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Physical Activity as a Preventative Factor for Frailty: The Health, Aging, and Body Composition Study

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Background. It is unclear if physical activity (PA) can prevent or reverse frailty. We examined different doses and types of PA and their association with the onset and severity of frailty.

Methods. Health, Aging and Body Composition (Health ABC) study participants (N = 2,964) were followed for 5 years, with frailty defined as a gait speed of less than 0.60 m/s and/or inability to rise from a chair without using one's arms. Individuals with one impairment were considered moderately frail and those with both severely frail. We examined PA doses of *volume* and *intensity*, *activity types* (eg, lifestyle vs exercise activities), and their associations with incident frailty and transition to severe frailty in those who became frail.

Results. Adjusted models indicated that sedentary individuals had significantly increased odds of developing frailty compared with the exercise active group (adjusted odds ratio [OR] = 1.45; 95% confidence interval [CI]: 1.04–2.01), whereas the lifestyle active did not. Number of diagnoses was the strongest predictor of incident frailty. In those who became frail during follow-up (n = 410), there was evidence that the sedentary (adjusted OR = 2.80; 95% CI: 0.98–8.02) and lifestyle active (adjusted OR = 2.81; 95% CI: 1.22–6.43) groups were more likely to have worsening frailty over time.

Conclusions. Despite the strong relationship seen between comorbid conditions and onset of frailty, this observational study suggests that participation in self-selected exercise activities is independently associated with delaying the onset and the progression of frailty. Regular exercise should be further examined as a potential factor in frailty prevention for older adults.

Key Words: Aging—Exercise—Frail elderly—Longitudinal studies.

THE unprecedented growth of the aging population has produced an increased focus on the importance of maintaining independent living, specifically delaying or preventing frailty and disability (1–5). Frailty, a primary pathway to disability, has been defined as a pathological condition that results in a constellation of signs and symptoms and is characterized by high susceptibility to adverse health outcomes, impending decline in physical function, and high risk of death (6,7). Physical inactivity is considered to be a major contributing factor for disability (2,8–10); yet, the association between physical activity (PA) and frailty remains poorly understood. It remains unknown whether PA can modify frailty onset, and if so, the specific doses and types of PA necessary to affect long-term risk. The modest impact of PA interventions using a variety of strength and endurance activities on frail status (11–13) indicates the need for more thorough research. Using data from the Health, Aging and Body composition (Health ABC) study, we examined the association between different doses and types of PA and development and progression of frailty in older adults.

Methods

Health ABC Study

The Health ABC study is a longitudinal, prospective cohort study with broad objectives of measuring higher functioning older adults to allow examination of health decline and improvement for several years (14). The cohort consists of 3,075 well-functioning black and white men and women aged 70–79 years. Black participants were recruited from all age-eligible residents, and white participants were recruited from a random sample of Medicare beneficiaries, located in the ZIP codes in and surrounding Pittsburgh, PA, and Memphis, TN. Participants reported no difficulty doing mobility-related tasks, such as walking quarter mile or climbing one flight of stairs or performing activities of daily living (ADL) at the time of enrollment. The University of Pittsburgh and University of Tennessee, Memphis, institutional review boards approved the study, and all participants provided written informed consent prior to participation.

Participants with missing functional testing data ($n = 11$) and those meeting frailty criteria at baseline ($n = 100$; see Determination of Frailty Status) were excluded, leaving 2,964 participants for these analyses. At the end of the follow-up period of 5 years, 563 participants died (18% of the original cohort).

