Can Physical Activity Attenuate Aging-related Weight Loss in Older People?

The Yale Health and Aging Study, 1982–1994

James Dziura1,2, Carlos Mendes de Leon3, Stanislav Kasl2, and Loretta DiPietro1,2

1 The John B. Pierce Laboratory, Yale University School of Medicine, New Haven, CT.
2 Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, CT.
3 Rush Presbyterian-St. Luke’s Medical Center, Chicago, IL.

Received for publication August 13, 2002; accepted for publication November 12, 2003.

The purpose of this analysis was to determine the longitudinal relation between physical activity and the trajectory of weight change in an older cohort (≥65 years) living in New Haven, Connecticut, who participated in the Established Populations for the Epidemiologic Study of the Elderly between 1982 and 1994 (n = 2,812). The authors hypothesized that body weight would decline over the follow-up and that physical activity would play an important role in minimizing weight loss over time. Physical activity and other covariables were self-reported at baseline, while body weight was self-reported annually over 12 years. Multivariable random effects regression demonstrated a curvilinear trajectory of weight loss per year with an accelerated loss at older ages. Baseline body weight was 155 (standard deviation, 30) pounds (70 (standard deviation, 14) kg) for those who survived the entire follow-up and was 153 (standard deviation, 32) pounds (70 (standard deviation, 15) kg) for those who did not. Each 1-unit increase in baseline total activity score minimized this aging-related weight loss, but this relation was most pronounced among those with chronic disease who did not survive the entire follow-up period (n = 973; 0.15 pounds (0.07 kg) per year). These data suggest that, among frail older people, even modest levels of physical activity can attenuate the rate of aging- and disease-related weight loss.

Aging is associated with several changes in body composition that have a direct impact on body weight and the maintenance of health and function. Both cross-sectional (1–4) and longitudinal (5–9) studies of middle-aged cohorts confirm that body weight increases throughout middle age but then starts to decline during older age. This decline occurs primarily as a result of a loss in lean tissue, including muscle mass and bone (10–14). Longitudinal evidence suggests that, during older age, muscle mass decreases 3–6 percent per decade (15), while bone loss occurs at a rate as high as −1–2 percent per year (16). The loss of lean tissue, with the accompanied rise in the proportion of body fat, has been associated with a decline in physical and metabolic reserve (14) and underscores the need to understand the etiology of aging-related weight loss. Although a genetic predisposition toward the loss in lean tissue and accretion of fat seems to be an important contributor (17), disuse has also been identified as a significant factor (18). In fact, aging-related changes in body composition are mirrored by a gradual decline in physical activity in older age (19–23).

The few epidemiologic studies that have tested the relation between physical activity and weight change have been done on middle-aged populations (24–29). In general, these studies have demonstrated the ability of higher baseline physical activity and improvements in physical activity to attenuate weight gain through middle age. Moreover, these studies provide evidence that habitual physical activity is more effective with regard to the prevention of overweight than it is for promoting weight loss. Unfortunately, similar studies have not been performed in older people among...
whom weight loss is a more important problem than weight gain and among whom the relation between physical activity and weight loss is heavily influenced by chronic disease and loss of mobility. Therefore, the purpose of this analysis was to determine, longitudinally, the trajectory of weight loss with age and the relation between physical activity and body weight change in a cohort of individuals aged 65 or more years. We hypothesized that body weight would decline over follow-up and that physical activity would play an important role in minimizing weight loss over time. Accordingly, we analyzed longitudinal data from a cohort of older men and women from the New Haven Established Populations for the Epidemiologic Study of the Elderly (EPESE), using random effects modeling to predict the trajectory of body weight change over time and its dependence on physical activity (30). This technique lends several advantages to the analysis, namely: 1) the ability to use repeated assessments (i.e., two or more) of body weight per individual; 2) the ability to include subjects with some missing body weight data; 3) the ability to control for correlation of body weights within subjects over time; and 4) the ability to account for between-subject random variation in weight and the slope of weight loss. To our knowledge, this is the first study determining the relation between physical activity and the trajectory of weight change in older individuals using serial body weight assessments.

