Physical Activity Program Participation and the Risk of Falls for Older Group Health Members

Mikael Anne Greenwood-Hickman

A thesis

Submitted in partial fulfillment of the

Requirements of the degree of

Master of Public Health

University of Washington

2014

Committee:

Annette L. Fitzpatrick

Dori Rosenberg

Elizabeth Phelan

Program Authorized to Offer Degree:

Public Health—Epidemiology

University of Washington

Abstract

Physical Activity Program Participation and the Risk of Falls for Older Group Health Members

Mikael Anne Greenwood-Hickman

Chair of the Supervisory Committee:
Annette L. Fitzpatrick
Epidemiology

Introduction: Falls are one of the biggest health concerns for aging adults. Despite evidence suggesting the importance of regular physical activity (PA) for reducing fall risk, few older adults engage in fall-prevention-oriented exercise. Regular PA through exercise programs offered as a Medicare or health-plan-covered benefit may be one method to increase PA and reduce fall risk. Here we investigate the effectiveness of participating in EnhanceFitness (EF) and Silver Sneakers (SS), two nationally-disseminated senior exercise programs, in reducing risk of falls resulting in medical care.

Methods: A population-based, retrospective cohort study was conducted using data from Group Health Cooperative (GHC) members over age 65. Participants were classified as consistent users (having used EF/SS 2 or more times each year they were enrolled in GHC during the study period [2005-2011]); intermittent users (having used EF/SS two or more times in one or more years they were enrolled in GHC during the study period but not all years), or non-users of the

EF/SS. A time-to-first fall requiring medical treatment (identified via ICD-9 code and E-codes in the medical record) analysis using Cox proportional hazards models was used for both programs to generate hazard ratios (HR) comparing consistent and intermittent users with non-users of either program. Hierarchical adjustment was used to address confounding by demographic characteristics and comorbidities (measured by ICD-9 codes in electronic health records).

Results: In fully adjusted models, there was evidence of a dose-response relationship between EF participation and decreased fall risk compared to non-users (consistent EF user HR= 0.75, 95% CI = 0.64-0.89 and intermittent EF user HR = 0.87, 95% CI = 0.80-0.94). Participation in SS was not significantly associated with a decrease in risk for consistent users (HR= 0.97, 95% CI = 0.90-1.04), but a small significant reduction in risk was seen for intermittent users (HR= 0.93 95% CI= 0.90-0.97). Analyses evaluating effect modification showed that SS use was related to significantly lower fall risk among individuals over age 75 or with a BMI of 28 or below.

Conclusion: Participation in EF provides a protective effect against falls resulting in medical care, with an indication of a dose-response relationship wherein this effect is strongest for consistent users. Results are less clear for SS participation, suggesting a small protective effect against medical falls for consistent and intermittent users that is potentially stronger for older and lower-BMI users.

Background

Falls are one of the biggest health concerns for many aging adults, affecting at least 30-40% of community-living adults over the age of 70 every year and often resulting in serious injury with major impacts on morbidity, mortality, and healthcare costs [1]. One study suggests that experiencing a fall that requires hospitalization can lead to higher health costs for the individual up to a year after the fall [2]. For many older adults (age 65 and above), fear of falls and their potential physical and psychological consequences are a serious concern, often acting as a major barrier to physical activity (PA) and leading to self-imposed activity restrictions [3, 4]. However, fall prevention research suggests that low PA increases an individual's risk of falling and being injured, rather than reducing it.

A failure to engage in regular PA tends to lead to increased weakness and poorer balance, substantially increasing fall risk [5]. Consequently, the recommendation to regularly engage in PA is a cornerstone of fall prevention, and much evidence suggests that older adults following PA recommendations are less likely to experience a serious fall and many other negative health outcomes [5, 6]. For example, a randomized controlled trial conducted among older women in Japan showed that women participating in a regular community exercise program experienced improvements in several gait and balance measures as well as markedly fewer falls than the control group [7].

Participation in community exercise programs can be a reliable way for older adults to incorporate regular PA into their routine. Within the Group Health Cooperative (GHC), Medicare-qualifying adult members age 65 and above are eligible to participate in two different nationally disseminated exercise programs at no additional cost: EnhanceFitness (EF), which offers regularly scheduled group fitness classes led by qualified instructors, and Silver Sneakers

(SS), which gives participants full membership to participating fitness centers [8, 9]. While previous investigations have suggested that similar community-based exercise programs can be effective for fall prevention [7, 10] and that the EF program successfully leads to improved physical performance in its participants [11, 12], no previous investigation has sought to directly connect participation in EF or SS to a reduced risk of falling or fall-related injury [13]. Our objective was to understand the relationship between EF and SS participation and risk for having a "medical fall," or a fall requiring medical treatment, in a sample of Group Health Medicare HMO plan enrollees between 2005 and 2011 using electronic health record data. Based on existing evidence of the important role of physical activity in fall prevention, it was hypothesized that consistent users of both programs would have the lowest risk of a medical fall, with intermittent users experiencing a marginal reduction in fall risk when compared to non-users.

Secondarily, we investigated whether users of EF were less likely to experience a fall resulting in medical care compared to users of SS. EF is a structured program that includes strength and balance exercises necessary for fall risk reduction [10, 14, 15], while SS is an unstructured membership benefit in which users can participate in classes or use gym equipment with their membership. Therefore, it was hypothesized that EF users would experience a greater reduction in medical falls than users of SS when compared to each other.

Methods

A population-based retrospective cohort study was conducted in which the exposure of interest was defined as participation in either the EF or SS program and the outcome was defined as the first occurrence of a medical fall during the study time period (2005-2011).

Study Subjects

Subjects were members over age 65 of Group Health Cooperative (GHC), which serves patients throughout the states of Washington and Northern Idaho. All subjects were members of the Group Health Integrated Group Practice, receiving medical care primarily within the GHC system. Subjects were selected using the following eligibility criteria: Group Health Integrated Group Practice members, continuous enrollment in GHC for at least one year, between the ages of 65 and 98, and eligible for the Medicare EF and/or SS programs for some portion of 2005-2011. In an effort to maintain a sample representative of the population of potential PA program users, individuals were excluded if they met any of the following specific criteria: residing in long-term care or nursing home setting, receiving hospice care (ICD-9 code V66.7), wheelchair-bound (ICD-9 V46 or V53.8), age 99 or over, or having a diagnosis of a serious mental health or substance use disorder (ICD-9 290-319.99, not including depression [296.2, 296.3, 300.4, 311] anxiety [300.02], or dementia [290]).