Determination of Frailty Status

Frailty status was determined at three time points (baseline, and 3 and 5 years), following the model developed by Gill and colleagues (11,15), as the component measures were readily available and key components of other frailty assessments were not. Frailty in the context of this study was described by the presence of functional limitations, or "physical frailty" as described by Gill. Frailty was defined as having a gait speed of less than 0.60 m/s or being unable to rise from a chair once with arms folded. Similar to Gill, we considered anyone meeting either frailty criterion as moderately frail, and those meeting both criteria as severely frail. Poor gait speed and chair stand performance predict several adverse health outcomes, including disability, institutionalization, and mortality (16–18). Specifically, Gill and colleagues reported that inability to rise from a chair more than doubled the risk for development of ADL dependence for 1 year in 563 community-dwelling elders (15), and there is a wealth of literature supporting gait speed as an important predictor of functional status (17). It is important to note that the Gill frailty model chosen for this study is one among numerous frailty models that exist in the literature, and the concept of frailty as a whole is somewhat fluid and changing (6,19–22).

Physical Activity

PA levels were collected from participants at baseline using a self-report instrument developed specifically for the Health ABC study (23). The standardized questionnaire was modeled after several commonly used activity questionnaires, particularly the well-validated Minnesota Leisure-Time PA questionnaire (23). Kilocalories per week (kcal/wk) expended in common exercise activities (eg, walking for exercise, exercise classes, weightlifting) and lifestyle activities (eg, gardening, housework, yard work, nonexercise walking) were collected. For each activity that participants reported doing at least 10 times in the past 12 months, participants were asked how much time they spent performing the activity for the past 7 days and the level of effort expended, where applicable. From reported volume and effort and estimated metabolic cost (24), a summary variable of kcal/wk was calculated for each activity performed in the past week.

Based on current public health recommendations for aerobic activity (25,26), we developed hierarchical doses within each PA category. Details of the PA categories are shown in Appendix 1. Briefly, doses within the *volume* category were low and recommended. Doses within the *intensity* category were sedentary, light (ie, shopping, volunteer work, doing laundry), moderate (ie, walking for exercise, outdoor chores, golf), and vigorous (ie, weightlifting, dancing, climbing stairs). Weightlifting and dancing were classified as vigorous based on estimates of the metabolic cost of specific types of weightlifting and dancing being quite variable and ranging from moderate to vigorous (24), and based on our previous measurement of the metabolic cost of exercise activities in an elderly population (unpublished data). An a*ctivity type* category was also developed, with the specific types being sedentary, lifestyle active, and exercise active. The activity type category is based on the previous construct developed by Brach and colleagues (27) in the Health ABC cohort. Briefly, the cut points for sedentary, lifestyle active, and exercise active categories were based on a combination of surgeon general's recommendations for PA (approximately at least 1,000 kcal/wk) and the cohort's distribution of weekly caloric expenditure in PAs (25th percentile = 2,719 kcal/wk).

Covariates

Demographic, lifestyle, and health variables were treated as covariates, including baseline age, sex, race, education, waist circumference, marital status, number of prevalent chronic conditions (cerebrovascular disease, heart disease, hypertension, lower limb osteoarthritis, pulmonary disease, diabetes, circulation problems in extremities, and depression), smoking status, and alcohol consumption. Chronic disease information was ascertained by self-report, clinical data, and current medication use. Abdominal circumference (cm) was measured with a flexible plastic tape to the nearest 0.1 cm at the level of the largest circumference (seen from the side), at the end of expiration, between the lower rib and the iliac crest, while subjects were standing with their weight equally distributed on both feet, arms at their sides, and head facing straight forward. The correlation between waist circumference measures and computerized tomography measures of visceral fat has been previously reported to be approximately 0.70 in the Health ABC study (28). Smoking status, weekly alcohol consumption, and education levels were self-reported.

