0.94, 1.23)	1.00 (0.88, 1.13)	1.06 (0.96, 1.18)	1.20 (1.08, 1.33)	1.08 (1.01, 1.16)	1.09 (0.99, 1.19)
CVD status (ref=no CVD)						
Yes, CVD (MI, CHD, or stroke)	1.43 (1.22, 1.68)	1.63 (1.45, 1.83)	1.13 (1.02, 1.25)	1.41 (1.28, 1.55)	1.18 (1.11, 1.26)	1.57 (1.44, 1.71)
Alcohol consumption (ref=not heavy drinker)						
Yes, heavy alcohol drinker	1.41 (1.20, 1.64)	1.09 (0.90, 1.32)	1.01 (0.88, 1.17)	0.84 (0.67, 1.05)	1.08 (0.93, 1.24)	1.28 (1.04, 1.58)
Health status (ref= excellent to good)						
Fair/poor	1.43 (1.28, 1.59)	3.60 (3.20, 4.05)	1.54 (1.40, 1.69)	2.89 (2.59, 3.24)	1.38 (1.29, 1.48)	2.40 (2.19, 2.62)

^aReference group is no injurious fall.

CHD, coronary heart disease; CVD, cardiovascular disease; HS, high school; LTPA, leisure-time physical activity; MI, myocardial infarction; PR, prevalence ratio.

Table 3. Multivariate Poisson Regression With Robust SEs to Calculate Prevalence Ratios and Their 95% CIs for Falls Resulting in Injury Among Adults (45 and Older); 2010 Behavioral Risk Factor Surveillance Survey

Predictors	45–54 years old (n=14,639) ^a		55–64 years old (n=17,503) ^a		65 and older (n=24,591) ^a	
	One	Two or more	One	Two or more	One	Two or more
	injurious fall	injurious falls	injurious fall	injurious falls	injurious fall	injurious falls
	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
LTPA (ref=no LTPA)						
Yes, LTPA	0.88 (0.78, 0.99)	0.69 (0.58, 0.83)	0.95 (0.86, 1.05)	0.78 (0.66, 0.93)	0.95 (0.88, 1.04)	0.80 (0.66, 0.98)
Gender (ref=males)						
Females	1.36 (1.22, 1.52)	1.21 (1.02, 1.43)	1.34 (1.21, 1.47)	1.42 (1.19, 1.69)	1.33 (1.21, 1.45)	1.26 (1.02, 1.57)
Educational attainment (ref= <HS diploma)						
HS diploma	0.99 (0.82, 1.18)	0.96 (0.74, 1.23)	0.99 (0.83, 1.18)	1.11 (0.85, 1.44)	1.01 (0.89, 1.15)	1.10 (0.85, 1.43)
Some college	1.13 (0.95, 1.36)	1.24 (0.97, 1.59)	1.00 (0.84, 1.20)	1.10 (0.85, 1.43)	1.06 (0.92, 1.21)	1.10 (0.80, 1.52)
College graduate	0.98 (0.81, 1.19)	1.23 (0.93, 1.62)	0.96 (0.80, 1.16)	1.19 (0.88, 1.60)	1.08 (0.93, 1.25)	1.46 (1.08, 1.97)
Race/ethnicity (ref=white, non-Hispanic)						
Black, non-Hispanic	1.02 (0.85, 1.22)	0.87 (0.65, 1.18)	1.01 (0.86, 1.20)	0.86 (0.65, 1.13)	0.93 (0.77, 1.12)	0.76 (0.52, 1.10)
Other, non-Hispanic	1.23 (0.94, 1.62)	1.08 (0.73, 1.60)	1.28 (0.98, 1.68)	1.92 (1.30, 2.83)	0.91 (0.67, 1.22)	1.78 (1.00, 3.14)
Multiracial, non-Hispanic	1.16 (0.88, 1.51)	1.74 (1.23, 2.44)	1.30 (1.03, 1.65)	1.35 (0.91, 1.99)	1.34 (1.01, 1.79)	1.21 (0.67, 2.16)
Hispanic	1.00 (0.81, 1.24)	0.93 (0.67, 1.29)	1.11 (0.90, 1.37)	0.73 (0.51, 1.05)	1.29 (1.09, 1.52)	1.15 (0.81, 1.65)
Obesity status (ref=healthy/normal weight)						
Overweight	1.01 (0.88, 1.14)	1.15 (0.93, 1.42)	1.06 (0.94, 1.20)	0.86 (0.69, 1.08)	0.90 (0.82, 0.99)	0.93 (0.74, 1.17)
Obese	1.09 (0.96, 1.24)	1.24 (1.01, 1.53)	1.11 (0.98, 1.25)	0.94 (0.76, 1.16)	0.90 (0.81, 0.99)	1.03 (0.81, 1.29)
Marital status (ref=married/unmarried couple)						
Divorced, widowed, or separated	1.01 (0.89, 1.14)	1.02 (0.85, 1.23)	1.01 (0.90, 1.13)	1.04 (0.87, 1.26)	1.03 (0.94, 1.12)	1.02 (0.83, 1.25)
Single	0.97 (0.82, 1.15)	0.96 (0.74, 1.24)	0.95 (0.80, 1.12)	1.02 (0.77, 1.37)	0.96 (0.77, 1.19)	0.73 (0.37, 1.43)
Household income total (\$, ref= <15,000)						
15,000 to <25,000	0.71 (0.60, 0.83)	0.70 (0.56, 0.86)	0.96 (0.83, 1.11)	0.90 (0.74, 1.11)	0.87 (0.78, 0.98)	0.92 (0.70, 1.19)
25,000 to <35,000	0.69 (0.56, 0.84)	0.58 (0.43, 0.78)	0.86 (0.71, 1.04)	0.67 (0.51, 0.87)	0.88 (0.76, 1.01)	0.64 (0.47, 0.89)