Data

All data for this investigation were previously collected by investigators at the Group Health Research Institute (GHRI), the research division of GHC. All demographic, health, and medical record data were extracted from GHC warehouse records and merged with participation data supplied by EF and SS programs for the years of 2005 to 2011.

Physical Activity Programs

EF is a nationally disseminated, evidence-based exercise program for older adults offering group-based exercise classes in a wide array of community settings. Classes are offered in more than 50 sites throughout Western Washington. Each class is one hour long and follows a set format including exercises that target cardiovascular endurance (20-25 minutes), strength (20 minutes), balance, and flexibility (10 minutes), all of which are highly adaptable to individual ability level [8, 16]. In the 12 month period prior to May 2010, 6,939 individuals attended at least 10 EF classes nationwide [16].

SS is a benefit offered to Medicare Advantage enrollees that allows access to more than 10,000 fitness facilities nationwide. Participants are essentially regular gym members and are given access to exercise equipment and group exercise classes offered through the selected fitness centers. Additionally, SS offers an older adult fitness class that participants may choose to attend [9].

Exposure Assessment

Participation in either program was defined as documentation of attendance at either the EF or SS programs at least twice in a given year. Because specific attendance counts were not available in the dataset, participation in the EF and SS programs was stratified into three levels in an effort to approximate more regular exposure to the programs. These strata were: consistent users, who participated every year they were enrolled in GHC during the study period (2005-2011); intermittent users, who participated at least one but not all years they were enrolled; and non-users, who never participated in either program while enrolled.

Outcome Assessment

While any fall is of concern, only those resulting in medical treatment were investigated here. Falls requiring medical treatment were identified through the use of both inpatient and out-patient recording of ICD-9 codes (805-829: fractures, including hip fracture; 830-839: joint dislocations; and 800-804 & 850-854: intracranial injury) and E-codes (880-888: accidental fall injury) indicating medical treatment for an injury highly related to having had a fall [17]. Either an E-code or one of the listed ICD-9 codes was necessary to define a study outcome consistent with definitions developed in previous research [2, 18].

Covariates

The following covariates were extracted from electronic health record data of both inpatient and outpatient treatment in the GHC system and were assessed as potential confounders to the relationship of interest (i.e. the relationship between PA program participation and risk of a medical fall): age (continuous), sex (male/female), race/ethnicity (white, black, Asian, Hispanic, Native American), body mass index (BMI, kg/m^2, calculated from most recent height and weight for each year; continuous), smoking status (yes/no), and Charlson Comorbidity Index score [19], a general measure of co-morbidity based on the presence or absence of 19 conditions weighted for severity (continuous). Because of their strong association with increased fall risk, an indicator of the use of sedatives and/or sleeping medications was also included (benzodiazepines and prescription sleep medications; yes/no) The following comorbidities were identified through ICD-9 codes in the medical record and were also included in the analysis to account for their potentially confounding relationship with program participation and risk of a medical fall: diabetes status (249-251; yes/no); diagnosis of dementia (290, 294.1, 294.2, 331.0, 331.1, 331.82, 331.83; yes/no), walking disorder (719.7: difficulty walking, 781.2: abnormal gait, and 728.87: generalized weakness; yes/no), osteoarthritis (715, 721.0-721.9; yes/no), osteoporosis (733; yes/no), musculoskeletal conditions (712-719: arthropathy, rheumatoid arthritis, joint derangement; yes/no), and visual impairment (365: glaucoma; 366: cataract; 362.50-362.53, 362.55, 362.63: macular degeneration; and 362.01-362.03, 362.10, 362.11, 362.2, 363.31: retinopathy; yes/no). All comorbidity diagnosis variables were time-varying and constructed to reference a diagnosis for the given condition in the year prior to the year of interest.

Data Analysis

A time-to-event analysis was conducted using days between entry into the study and the date of a fall, loss to follow-up or the end of the study period (December 31, 2011). Individuals were censored if loss to follow-up occurred due to death or withdrawal from the GHC system. Specific dates for these events were unavailable and therefore defined as June 30 of the last year an individual appeared in the data set if that year was prior to 2011. A series of Cox Proportional Hazard models compared time-to-fall of non-users to that of consistent and intermittent users of each program. We conducted a series of models for both EF and SS: a crude model (no adjustment for confounders), a demographic model (adjusted for age, race, and sex), and a full model (adjusted for age, race, sex, BMI, smoking, and the following comorbidities: dementia, walking disorder, osteoarthritis, osteoporosis, musculoskeletal conditions, and visual impairment).

Interaction terms between fitness program participation and age, sex, and BMI, respectively, were calculated and fit in the demographic models for EF and SS to test for effect modification by these variables. If an interaction term yielded a p value <0.05, it was considered a significant effect modifier, and all subsequent hazard estimates were stratified upon the effect modifier.

Sensitivity analyses were performed to ascertain the effect of dementia, osteoporosis, osteoarthritis, walking disorders, and diabetes on the observed HRs for a medical fall. The sample was stratified upon the given comorbidity and the primary analysis was repeated for each stratum. Where sample size was sufficient for interpretation (all groups containing >50 individuals after stratification), differences in effect between the strata were noted for later discussion.

The same modeling approach was used to address the secondary aim investigating differences in fall risk exclusively among program participants through models comparing each group of PA program participants to intermittent SS users hypothesized to be the lowest level of participation. Specifically, crude, demographic, and full models were fit as described above. No interaction was evaluated within strata.

Results

Compared to non-users, users of both PA programs, whether consistent or intermittent, were more likely to be female, where EF users were more likely to be female than both SS users and non-users (Table 1). Both consistent and intermittent users of EF and SS were also less likely to be smokers and tended to have lower Charlson comorbidity scores than did non-users. However, for certain fall-related comorbidities, users of EF and SS were more likely to have had a diagnosis for osteoarthritis, osteoporosis, visual impairment, and musculoskeletal conditions during the study period. Consistent users of both EF and SS were less likely to use sedatives or sleeping medications compared to non-users and intermittent users of either program.