Statistical Analysis

Baseline characteristics of the cohort were examined using univariate procedures including proportions or mean ± standard deviation, as appropriate. For continuous not normally distributed data, we provide the median and interquartile range. Participants who were missing one or more baseline covariates were assigned imputed values using multiple imputation methods (PROC MI), with standard errors corrections performed using the PROC MIANALYZE procedure. Covariates with missing data included marital status, education, smoking status, drinking status, cerebrovascular disease, diabetes, osteoarthritis, high blood pressure, depression, pulmonary disease, and heart disease. Number of participants with missing data ranged from 8 (education) to 195 (marital status). Due to the data not satisfying proportionality assumptions, we developed two separate generalized estimating equation (GEE) logistic regression models using an autoregressive covariance structure: the first model tested the association between PA and incident moderate or severe frailty. The second model tested the extent to which PA was associated with level of *severity of frailty in those who became moderately frail over time*. PA group by covariate and group by time interactions were tested in both models. None was significant with the given power to detect interactions. We were 80% powered to detect an interaction (ratio of odds ratios [ORs]) of 2.7 and 2.1, respectively, for rates of factors of 20% and 50% in the exercise active group, with rates of events and prevalence of exercise active held fixed. Trends were tested using the chi-square test, with significance determined to be at the $p < .05$ level. ORs and 95% confidence intervals (CIs) are reported with the most active group as the referent group in all models. All analyses were conducted using SAS v8.2 software (SAS, Cary, NC).

Table 1. Baseline Characteristics of Not-Frail Health, Aging, and Body Composition Participants (N = 2,964)

Characteristics	Mean ± *SD*	Range
Female, %	51	
Age, yr	3.6 ± 2.9	68–80
Height, m	1.66 ± 0.09	1.37–2.01
Weight, kg	75.7 ± 14.9	33.5–141.0
Waist circumference, cm	99.5 ± 13.2	53.7–224.7
Body mass index, kg/m^2	27.4 ± 4.8	14.9–52.0
	%	
Race		
White	59	
Black	41	
Marital status		
Married	55	
Unmarried	45	
Smoking status		
Never	44	
Former	46	
Current	10	
Alcohol (drinks/wk)		
None	50	
1–7	42	
7+	8	
Education		
Less than high school	24	
High school graduate	33	
Postsecondary	43	
Disease prevalence		
Cerebrovascular disease	8	
Heart disease	20	
Hypertension	51	
Lower limb osteoarthritis	10	
Pulmonary disease	12	
Diabetes	15	
Circulatory problems	5	
High depressive symptoms[a]	5	

Notes: *SD* = standard deviation.

[a] High depressive symptoms defined as ≥16 on Center for Epidemiology Study Depression Scale.

Results

Baseline Characteristics

The mean age of the cohort (N = 2,964) was 73.6 years (Table 1). Due to intentional oversampling of black men and women, 41% of the cohort were black and 59% were white. The remaining baseline demographics were characteristic of a high-functioning group of older adults, with low prevalence of current smoking, heavy drinking, and chronic diseases, and a majority of the cohort with high school or higher education levels (29).

Baseline PA Levels

Thirty-seven percent of the cohort engaged in at least 150 min/wk of PA ranging from light to vigorous intensity (Table 2). Forty-six percent regularly engaged in activities of light intensity [<3 metabolic equivalents (METs): 1 MET = energy expended at rest] such as light housework, shopping, doing volunteer or light paid work, and caregiving. Twenty-two percent reported participating in moderate-intensity activities on a regular, weekly basis. Almost 19% reported regular participation in vigorous activities, such as dancing, strength training, or heavy yard work. More than half of the participants met criteria for the lifestyle active group (>2,700 kcal/wk in any PAs, but <1000 kcal/wk in exercise activities), with the remaining individuals evenly divided between the sedentary (<2,700 kcal/wk in any PAs, and <1,000 kcal/wk in exercise activities) and the exercise active groups (>1,000 kcal/wk in exercise activities). The median kcal/wk generally followed a dose-response form within the PA categories. The median kcal/wk expended in PAs (not including paid/volunteer work and caregiving activities) for the entire cohort was 3,800 kcal/wk, which is considerably higher than previously reported levels from similarly aged U.S. populations (~1,200 kcal/wk) (30).