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Table 3. Multivariate Poisson Regression With Robust SEs to Calculate Prevalence Ratios and Their 95% CIs for Falls Resulting in Injury Among Adults (45 and Older): 2010 Behavioral Risk Factor Surveillance Survey (*continued*)

Predictors	45–54 years old (n=14,639) ^a		55–64 years old (n=17,503) ^a		65 and older (n=24,591) ^a	
	One	Two or more	One	Two or more	One	Two or more
	injurious fall	injurious falls	injurious fall	injurious falls	injurious fall	injurious falls
	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
35,000 to <50,000	0.60 (0.48, 0.74)	0.51 (0.36, 0.71)	0.90 (0.76, 1.07)	0.64 (0.46, 0.89)	0.98 (0.84, 1.13)	0.46 (0.31, 0.69)
≥ 50,000	0.62 (0.52, 0.74)	0.35 (0.25, 0.49)	0.91 (0.77, 1.07)	0.51 (0.37, 0.69)	0.89 (0.76, 1.04)	0.52 (0.36, 0.74)
Diabetes status (ref=no diabetes)						
Yes, diabetic	0.94 (0.80, 1.09)	0.78 (0.61, 1.01)	0.92 (0.82, 1.04)	1.00 (0.83, 1.21)	1.11 (1.01, 1.22)	1.11 (0.90, 1.38)
CVD status (ref=no CVD)						
Yes, CVD (MI, CHD, or stroke)	1.12 (0.97, 1.31)	1.28 (1.06, 1.56)	1.16 (1.04, 1.30)	1.44 (1.21, 1.72)	1.07 (0.98, 1.17)	1.59 (1.31, 1.94)
Alcohol consumption (ref=not heavy drinker)						
Yes, heavy alcohol drinker	0.99 (0.80, 1.23)	0.68 (0.42, 1.10)	1.06 (0.86, 1.30)	0.92 (0.56, 1.50)	1.10 (0.90, 1.34)	1.13 (0.70, 1.84)
Health status (ref= excellent to good)						
Fair/poor	1.15 (1.01, 1.32)	3.05 (2.36, 3.94)	1.33 (1.19, 1.49)	3.14 (2.50, 3.95)	1.23 (1.13, 1.35)	2.76 (2.22, 3.44)

^aReference group is no injurious fall.