MATERIALS AND METHODS

Study population

Subjects were older residents (≥65 years) of New Haven, Connecticut, who were enrolled in the Yale Health and Aging Project, one of the funded sites for EPESE. Selection of this sample has been described previously in detail (31). Briefly, the New Haven EPESE cohort was a cluster sample stratified by three different housing types for older residents: public housing, private housing, and housing in the general community. Of the 3,337 eligible residents contacted, 2,812 (82 percent) enrolled in the study at baseline in 1982. The study was approved by the Human Investigation Committee of the Yale University School of Medicine. All aspects of the study were explained to subjects, and they signed a form indicating their understanding of the study details and their willingness to participate.

Longitudinal assessments were completed annually from 1982 to 1990 with an additional follow-up in 1994. At baseline and each 3-year interval, interviews were conducted face-to-face in the subject’s home, while interviews for the other annual contacts were conducted by telephone. A total of 321 individuals (11 percent) were sequentially excluded for not reporting the following at baseline: body weight (n = 113); height (n = 150); physical activity (n = 32); education (n = 25); and current smoking (n = 1). In addition, 191 individuals (6.8 percent) were excluded for having less than two body weight assessments from subsequent interviews. During each year of follow-up, there was a decrease in the proportion of individuals providing information, primarily as a result of death. Of the 2,300 included initially, 1,846 (80 percent) were included after 3 years of follow-up, 1,415 (62 percent) were included after 6 years, and 801 (35 percent) reported the necessary information after 12 years.

Body weight

Current body weight was self-reported at each interview and was recorded to the nearest whole number in pounds. Therefore, each individual could have as many as 10 weight assessments over the 12-year follow-up.

Physical activity

The physical activity portion of the questionnaire was designed to assess the frequency of four general activities at baseline: walking; gardening/housework; physical exercise; and active sports or swimming. Respondents were asked to report the frequency of participation in these activities within the past month with the responses of never (coded as 0), sometimes (coded as 1), or often (coded as 2). Responses to each of the questions were then summed over all four activities to create a total activity score for each respondent that ranged from 0 to 8, with higher scores indicating higher levels of physical activity. The total activity score was considered a continuous variable for all analyses. The absence of deviation from linear trend was confirmed by comparing a model with the total activity score categorized nominally with a model with the total activity score remaining continuous (data not shown). These physical activity questions have previously demonstrated predictive validity in this same New Haven cohort (32, 33).

Study covariables

A number of variables were self-reported at baseline and were included because of their potential confounding effects on body weight and physical activity. Baseline age was calculated from the date of the initial interview and the self-reported birth date. Race was classified as “White” or “non-White.” Education, reported in total number of years, was used in this analysis as an indicator of socioeconomic status. The number of prevalent chronic conditions at baseline was defined as the total number of self-reported physician diagnoses of heart disease, cancer, stroke, diabetes, liver disease, or high blood pressure. Smoking status was defined as either “smoker” or “nonsmoker” at the initial interview. Height (inches) was reported at baseline in 1982.

To control for the ability to be physically active, we assessed functional disability at baseline from responses to seven commonly used questions pertaining to the degree of help required to perform activities of daily living, such as walking, bathing, dressing, eating, using the toilet, and personal grooming (34). The functional disability score had a range of 0–14, with higher scores indicating greater impairment. In addition, mobility was assessed from three questions on the Rosow-Breslau functional health scale (35) that queried the ability (yes/no): 1) to climb stairs; 2) to perform heavy housework; and 3) to walk one-half mile (0.81 km) without help. The total mobility score ranged from 0 to 3, with lower scores indicating greater mobility.
Univariate statistics (mean (standard deviation) and frequencies (percent)) were calculated first for the primary study variables, as well as for the selected demographic characteristics and potential confounding variables. A multivariable random effects model was then used to determine the longitudinal relation between age and body weight, as well as the ability of physical activity to modify this relation. For these analyses, repeated body weight assessments over a maximum of 10 times (1982–1994) were modeled as the outcome variable. To determine the trajectory of weight loss with aging, we used a random effects model accounting for between-subject variation in baseline body weight (intercept) and the change in body weight with age (slope; as indicated by the follow-up time variable) and adjusted for baseline age, sex, and housing strata. To maximize the stability of parameter estimation (beta) in this model, we centered baseline age by subtracting the mean age from the observed age. A second regression model was fit to test the effect of physical activity on weight change during follow-up. This model was also adjusted for baseline-centered age, sex, height, race, education, housing, functional disability score, mobility, smoking, and the prevalence of chronic conditions.