Table 2. Physical Activity Categories and Self-Reported Weekly Activity (N = 2,964)

	n (%)	Kcal/wk, median (IQR)
Volume		
Low dose	1,880 (63.4)	338 (798)
Recommended dose	1,084 (36.6)	1,638 (1,734)
Intensity		
Sedentary dose	386 (13.0)	686 (463)
Light dose	1,374 (46.4)	3,757 (3,719)
Moderate dose	650 (21.9)	5,721 (4,706)
Vigorous dose	554 (18.7)	8,116 (6,495)
Activity types		
Sedentary	707 (23.9)	1,747 (1,126)
Lifestyle active	1,525 (51.1)	5,939 (4,779)
Exercise active	732 (24.7)	6,073 (5,517)
Prevalent reported activities		
Lifestyle		
Light housework	2,645 (89.2)	
Grocery shopping	2,388 (80.6)	
Climbing stairs	2,111 (71.2)	
Doing laundry	2,013 (67.9)	
Heavy chores	1,291 (43.6)	
Volunteer work	1,150 (38.8)	
Outdoor chores	936 (31.6)	
Other walking	854 (28.8)	
Exercise		
Walking for exercise	1,189 (40.1)	
Strengthening exercises	148 (5.0)	

Note: IQR = interquartile range.

The majority of individuals reported participating in non-exercise activities, such as light housework (89%), grocery shopping (81%), climbing stairs (71%), and doing laundry (68%). The most prevalent exercise activity was walking for exercise (40%), and only 5% of the participants reported participating in any strengthening exercises.

Prevalence and Incidence of Frailty for a Period of Five Years

Prevalence and incidence of frailty status in 2,018 men and women with frailty information at all waves is shown in Table 3. This table includes those who were frail at baseline who were subsequently excluded from the main analyses. At baseline, approximately 2% of the men and 3% of the women were moderately or severely frail. At 3 years, 5% and 9% of the men and women were frail, respectively. At 5 years, prevalence of frailty increased to more than 13% for men and 17% for women. There were 6,111 person-years of follow-up at 3 years and 9,229 person-years of follow-up at 5 years. Incidence rates at 3 and 5 years indicated that women had overall higher rates of incident moderate frailty. At 3 years, women had double the incidence rates of moderate frailty compared with men, 12.8 per 1,000 person-years versus 6.2 per 1,000 person-years, respectively. Generally, incidence of severe frailty was quite low for both genders (5 years = 1.0 per 1,000 person-years in men and 2.0 per 1,000 person-years in women).

PA and the Development of Any Frailty

In general, there were increased odds of frailty associated with lower doses of PA in each category, and with sedentary behavior, when compared with the highest dose (Table 4). After adjustment, the associations between low doses of PA and frailty were mostly attenuated and no longer significant. However, in comparison with those who regularly participated in exercise activities, the sedentary group had significantly increased odds for developing frailty (OR = 1.45; 95% CI: 1.04–2.01). In the adjusted model, there was no difference in odds of developing frailty between the lifestyle active and exercise active groups. There was also a significant dose-response association (p = .03) between the activity types and development of frailty.

The strongest and most consistent predictor of incident frailty in all the fully adjusted models was baseline number of diagnoses, with an approximate doubling of odds for frailty with each diagnosis reported (adjusted OR = 1.90; 95% CI: 1.55–2.34; not shown in Table 4). This suggests that the presence of multiple health conditions places an older individual at increased risk for frailty and that this risk is independent of exercise or lifestyle activity levels. Other significant covariates included in the final models were age (older more likely to be frail; p < .001), gender (men more likely to be frail; p = .001), race (black adults more likely to be frail; p < .001), and education (higher educated less likely to be frail; p < .001).