Initially, Kaplan-Meier survival curves were fit in order to generate a graphical depiction of time-to-medical fall for each group. Figure 1a shows consistent and intermittent EF users compared to non-users. This figure suggests that consistent EF users had the highest proportion of the sample remaining without a medical fall at the end of the study period, followed by intermittent EF users, and, finally, non-users who had the smallest remaining proportion without a medical fall. Figure 1b shows consistent and intermittent SS users against non-users. Both SS groups had very similar curves with a larger remaining proportion of the population without a medical fall than the non-user group.

In the primary set of analyses, both consistent and intermittent users of EF were compared to non-users of either PA program using a series of hierarchically adjusted Cox regression models (Table 2). Specifically, the demographic model yielded a decreased risk of medical fall for both consistent and intermittent users of EF (Hazard Ratio [HR] = 0.71, 95% confidence interval [CI] = 0.60-0.84; HR = 0.84, 95% CI = 0.77- 0.91, respectively). In the full model, the same pattern remained, suggesting consistent EF users had a significantly decreased risk of a medical fall compared to non-users (HR= 0.74, 95% CI = 0.63-0.88) and intermittent EF users also had a significant, but smaller decreased risk (HR = 0.87, 95% CI = 0.80-0.94). Interaction-term beta coefficients for models fit with interaction terms between participation and sex, age, and BMI, respectively, were all insignificant ($p > 0.42$), providing no evidence for effect modification by any of these variables (data not shown).

Table 2 also shows results of models comparing consistent and intermittent users of SS compared to non-users. The demographic model suggested a small significant reduction for consistent and intermittent users (HR= 0.93, 95% CI = 0.87-0.99; HR=0.92, 95% CI = 0.88-0.95, respectively). The full model yielded similar results for intermittent SS users showing a 7% decrease in fall risk compared to non-users. However, this relationship was no longer significant for the consistent SS group after adjustment for lifestyle factors and comorbidities (HR= 0.95, 95% CI = 0.89-1.02). As with the EF analysis, models with interaction terms between SS participation and age, sex, and BMI, respectively, were fit to the data. There was no indication of an interaction with sex, but beta coefficients for the age-participation and BMI-participation terms were significant (data not shown).

To explore the significant interactions, the SS data were stratified by the sample's mean age and BMI, respectively, and models were fit for each (Table 3). The findings suggested that individuals above the age of 75 had a reduced risk of medical falls associated with consistent and intermittent SS use (HR= 0.85, 95% CI = 0.76-0.95); HR= 0.89, 95% CI= 0.85-0.95, respectively), whereas SS participation by those ≤75 had no reduction in risk of a medical fall (HR = 0.99, 95% CI = 0.90-1.10; HR = 0.97, 95% CI = 0.91-1.03, respectively). Similarly, consistent and intermittent SS users with a BMI of 28 or lower had a reduced risk of medical falls compared to non-users (HR= 0.86, 95% CI = 0.78-0.94; HR= 0.90, 95% CI= 0.86-0.95, respectively) while consistent and intermittent SS users with a BMI above 28 did not (HR= 1.07 95% CI= 0.95, 1.20; HR= 0.94 95% CI= 0.89-1.00).

A secondary analysis exclusively among the fitness program users compared the associations of fall risk for EF users to that of SS users (Table 4). Intermittent SS users, the group hypothesized to experience the smallest reduction in medical fall risk, served as the comparison group. After full adjustment, relative to the intermittent SS users, both intermittent EF users and consistent SS users experienced approximately the same level of risk reduction (Intermittent EF HR= 1.00 95% CI= 0.91-1.11; Consistent SS HR= 1.02 95% CI= 0.94-1.10). After adjustment for demographics, consistent EF users, however, experienced a decrease in risk compared to the intermittent SS users (HR= 0.81 95% CI= 0.67-0.98), though the association was attenuated after complete adjustment in the full model (HR= 0.83 95% CI= 0.69-1.00).

A series of analyses were performed to examine the sensitivity of these models based on prevalence of the following comorbidities: dementia, osteoporosis, osteoarthritis, walking disorders, and diabetes. For dementia, osteoporosis, and walking disorders, when stratified upon the baseline comorbidity of interest, the resulting sample size was too small (≤50 individuals) in certain strata to draw meaningful conclusions (data not shown). When stratified by osteoarthritis status (Table 5), analysis results suggested that consistent use of SS may be more meaningful to medical fall risk reduction for individuals with osteoarthritis than for individuals without. Similarly, there was some indication that any use of the EF program may have a slightly greater impact on fall risk for individuals with diabetes than for those without (Table 6).

Discussion

The results of these analyses suggest that any use of the EF program, whether consistent or intermittent, has a beneficial effect, decreasing risk of medical falls for participants in this sample. Consistent use, which serves as a proxy for regular participation in the program over several years, has the strongest impact, lowering medical fall risk between 20 and 30%. However, these results suggest that even occasional use of the EF program may decrease medical fall risk by 10 to 20% compared to non-participation. Furthermore, the reduction in medical fall risk from consistent EF participation may be even larger among individuals with osteoarthritis and diabetes.

The results are less clear for the impact of the use of the SS program. Both the intermittent and consistent SS groups experienced a 5 to 10% reduction in medical fall risk in some models. However, this apparent reduction loses significance in the consistent SS users, but not in the intermittent SS users, after full adjustment for comorbidities. While this effect may be due to a substantially larger sample size in the intermittent SS group, the indication of effect modification by age and BMI suggest that something else may be responsible for the inconsistent relationships in the SS group.

Among both consistent and intermittent SS users, SS participation appeared to have a larger effect for both older individuals (those over age 75) and those with a BMI of 28 or below, but relatively little effect for individuals age 75 and younger or with a BMI above 28. In the case of the age effect, it is hypothesized that the effect of SS participation may not be strong enough to be detectable until individuals are older and at a higher risk for medical falls [20], at which point the program's protective effects come into play more strongly. Alternatively, it is also possible that older SS participants are simply more likely to be the most frequent and long-term users, leading to a reduction in medical fall risk such that long-term PA participation would confer. Older SS participants may also be healthier than those that do not participate at this age due to a survival effect that may not be completely controlled by covariates. The younger users, however, are a more diverse group in which the program's impact is masked by more short-term participating individuals receiving less effect. In terms of BMI, some evidence suggests that obesity, while increasing the risk of a fall itself, may reduce the risk of fall related injury [21], the outcome investigated here. As such, it is possible that the protective impacts of SS participation are masked by the reduced risk of fall injury from being overweight or obese. It is also possible that the higher BMI individuals, who tend to have more comorbidities, may use the program with lower frequency, decreasing their program exposure and making it less likely to have a detectable impact. Lower BMI has also been shown to increase the risk of a serious injury from a fall [22]; our data would be consistent with this. In any case, the effect modification of age and BMI merit finer inspection to fully understand the impact of SS participation on fall risk.