CHD, coronary heart disease; CVD, cardiovascular disease; HS, high school; LTPA, leisure-time physical activity; MI, myocardial infarction; PR, prevalence ratio.

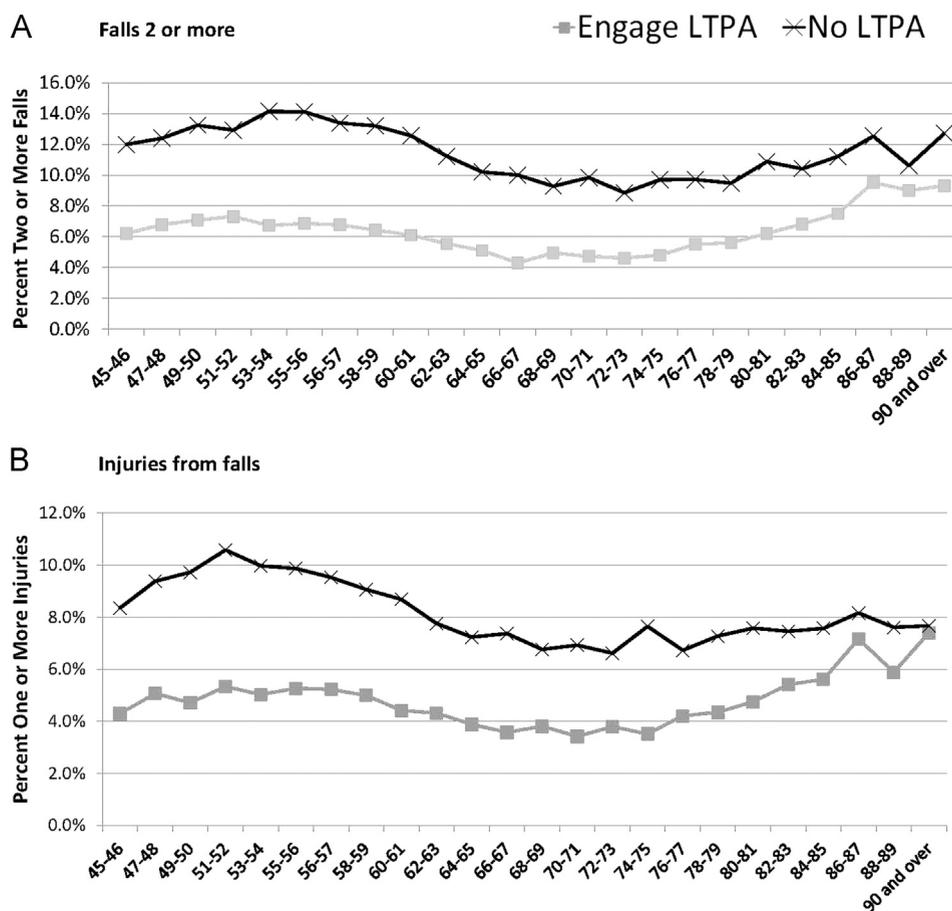


Figure 1. Percentage of adults by 2-year age groups who self-reported two or more falls (A) and percentage of adult who reported fall injuries⁴ (B) in the previous 3 months stratified by their engagement in leisure-time physical activity (i.e., engage in LTPA): 2010 Behavioral Risk Factor Surveillance Survey.

Note: The denominator includes the overall adult population over 45 years of age and not just fallers.

status were significantly associated with the risk of falls and fall-related injuries.

The results have important implications for prevention efforts in middle-aged adults. The 2010 U.S. Census reported that 81.5 million adults (26.4% of the population) were aged 45–64 years.³⁸ A 5% reduction in falls and injuries from falls in this age group would prevent the loss of approximately 20,000 DALYs in the U.S.^{8,9} Furthermore, in most developed countries, wage earnings are highest among individuals in their 40s and 50s.³⁹ Therefore, an injury and concomitant loss of income during this phase of the life course may lead to a significant economic impact at the individual level. Improved muscle strength training, balance, proprioception development, and maintenance via LTPA during middle-aged adulthood may be carried over when the individual gets older, and it may also aid in the reduction of falls and fall-related injuries in older adulthood.