PA and the Development of Severe Frailty

Of those who became and remained frail for a period of 5 years (n = 410), we sought to determine if higher doses of PA could prevent further deterioration to severe frailty status (Table 5). However, within the activity types, the sedentary (adjusted OR = 2.80; 95% CI: 0.98–8.02) and lifestyle active (adjusted OR = 2.81; 95% CI: 1.22–6.43) groups had almost triple the odds of developing frailty compared with the exercise active group, although this was only significant for the lifestyle active. There were no associations between differing doses of volume or intensity of PA and odds of transitioning to severe frailty.

Sensitivity Analyses

We performed sensitivity analyses to quantify the pattern of data missing to follow-up. First, we estimated the odds of being frail at 3 years in those with missing data at 5 years (n = 357), compared with those with complete data at 5 years (n = 2,018). The group with incomplete follow-up data were nearly four times more likely to be frail at 3 years

Table 3. Prevalence and Incidence of Frailty at Baseline, and 3 and 5 years of Follow-Up in Those With Complete Follow-Up Data (n = 2,018)

	Men (N = 962)		Women (N = 1,056)	
	Moderately Frail	Severely Frail	Moderately Frail	Severely Frail
Prevalence, n (%)				
Baseline	18 (1.8)	1 (0.1)	32 (2.8)	3 (0.3)
3 yr	38 (3.8)	13 (1.3)	78 (6.9)	23 (2.0)
5 yr	109 (10.9)	20 (2.0)	153 (13.6)	41 (3.6)
Incidence[a]				
3 yr	6.2	2.1	12.8	3.8
5 yr	10.1	1.0	11.8	2.0

Note: [a] Per 1,000 person-years.

(OR = 3.90; 95% CI: 2.91–5.23) compared with the group with complete follow-up data. This indicated that data missing at follow-up were not missing at random. We then imputed those with missing follow-up data as frail and reran the GEE models. Adjusted ORs and CIs in the secondary models were very similar to those of the original models presented in Tables 4 and 5, and there were no changes in any significant findings.

Discussion

We found that individuals who regularly engaged in exercise activities at baseline were less likely to develop frailty for a period of 5 years compared with those who were sedentary. This significant association persisted after adjusting for baseline health conditions and several important demographic characteristics (adjusted OR = 1.45; 95% CI: 1.04–2.01). Additionally, there was evidence for an almost threefold increased likelihood of a transition from moderate to severe frailty in the sedentary and lifestyle active groups, compared with the exercise active. It is important to point out that neither volume nor intensity of lifestyle activity or structured exercise was related to progression of frailty, only the categorization of someone as participating in structured exercise or not.

Findings from this observational study could guide future clinical trials in designing optimal interventions aimed at frailty and subsequently lead to a higher probability of preventing or attenuating frailty. For instance, we found that the presence of multiple diagnoses considerably attenuated the beneficial association of regular involvement in exercise activities on subsequent frailty. As an a priori covariate, multiple existing diagnoses were expected to somewhat mitigate any observed association between activity types and incident frailty. This was due to the exercise active group being less likely to report multiple diagnoses compared with the lifestyle and sedentary groups (p = .02). However, the strength of the adjusted association between number of diagnoses and incident frailty (adjusted OR = 1.90; 95% CI: 1.55–2.34) is worthy of further discussion. This finding suggests the need to consider

Table 4. Odds of Incident Moderate or Severe Frailty by Physical Activity Category (N = 2,964)

	Unadjusted OR (95% CI)	Adjusted OR[a] (95% CI)
Volume		
Low	1.33 (1.08–1.64)	1.03 (0.83–1.28)
Recommended	1.00	1.00
p for trend	—	—
Intensity		
Sedentary	1.30 (0.90–1.88)	1.10 (0.75–1.63)
Light	1.58 (1.19–2.08)	1.48 (0.88–1.59)
Moderate	0.94 (0.68–1.30)	0.91 (0.65–1.28)
Vigorous	1.00	1.00
p for trend	.002	.22
Activity types		
Sedentary	2.11 (1.58–2.81)	1.45 (1.04–2.01)
Lifestyle active	1.39 (1.08–1.79)	1.08 (0.83–1.41)
Exercise active	1.00	1.00
p for trend	<.0001	.03

Notes: OR = odds ratio; CI = confidence interval.