Results from the EF analyses reliably demonstrate that consistent EF users had a greater reduction in medical fall risk compared to intermittent EF users. This result suggests that there may be some level of a dose-response relationship, wherein greater use of the EF program leads to larger reductions in risk. This would suggest that a causal relationship between EF participation and reduced risk of a medical fall is plausible, which would corroborate previous evidence suggesting that strength and balance exercises, which are major components of the EF program, are essential to reducing fall and fall injury risk in older adults [5, 6, 23]. Furthermore, these results suggest that even smaller doses (intermittent use) of the EF program lead to significant impacts on fall risk. More broadly, this would suggest that even intermittent PA may have a significant effect on the health and well-being of older adults. This is similar to other research showing dose-response relationships between engagement in PA and health outcomes [24-26]. However, due to the inability to measure participation in EF more precisely in these analyses, the observed dose-response relationship cannot be firmly asserted. In future analyses, the use of continuous participation data, that can more accurately quantify and classify the number of classes in which individuals participated, may allow for the further exploration of this hypothesis.

Additionally, using the current participation classification strategy to compare all fitness program users to each other, the results suggest a very similar level of risk reduction for all participant groups other than the consistent EF group. In other words, consistent participation in the EF program provides approximately 15% additional reduction in fall risk compared to intermittent EF use or any use pattern of SS, which all provide relatively equivalent risk reduction. Given the different nature of the two programs, it is somewhat surprising that intermittent use of EF would have an equivalent impact to both consistent and intermittent use of SS. As such, consideration much be given to why this pattern is seen. It is possible that this effect could simply be credited to the design of the EF program, which includes strength and balance exercises that would be expected to reduce fall risk if practiced regularly. Inconsistent practice of this strength and balance training (i.e., intermittent EF use) simply may not confer the same level of protective benefit, yielding an impact more in line with the use, consistent or otherwise, of SS, which has no structured incorporation of strength and balance exercise. Or, perhaps some of the reduction in risk observed in all groups results from the type of people in that group rather than the participation in the PA program itself. Specifically, perhaps people that are willing to try an exercise program, even inconsistently, are more likely to try a variety of PA activities and be more active in general. If that is the case, this could account for the roughly equivalent reduction in risk seen in the SS groups and intermittent EF group, and the additional reduction seen only for consistent EF could be assumed to be due to the targeted benefits of the program itself, – i.e., the assurance of routine practice of strength and balance exercise. However, as it is not possible to quantify exactly how many times participants used the fitness programs each week/month, findings here may also be related to measurement error.

As previously mentioned, a small decrease in risk of medical falls was seen for SS users (approximately the same for consistent and intermittent users), with a suggestion that older users (>75) and users with a lower BMI (<28) may see even more benefit. However, even within these subgroups with a stronger effect, SS does not appear to be as effective in targeting medical fall risk reduction as the EF program. This can be explained by a combination of contributing factors. First, EF is a much more structured, regular program that includes the balance and strength exercises that research suggests are critical to reducing fall risk [14]. Because of the free-form nature of the SS program, we know very little about the type or intensity of each session, likely meaning that a wide variety of PA exists within the sample—very little of which likely focuses on the balance exercise essential to fall prevention, even among the most regular SS users. With the EF program, this is not the case, as each session follows a set pattern and duration, eliminating this as a source of variation.

Secondly, because of its routinely offered classes and strong social environment, regular attendance at the EF program over many years is common. Users of the more free-form and independently-driven SS program may be more likely to come and go in its use. Aggregate use statistics for this sample in 2011 support this differential attendance pattern. EF users had a mean attendance of 65 times in the year with a median of 67, whereas SS users' mean attendance is 51 times in 2011 with a median of 33. This suggests not only that EF users tend to use the program more frequently, but also that the use pattern in the sample is more normally distributed where the SS users may have a few very frequent users skewing the mean use statistic. This difference in usage pattern may make the consistent and intermittent categories used in these analyses more problematic for SS. The consistent category would be less likely to strongly parallel regular use, thus making it more likely to wash out the effects that regular use may have. In short, while these results suggest that the EF program is more successful in reducing medical fall risk for this population, it must be acknowledged that the nature of SS makes it more challenging to assess, and it is possible that, if used in a certain manner, SS could be equally effective in reducing fall risk as the EF program has been shown to be.

This study has several limitations. First, the focus is only on falls resulting in injury and subsequent medical care, as these appear in the inpatient or outpatient medical record and so made it possible to measure frequency of this fall-related outcome. However, while these were the only falls that could be assessed without self-report, this outcome definition may exclude less-severe falls for which people do not seek medical attention. Furthermore, some falls may still be missed in this analysis if an injury is truly due to a fall but is not reported as such in the medical record. Despite this, falls resulting in medical care are of high priority for risk reduction efforts given their adverse personal [27, 28] and societal effects [29].

Similarly, missing data on certain individuals can greatly hinder data analysis. While missing data was not an issue for the outcome of interest—medical falls— some missingness existed for certain covariates, primarily race and BMI. While it was deemed that the proportion of missing values was not large enough for these variables to be hugely problematic to the interpretation of analysis results, we know nothing about the status of these variables for the individuals lacking this data. Considering that these covariates were included in the analysis because of their potential association with the risk of a fall requiring medical attention, lacking this information in the analysis could substantially impact the results, particularly if missingness is somehow associated with the likelihood of either EF or SS participation or a medical fall.