We also observed strong relationships between demographic and health-related factors and the risk of falls

and fall-related injuries. Several prior studies have reported female gender to be associated with a higher risk of falls and fall-related injuries.^{40–42} In this study, female gender was associated with a higher risk of fall-related injuries among both the middle-aged and older adult groups. Other risk factors for falls and fall-related injuries were also similar among middle-aged and older adults, including higher household income, which was protective against falls and injuries resulting from a fall. Other studies have documented an inverse relationship between income and falls.⁴³ Lower household income is associated with poorer living environments, poor health behaviors, and barriers to healthcare services, which may in turn affect health status and increase the risk of falling.⁴⁴

Among health-related factors, cardiovascular disease and self-reported health were associated with falls and fall-related injuries in all three age groups. The apparent higher risk of falls and injurious falls among middle-aged and older adults with cardiovascular disease and self-reported health

status is consistent with studies of falls among older adults with multimorbidity.⁴⁵ Alcohol consumption was associated with increased risk of falls but not fall-related injuries. However, the association between alcohol use, even in moderation, and injury in the general population is well established. For example, a study of more than 19,500 adults in Finland found a positive association between alcohol use and risk of injurious falls, strongest in younger adults.⁴⁶ More research is needed to better understand the relationships between demographic and health-related factors on the risk of falling and fall-related injuries among middle-aged and older adults.

Strengths and Limitations

This study adds to the literature as the first to examine associations between LTPA and self-reported falls and fall-related injuries among middle-aged adults using recent population-based data across multiple U.S. states. The relatively large and nationally representative sample of participants in the BRFSS provides good external generalizability to the experience of the U.S. population. We do note some important limitations of this study. First, the cross-sectional design does not allow assessment of the temporal relationship. Future studies need to examine the effect of LTPA on the future risk of falls and fall-related injuries among middle-aged adults.

Because the BRFSS is a telephone-based survey and the response rate is approximately 54%, there is the possibility of selection bias. In addition, the BRFSS questions related to falls had a 3-month recall period. The recall period could affect the reported prevalence of falls and fall-related injuries. The Prevention of Falls Network Europe recommendations regarding fall data collection include prospective daily recording and a notification system with a minimum of monthly reporting.⁴⁷ Nonetheless, information on LTPA was asked before the fall and injury history was taken among participants of the BRFSS, which may limit the differential recall of LTPA by fall experience. Lastly, the definition of LTPA was based on self-report, and we did not have objectively measured data on the physical activity levels obtained from either work or leisure time. Owing to the limited information available on individual participant LTPA levels, the amount of LTPA needed to reduce the risk of falls and fall-related injuries could not be assessed in this study. Thus, the findings from this study warrant replication using more-detailed objective measures on LTPA.

Conclusions

There are well-established relationships between physical activity and fall prevention in the geriatric literature.^{48,49}

However, the present findings suggest that engagement in LTPA is associated with lower reporting of falls and fall-related injuries among middle-aged adults (aged 45–64 years). This finding is particularly encouraging given the increasing knowledge of the positive effects that regular physical exercise has on other chronic health conditions. The public health impact of physical activity on falls and injury-related falls is particularly important within this critical segment of the U.S. population in terms of primary and secondary prevention efforts. Providers may now offer an additional positive benefit when encouraging middle-aged adults to remain physically active during their leisure time. Replicating this finding and exploring this protective association further can be achieved by including measures of falls and fall-related injuries in future physical activity interventions.

AJC-M, TKC, and SKV had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. This work was supported by the Liberty Mutual Research Institute for Safety and, from the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), grant T32 AR055885 (principal investigator, Katz) to the Clinical Orthopedic and Musculoskeletal Education and Training Program at Brigham and Women's Hospital, Harvard Medical School, and Harvard T.H. Chan School of Public Health (Trainee, AJC-M). The authors would like to thank Mr. Ray McGorry and Dr. Mary Lesch, who reviewed earlier drafts of this manuscript, for their insightful comments.

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