[a] Adjusted for age, sex, race, education, marital status, smoking status, drinking status, waist circumference, and count of diagnoses.

Table 5. In the Moderately Frail, Odds of Incident Severe Frailty by Physical Activity Category (N = 410)

	Unadjusted OR (95% CI)	Adjusted OR[a] (95% CI)
Volume		
Low	1.26 (0.75–2.13)	0.97 (0.55–1.70)
Recommended	1.00	1.00
p for trend	—	—
Intensity		
Sedentary	2.28 (0.95–5.48)	1.47 (0.58–3.73)
Light	2.03 (0.94–4.35)	1.31 (0.58–2.95)
Moderate	0.76 (0.26–2.20)	0.66 (0.22–1.98)
Vigorous	1.00	1.00
p for trend	.009	0.19
Activity types		
Sedentary	4.26 (1.82–9.98)	2.80 (0.98–8.02)
Lifestyle active	2.66 (1.15–6.13)	2.81 (1.22–6.43)
Exercise active	1.00	1.00
p for trend	.0003	.06

Notes: OR = odds ratio; CI = confidence interval.

[a] Adjusted for age, sex, race, education, marital status, smoking status, drinking status, waist circumference, and count of diagnoses.

prevalent health conditions when designing *frailty prevention* programs. It may be beneficial in future frailty prevention studies to triage individuals with multiple chronic illnesses to an enhanced intervention consisting of focused, medical management of chronic diseases, *in combination with a structured exercise program*. This is in line with geriatric evaluation and management clinics, in which a comprehensive assessment and follow-up with a multidisciplinary team approach is used to medically manage the older adult with multiple, difficult health issues (31). To our knowledge, however, few geriatric management teams incorporate exercise training beyond basic physical therapy as part of a comprehensive medical management program.

When intervening on the *progression of frailty* in older adults who have already developed moderate frailty, our data suggest that being either sedentary or participating in self-prescribed lifestyle PA confers similar increased odds for developing frailty compared with regularly engaging in exercise activities. Lifestyle activities such as housework, gardening, and leisurely walking may not be sufficient to attenuate the progression of frailty. Previous studies have compared the differing effects of lifestyle activity versus structured exercise on levels of PA and physiological outcomes. Project ACTIVE demonstrated comparable 24-month improvements in PA, cardiorespiratory fitness, and blood pressure between lifestyle activity and structured exercise groups (32). Similarly, in the present study, the lifestyle active and exercise active reported comparable total kcal/wk expended (median kcal/wk of 5,939 and 6,073, respectively). Although total volume of activity was comparable between the groups, there appears to be an additional benefit in being exercise active in slowing the progression of frailty. The mechanisms underlying this benefit need further examination.

The literature currently emphasizes high intensity strength training for maintaining strength and mobility in frail older adults (33–35). Approximately 5% of this cohort engaged in strength training activities. This proportion is lower than expected for a high-functioning group with a low prevalence of disabling conditions (eg, lower limb osteoarthritis), as the Centers of Disease Control (CDC) estimate of U.S. older adults' participation in strength training is closer to 11% (36). However, data from the recent CDC estimates were collected in 2001, and the Health ABC baseline data were collected in 1997–1998. The public health emphasis on strength training in older adults gained much momentum in the late 1990s; therefore, these comparisons in strength training rates should be made with caution.