Additionally, participation in EF and SS is voluntary and, therefore, inherently self-selected. It is possible that those individuals who choose to participate in these PA programs are systematically different from those who do not participate in ways that may impact their fall risk. Though appropriate adjustments for potentially confounding variables were made in the analysis to correct for this possibility, there is still the potential for residual confounding to remain, skewing the estimate. Furthermore, we use attendance at these programs as a proxy for PA. While regularly attending these programs would imply regular PA, we have no measure of type or intensity of PA. Additionally, the threshold for "participation" is only 2 uses in a year, which is far from being indicative of regular PA through these programs. Because of this, this study will be able only to draw conclusions about the effects of attending these PA programs 2 or more times per year and will be unable to firmly connect this to a particular threshold of necessary physical activity necessary for the observed impact on fall risk.

Despite these limitations, this study has several strengths. First, all outcomes and comorbidities were based upon ICD-9 codes in the medical record rather than self-report. This greatly reduces the potential for misclassification of comorbidity and outcome status, lending itself to a higher degree of accuracy in risk estimates. Additionally, these analyses are based upon a large, population-based sample, increasing power to detect associations and maximizing the generalizability of findings.

A great deal of evidence supports an array of physiological and psychological benefits to evidence-based, nationally disseminated community-based PA programs like EF and SS. For instance, various studies demonstrated reduced weight, blood pressure and risk of depression with participation in Active Living Everyday and Fit & Strong!, two other such community programs that were not developed specifically for fall prevention [30-32]. However, evidence on the reduction of falls due to participation in these programs is limited, and this is the first study to directly investigate the impact of two non-fall specific exercise programs (EF and SS participation) on the risk for a medical fall. Furthermore, the relatively low cut-point of program use employed in this investigation is likely to include less frequent users in the highest use category (the consistent users), minimizing the exposure of the group as a whole. This type of exposure misclassification would be expected to minimize any present association, rather than inflate it. While a continuous measure of the number of times each individual used each program (potentially in combination with a measure of intensity of each use) would optimize the ability to draw conclusions, finding a significant effect using this exposure definition provides strong evidence that participation in these programs, particularly EF, has a significant impact on fall risk of at least the magnitude reported here, if not greater.

Conclusions

The results of this analysis provide evidence that participation in EF is associated with a reduced risk of falls resulting in medical care. This protective effect appeared to have a dose-response relationship, with the strongest effect for consistent users of the program. Participation in SS may also provide a moderate degree of protection, particularly for older individuals and those with a lower BMI. While the evidence for reduced risk of a medical fall is strong for the EF program, the results of this analysis also more generally emphasize the importance of any participation in a PA program. Even the intermittent users of both SS and EF showed some reduction in medical fall risk, suggesting that even infrequent or sporadic use of these programs may have an impact, which may be essential for older adults who are more frail or deal with chronic illnesses that make regular PA challenging. It should be emphasized to the older adult community that even if PA is somewhat sporadic due to illness or other factors, they should not get discouraged but rather, aim to continue their PA as frequently as possible. Furthermore, these results suggest that the decreased risk for a medical fall may be amplified for sufferers of certain chronic illnesses, like osteoarthritis and diabetes, who are at a greater risk for fall and often find it challenging to engage in regular PA [33-35]. Together, these results suggest that evidence-based PA programs, particularly EF, should be more widely disseminated into communities not only for their general effects on fitness but also in recognition of their likely benefits on prevention of fall injuries.

References

1. Hausdorff, J.M., D.A. Rios, and H.K. Edelberg, *Gait variability and fall risk in community-living older adults: a 1-year prospective study.* Arch Phys Med Rehabil, 2001. **82**(8): p. 1050-6.
2. Bohl, A.A., et al., *A longitudinal analysis of total 3-year healthcare costs for older adults who experience a fall requiring medical care.* J Am Geriatr Soc, 2010. **58**(5): p. 853-60.
3. Bethancourt, H.J., et al., *Barriers to and Facilitators of Physical Activity Program Use Among Older Adults.* Clin Med Res, 2014.
4. Yardley, L. and H. Smith, *A prospective study of the relationship between feared consequences of falling and avoidance of activity in community-living older people.* Gerontologist, 2002. **42**(1): p. 17-23.
5. American College of Sports, M., et al., *American College of Sports Medicine position stand. Exercise and physical activity for older adults.* Med Sci Sports Exerc, 2009. **41**(7): p. 1510-30.
6. Bird, M.L., et al., *Age-related changes in physical fall risk factors: results from a 3 year follow-up of community dwelling older adults in Tasmania, Australia.* Int J Environ Res Public Health, 2013. **10**(11): p. 5989-97.
7. Suzuki, T., et al., *Randomized controlled trial of exercise intervention for the prevention of falls in community-dwelling elderly Japanese women.* J Bone Miner Metab, 2004. **22**(6): p. 602-11.
8. *Enhance: What is EnhanceFitness?* 2013 [cited 2014 Feb 19]; Available from: http://www.projectenhance.org/enhancefitness.aspx.
9. *Healthways Silver Sneakers: what is the Silver Sneakers fitness program?* 2014 [cited 2014 Feb 19]; Available from: http://www.silversneakers.com/TellMeEverything/WhatisSilverSneakers.aspx
10. Franco, M.R., L.S. Pereira, and P.H. Ferreira, *Exercise interventions for preventing falls in older people living in the community.* Br J Sports Med, 2014. **48**(10): p. 867-8.
11. Belza, B., et al., *The effects of a community-based exercise program on function and health in older adults: the EnhanceFitness program.* J App Gerontology, 2006. **25**(4): p. 291-306.
12. Tomioka, M., N. Sugihara, and K.L. Braun, *Replicating the EnhanceFitness physical activity program in Hawai`i's multicultural population, 2007-2010.* Prev Chronic Dis, 2012. **9**: p. E74.
13. Yoon, P.W., et al., *Potentially preventable deaths from the five leading causes of death - United States, 2008-2010.* MMWR Morb Mortal Wkly Rep, 2014. **63**(17): p. 369-74.
14. *AoA Evidence-Based Prevention Program.* , A.o.A. US Department of Health & Human Services, Editor 2010: Washington D.C.
15. Liu-Ambrose, T., et al., *Otago home-based strength and balance retraining improves executive functioning in older fallers: a randomized controlled trial.* J Am Geriatr Soc, 2008. **56**(10): p. 1821-30.
16. Belza, B., et al., *EnhanceFitness, an innovative community-based senior exercise program. .* Topics in Geriatric Rehabilitation, 2010. **26**(4): p. 299-309.
17. Tinetti, M.E., et al., *Effect of dissemination of evidence in reducing injuries from falls.* N Engl J Med, 2008. **359**(3): p. 252-61.
18. Bohl, A.A., et al., *How are the costs of care for medical falls distributed? The costs of medical falls by component of cost, timing, and injury severity.* Gerontologist, 2012. **52**(5): p. 664-75.
19. Charlson, M.E., et al., *A new method of classifying prognostic comorbidity in longitudinal studies: development and validation.* J Chronic Dis, 1987. **40**(5): p. 373-83.
20. Owens, P.L., et al., *Emergency Department Visits for Injurious Falls among the Elderly, 2006: Statistical Brief #80*, in *Healthcare Cost and Utilization Project (HCUP) Statistical Briefs*. 2006: Rockville (MD).