Fewer than 20% of individuals who were regularly exercise active were regularly participating in strengthening activities at baseline but instead were, on average, reportedly expending about 2,500 kcal/wk walking for exercise. This is approximately equal to walking 1 h/d for exercise (24). Although this volume of walking may have allowed for the maintenance of mobility and was associated with lower incidence of frailty, it should not be considered the optimal exercise program for prevention of frailty. Our findings reemphasize that improving older adults' participation rates in strengthening activities remains a public health challenge, as it is plausible that higher rates of strengthening activities in this cohort could have resulted in associations stronger than those observed. This is particularly true when using the Gill frailty definition, as the inability to rise from a chair is directly related to poor lower body strength and balance; additionally, lower limb joint pain secondary to osteoarthritis can affect chair rise performance; however, osteoarthritis was not highly prevalent in this group. Lower body strengthening and balance exercises (eg, progressive resistance training, Tai Chi, and balance training) would likely be optimal in improving the ability to rise from a chair (2). Thus, continued work is essential to determine exactly which specific behaviors should be emphasized and targeted in practice.

Our findings regarding the potential protective effects of engaging in exercise-related PA are consistent with the work of Brach and colleagues (27), who found that the exercise active group had better functional performance, such as gait speed, chair rises, and long distance walk times, than either the lifestyle active or the sedentary groups. Based on Brach's findings, the development of frailty over time, as measured by impaired mobility (gait speed) and strength (chair rises), should be more likely in the lifestyle and sedentary groups due to their lower physical performance at baseline. This longitudinal study lends some support to the idea that older adults who report exercise activity maintain higher levels of subsequent functioning (strength and mobility) and are less likely to develop frailty. This is encouraging, particularly when coupled with very recent information indicating that frailty is a very dynamic process with good potential for reversal (37).

This study had several limitations. First, we used a self-report questionnaire to derive levels of PA during the previous 7 days. Direct activity measurement tools, such as accelerometers, could provide more accurate assessments of PA (38). Second, the detailed PA questionnaire was administered only at baseline. Follow-up detailed assessment of activities would have been optimal. Third, optimally we would have been able to assess whether very specific types of PA, particularly strengthening and balance exercises, were associated with frailty. Fourth, because of inadequate sample sizes, we were unable to create highly active groups (ie, high volume >210 min/wk or dually active with lifestyle and exercise activities), and examine their likelihood of frailty. Finally, the missing follow-up data from those who died during follow-up could have lead to estimates

Appendix 1. Physical Activity Categories

Volume category

Low-volume dose: individuals accumulating less than 150 min/wk in physical activities of any intensity.
Recommended volume dose: individuals accumulating at least 150 min/wk in physical activities of any intensity.

Intensity category

Sedentary dose: individuals accumulating less than 1,000 kcal/wk in any physical activities.
Light-intensity dose: individuals accumulating at least 1,000 kcal/wk in physical activities of an intensity of less than 3 metabolic equivalents (METs): 1 MET = energy expended at rest), and less than 1,000 kcal/wk in vigorous- and moderate-intensity activities.
Moderate-intensity dose: individuals accumulating at least 1,000 kcal/wk in physical activities of an intensity of 3–6 METs, and less than 1,000 kcal/wk in vigorous-intensity activities.
Vigorous-intensity dose: individuals accumulating at least 1,000 kcal/wk in physical activities of an intensity of 6 METs or greater.

Activity type category

Sedentary: individuals accumulating less than 1,000 kcal/wk in exercise activity and less than 2,719 kcal/wk in physical activity.
Lifestyle active: individuals accumulating at least 2,719 kcal/wk in physical activity and less than 1,000 kcal/wk in exercise activity.
Exercise active: individuals accumulating at least 1,000 kcal/wk in exercise activities.

not representative of the entire group, an issue ubiquitous to aging research.

In conclusion, this study provided concurrent comparisons of differing weekly doses of volume, intensity, and types of PA and their association with incident frailty in an initially high-functioning group of older adults. The data suggested a potential benefit of preventing frailty through regular participation in exercise activities, but this association was attenuated by the presence of multiple medical conditions, highlighting the importance of multidisciplinary approaches in preventing frailty. Additionally, engaging in self-selected exercise activities may also play a part in attenuating the transition to severe frailty in moderately frail older adults. Future studies are warranted to confirm these findings.

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