21. Himes, C.L. and S.L. Reynolds, *Effect of obesity on falls, injury, and disability.* J Am Geriatr Soc, 2012. **60**(1): p. 124-9.
22. Tinetti, M.E., J.T. Doucette, and E.B. Claus, *The contribution of predisposing and situational risk factors to serious fall injuries.* J Am Geriatr Soc, 1995. **43**(11): p. 1207-13.
23. El-Khoury, F., et al., *The effect of fall prevention exercise programmes on fall induced injuries in community dwelling older adults: systematic review and meta-analysis of randomised controlled trials.* BMJ, 2013. **347**: p. f6234.
24. Dondzila, C., et al., *Dose-Response Walking Activity and Physical Function in Older Adults.* J Aging Phys Act, 2014.
25. Foulds, H.J., et al., *Exercise volume and intensity: a dose-response relationship with health benefits.* Eur J Appl Physiol, 2014.
26. Ewald, B., J. Attia, and P. McElduff, *How many steps are enough? Dose-response curves for pedometer steps and multiple health markers in a community-based sample of older australians.* J Phys Act Health, 2014. **11**(3): p. 509-18.
27. Hartholt, K.A., et al., *Societal consequences of falls in the older population: injuries, healthcare costs, and long-term reduced quality of life.* J Trauma, 2011. **71**(3): p. 748-53.
28. Gill, T.M., et al., *The course of disability before and after a serious fall injury.* JAMA Intern Med, 2013. **173**(19): p. 1780-6.
29. Bishop, C.E., et al., *Medicare spending for injured elders: are there opportunities for savings?* Health Aff (Millwood), 2002. **21**(6): p. 215-23.
30. King, A.C., et al., *Effects of moderate-intensity exercise on physiological, behavioral, and emotional responses to family caregiving: a randomized controlled trial.* J Gerontol A Biol Sci Med Sci, 2002. **57**(1): p. M26-36.
31. Wallace, J.I., et al., *Implementation and effectiveness of a community-based health promotion program for older adults.* J Gerontol A Biol Sci Med Sci, 1998. **53**(4): p. M301-6.
32. Dunn, A.L., et al., *Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: a randomized trial.* JAMA, 1999. **281**(4): p. 327-34.
33. Khalaj, N., et al., *Balance and risk of fall in individuals with bilateral mild and moderate knee osteoarthritis.* PLoS One, 2014. **9**(3): p. e92270.
34. Yau, R.K., et al., *Diabetes and risk of hospitalized fall injury among older adults.* Diabetes Care, 2013. **36**(12): p. 3985-91.
35. Hermsen, L.A., et al., *Frequency, severity and determinants of functional limitations in older adults with joint pain and comorbidity: Results of a cross-sectional study.* Arch Gerontol Geriatr, 2014. **59**(1): p. 98-106.

Table1: Demographic characteristics of EF/SS Users and Non-Users of either program

Trait*	Non-Users N=55,127		EF Users: Consistent N=517		EF Users: Intermittent N=1,578		p-value[†]	SS Users: Consistent N=3,953		SS Users: Intermittent N=9,623		p-value[†]
	n mean	(%) (range)	n mean	(%) (range)	n mean	(%) (range)		n mean	(%) (range)	n mean	(%) (range)	
Age	74.1	(65-98)	73.7	(65-95)	75.0	(65-97)	<0.001	70.0	(65-95)	71.5	(65-96)	<0.001
Female	30640	(55.6)	381	(73.7)	1169	(74.1)	<0.001	2377	(60.1)	5879	(61.1)	<0.001
Race[††]:												
White	45471	(90.6)	436	(85.5)	1356	(88.6)	<0.001	3462	(91.6)	8571	(92.4)	<0.001
Black	1418	(2.8)	21	(4.2)	60	(3.9)		65	(1.7)	210	(2.3)	
Asian	2420	(4.8)	40	(7.9)	96	(6.3)		202	(5.4)	388	(4.2)	
Other	880	(1.8)	7	(1.4)	19	(1.2)		49	(1.3)	109	(1.2)	
BMI[††] (kg/m^2)	28.3	(7.4-77.1)	26.9	(16.3-45.7)	27.3	(14.9-49.4)	<0.001	27.9	(16.2-51.7)	28.6	(10.0-111.0)	<0.001
<18.5	531	(1.0)	4	(0.8)	12	(0.8)	<0.001	20	(0.5)	31	(0.3)	<0.001
18.5-24.9	8851	(16.1)	142	(27.1)	367	(24.0)		862	(21.8)	1565	(16.3)	
25-29.9	11142	(20.2)	145	(28.1)	428	(27.1)		1145	(29.0)	2253	(23.4)	
30 +	34603	(62.8)	228	(44.1)	771	(48.9)		1926	(48.7)	5774	(60.0)	
Smoker[††]	4359	(7.9)	22	(4.3)	59	(3.7)	<0.001	118	(3.0)	485	(5.0)	<0.001
Charlson Score	0.92	(0-18)	0.63	(0-10)	0.60	(0-10)	<0.001	0.57	(0-10)	0.61	(0-10)	<0.001
Diagnosis in study period:												
Diabetes	10984	(19.9)	87	(16.8)	278	(17.6)	<0.001	572	(14.5)	1968	(20.5)	<0.001
Dementia	1965	(3.6)	9	(1.7)	63	(4.0)	0.002	25	(0.6)	214	(2.2)	<0.001
Walking Disorder[‡]	624	(1.1)	9	(1.7)	37	(2.3)	0.093	34	(0.9)	130	(1.4)	0.090
Osteoarthritis	22801	(41.4)	277	(53.6)	990	(62.7)	<0.001	1854	(46.9)	6034	(62.7)	<0.001
Osteoporosis	873	(1.6)	22	(4.3)	63	(4.0)	<0.001	108	(2.7)	265	(2.8)	<0.001
Musculoskeletal condition[††]	27254	(49.4)	330	(63.8)	1151	(72.9)	<0.001	2189	(55.4)	6893	(71.6)	<0.001
Visual Impairment[¥]	31894	(57.9)	371	(71.8)	1271	(80.5)	<0.001	2446	(61.9)	7453	(77.5)	<0.001
Coronary Heart Disease	11265	(20.4)	99	(19.2)	371	(23.5)	<0.001	561	(14.2)	2226	(23.1)	<0.001
Hypertension	28598	(51.9)	306	(59.2)	1053	(66.7)	<0.001	1850	(46.8)	5985	(62.2)	<0.001
Use of Sedatives or Sleeping Medication	7106	(12.9)	43	(8.3)	208	(13.2)	<0.001	344	(8.7)	1357	(14.1)	<0.001
Fall Resulting in Medical Treatment	16834	(30.5)	146	(28.2)	672	(42.6)	<0.001	861	(21.8)	3563	(37.0)	<0.001

*Unless otherwise specified, traits are described at first enrollment

[†] p-values correspond to a Pearson's X^2 analysis (for categorical covariates) or a one-way ANOVA (for continuous covariates) comparing trends in the covariate across levels of either EF or SS participation

[‡]Includes: difficulty walking (719.7), abnormal gait (781.2), and generalized weakness (728.87)

[††]Includes: arthropathy, rheumatoid arthritis, and joint derangement (712-719)

[¥] Includes: glaucoma (365), cataract (366), macular degeneration (362.50-362.53, 362.55, 362.63), and retinopathy (362.01-362.03, 362.10, 362.11, 362.2, 363.31)

[††]Variables have missing values for some individuals. Approximate percent missing for each follows: race (6.1%), BMI (19.7%), and smoking (2.3%)

Table 2: Risk of a medical fall among EF/SS users compared to non-users

	Comparison Group	N	Crude Model HR	Crude Model (95 % CI)	p-value	Demographic Model[±‡] HR	Demographic Model[±‡] (95 % CI)	p-value	Full Model*[†] HR	Full Model*[†] (95 % CI)	p-value
EF	Non-Users	55,127	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent EF	1.578	0.90	(0.84, 0.98)	0.009	0.84	(0.77, 0.91)	<0.001	0.87	(0.80, 0.94)	0.001
	Consistent EF	517	0.73	(0.62, 0.86)	<0.001	0.71	(0.60, 0.84)	<0.001	0.74	(0.63, 0.88)	<0.001
SS	Non-Users	55,127	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent SS	9,623	0.85	(0.82, 0.88)	<0.001	0.92	(0.88, 0.95)	<0.001	0.93	(0.90, 0.97)	<0.001
	Consistent SS	3,953	0.83	(0.78, 0.89)	<0.001	0.93	(0.87, 0.99)	0.033	0.95	(0.89, 1.02)	0.184

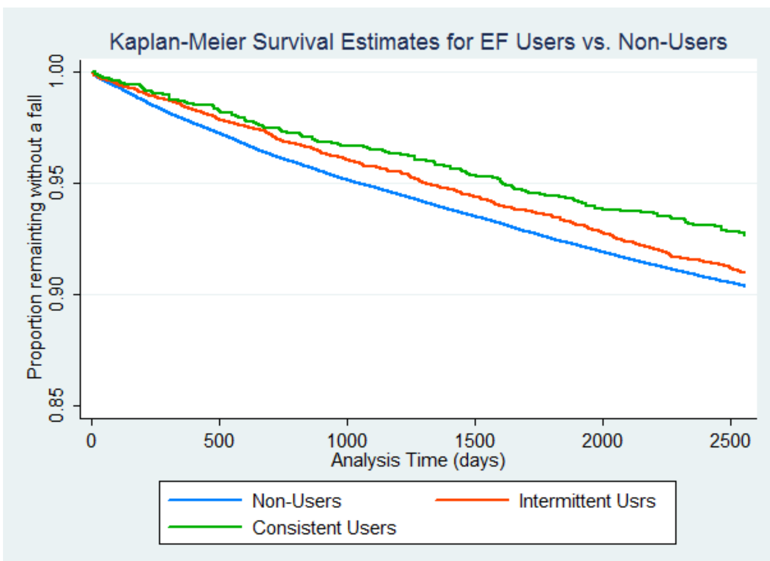
*Based on a reduced sample size due to missingness of race variable included in the model

‡ Model adjusted for age, sex, and race

† Model adjusted for age, sex, race, and all covariates outlined in Table 1

Figure 1: Kaplan-Meier survival curves of time to first medical fall for EF and SS users

a)



b)

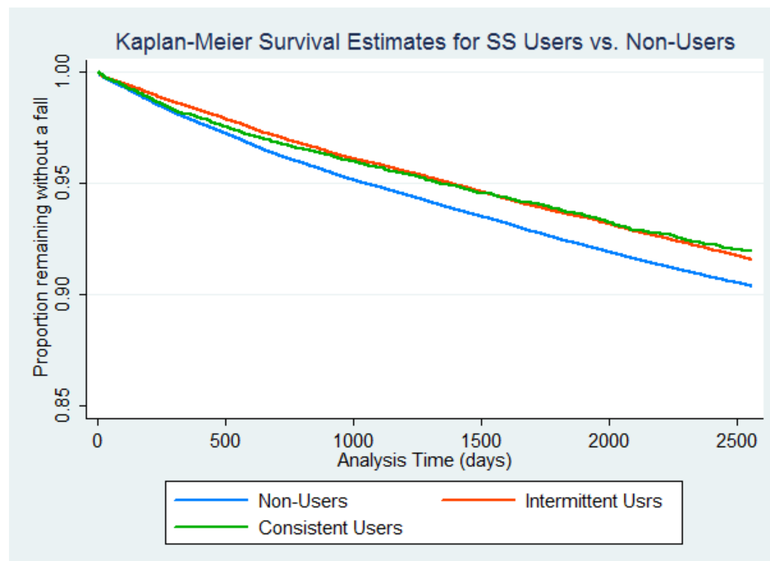


Table 3: Effect of SS participation on risk of a medical fall, by category of age and BMI

	HR*	95% CI	p-value
Consistent Users			
AGE			
75 and younger	0.99	(0.90, 1.10)	0.905
Over 75	0.85	(0.76, 0.95)	0.005
BMI†			
28 and below	0.86	(0.78, 0.94)	0.002
Above 28	1.07	(0.95, 1.20)	0.259
Intermittent Users			
AGE			
75 and younger	0.97	(0.91, 1.03)	0.290
Over 75	0.89	(0.85, 0.95)	<0.001
BMI			
28 and below	0.90	(0.86, 0.95)	<0.001
Above 28	0.94	(0.89, 1.00)	0.059

*Adjusted for age, sex, and BMI within strata as applicable (i.e. model stratified by age does not adjust for age, etc.)

Table 4: Risk of a medical fall among EF/SS users compared to other users

Comparison Group	N	Crude Model		p-value	Demographic Model*‡		p-value	Full Model*†		p-value
		HR	(95% CI)		HR	(95% CI)		HR	(95% CI)	
Intermittent SS	9,623	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
Intermittent EF	1,578	1.14	(1.04, 1.26)	0.007	0.99	(0.89, 1.09)	0.793	1.00	(0.91, 1.11)	0.959
Consistent SS	3,953	0.99	(0.92, 1.06)	0.742	1.01	(0.93, 1.08)	0.884	1.02	(0.94, 1.10)	0.636
Consistent EF	517	0.89	(0.74, 1.07)	0.214	0.81	(0.67, 0.98)	0.029	0.83	(0.69, 1.00)	0.055

*Based on a reduced sample size due to missingness of race variable included in the model

‡ Model adjusted for age, sex, and race

† Model adjusted for age, sex, race, and all covariates outlined in Table 1

Table 5: Sensitivity analysis of the effects of osteoarthritis on risk of a medical fall

a) Individuals with osteoarthritis

	Comparison Group	N	Crude Model		p-value	Demographic Model*‡		p-value	Full Model*†		p-value
			HR	(95 % CI)		HR*	(95 % CI)		HR*	(95 % CI)	
EF	Non-Users	22,801	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent EF	990	0.91	(0.78, 1.07)	0.253	0.86	(0.73, 1.01)	0.059	0.89	(0.76, 1.06)	0.189
	Consistent EF	277	0.86	(0.63, 1.18)	0.338	0.83	(0.61, 1.14)	0.254	0.81	(0.58, 1.13)	0.221
SS	Non-Users	22,801	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent SS	6,034	0.88	(0.82, 0.95)	0.001	0.93	(0.86, 1.00)	0.056	0.94	(0.87, 1.02)	0.130
	Consistent SS	1,854	0.78	(0.68, 0.90)	0.001	0.85	(0.74, 0.98)	0.028	0.86	(0.74, 1.01)	0.063

b) Individuals without osteoarthritis

	Comparison Group	N	Crude Model		p-value	Demographic Model*‡		p-value	Full Model*†		p-value
			HR	(95 % CI)		HR	(95 % CI)		HR	(95 % CI)	
EF	Non-Users	3,699	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent EF	161	0.93	(0.84, 1.04)	0.210	0.84	(0.76, 0.94)	0.002	0.86	(0.77, 0.97)	0.013
	Consistent EF	52	0.82	(0.66, 1.01)	0.057	0.77	(0.62, 0.94)	0.012	0.78	(0.62, 0.98)	0.032
SS	Non-Users	3,699	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent SS	856	0.88	(0.84, 0.92)	<0.001	0.96	(0.91, 1.01)	0.090	0.94	(0.89, 1.00)	0.046
	Consistent SS	238	0.92	(0.84, 1.00)	0.050	1.01	(0.92, 1.11)	0.807	0.99	(0.89, 1.09)	0.825

*Based on a reduced sample size due to missingness of race variable included in the model.
‡ Model adjusted for age, sex, and race
† Model adjusted for age, sex, race, and BMI.

Table 6: Sensitivity analysis of the effects of diabetes on risk of a medical fall

a) Individuals with diabetes

	Comparison Group	N	Crude Model HR	(95 % CI)	p-value	Demographic Model*‡ HR*	(95 % CI)	p-value	Full Model*† HR*	(95 % CI)	p-value
EF	Non-Users	10,984	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent EF	278	0.76	(0.59, 0.98)	0.037	0.73	(0.57, 0.94)	0.016	0.71	(0.54, 0.93)	0.014
	Consistent EF	87	0.74	(0.46, 1.20)	0.226	0.70	(0.43, 1.12)	0.138	0.79	(0.49, 1.27)	0.331
SS	Non-Users	10,984	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent SS	1,968	0.86	(0.78, 0.95)	0.004	0.91	(0.82, 1.01)	0.068	0.91	(0.81, 1.01)	0.076
	Consistent SS	572	0.89	(0.73, 1.10)	0.279	0.97	(0.79, 1.20)	0.797	0.94	(0.75, 1.17)	0.584

b) Individuals without diabetes

	Comparison Group	N	Crude Model HR	(95 % CI)	p-value	Demographic Model*‡ HR	(95 % CI)	p-value	Full Model*† HR	(95 % CI)	p-value
EF	Non-Users	7,538	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent EF	432	0.97	(0.89, 1.07)	0.590	0.88	(0.80, 0.97)	0.009	0.91	(0.82, 1.01)	0.078
	Consistent EF	135	0.85	(0.71, 7.03)	0.092	0.81	(0.67, 0.98)	0.026	0.80	(0.65, 0.98)	0.029
SS	Non-Users	7,532	1.00	(ref)	--	1.00	(ref)	--	1.00	(ref)	--
	Intermittent SS	2,327	0.90	(0.86, 0.95)	<0.001	0.98	(0.93, 1.02)	0.343	0.97	(0.92, 1.02)	0.234
	Consistent SS	674	0.89	(0.82, 0.96)	0.003	0.98	(0.90, 1.06)	0.622	0.97	(0.88, 1.06)	0.473

*Based on a reduced sample size due to missingness of race variable included in the model.

‡ Model adjusted for age, sex, and race

† Model adjusted for age, sex, race, and BMI.