To select the most appropriate statistical model, we first explored the covariance structure of the data by graphing a sample variogram to estimate the contributions of serial correlation, measurement error, and random effects (36). Selection of the appropriate type of covariance structure was accomplished by maximizing Schwarze’s Bayesian criteria after fitting models with alternative covariance structures. The final models included an unstructured covariance to account for random variation in the intercept and slope parameters between individuals, as well as a first-order autoregressive structure to account for serial correlation of body weights within individuals. Multicollinearity among the covariables was determined by inspection of the parameter estimates after the separate removal of each independent variable from the full model.

In preliminary analyses, we observed no effect modification by sex of the relation between physical activity and weight loss; therefore, data for men and women were combined for the remaining analyses. However, the longitudinal relation between physical activity and weight change in older people is most likely influenced heavily by chronic disease and survival over the 12-year follow-up period. Therefore, statistical modeling was performed on the entire cohort, stratified by survival status, and then stratified again by survival and chronic disease status.

**RESULTS**

**Demographics**

Table 1 shows the cross-sectional distribution of body weight at each year of follow-up according to subjects who did and did not survive to the next interview year. There was no observable pattern of lower or higher body weight between these two groups over the follow-up that might suggest weight loss was secondary to chronic disease.

The baseline characteristics of the study population are described by survival status in table 2. These data suggest small, but statistically significant, differences between survivors (*n* = 905) and nonsurvivors (*n* = 1,395) in several important study variables, namely, age, functional disability score, mobility score, and total activity score. On the other hand, the number of chronic conditions, smoking, and body weight were similar between groups. Total activity scores ranged from 0 to 8; however, 91 percent of the scores were between 0 and 4 (figure 1). The average total activity score was 2.62 (standard deviation, 1.78) among the survivors and
2.11 (standard deviation, 2.19) among the nonsurvivors. For reference, obtaining the median score of 2 could be accomplished by participating in a single activity, such as walking, “often in the past month.” This low frequency of reported activity is consistent with other data for older populations (19, 20, 22).

Aging-related weight change

Figure 2 shows the predicted weight loss (95 percent confidence intervals) in survivors and nonsurvivors over the first 8 years of follow-up based on a simple random effects model of baseline age, sex, housing, and the interaction of each of these variables with follow-up time. The difference between the two groups in their aging-related trajectories of weight loss is striking, especially after 1985.

Table 3 contains the estimates for the simple relation of physical activity to baseline body weight and to weight change over the entire 12 years of follow-up. The regression estimates represent either the difference in body weight at baseline (total activity score (TAS)) or the change in the rate of weight loss (TAS \times \text{time}) per unit of increase in baseline total activity score. Among the combined cohort, active older people initially weighed more at baseline (1.29 pounds (0.59 kg)) than their less active counterparts, and the interaction of total activity score and follow-up time suggests that each unit of increase in baseline activity score attenuated the rate of weight loss by 0.16 pounds (0.07 kg) per year. This relation among the entire cohort, however, is explained almost entirely by the inverse relation of physical activity to the rate of weight loss among the nonsurvivors (beta = 0.20, 95 percent confidence interval (CI): 0.09, 0.31) and not among the survivors (beta = 0.05, 95 percent CI: −0.01, 0.11), confirming the effect modification of this relation by survival status, as well as possible confounding and/or effect modification by disability and chronic disease.

Regression estimates for the random effects model examining the dependence of the weight change trajectory on physical activity while adjusting for sociodemographic characteristics, mobility, chronic conditions, smoking, and the

![FIGURE 1. Distribution of total activity scores at baseline, New Haven Established Populations for the Epidemiologic Study of the Elderly, 1982. For reference, obtaining the median score of 2 could be accomplished by participating in a single activity, such as walking, “often in the past month.”](https://academic.oup.com/aje/article-abstract/159/8/759/91387)
interaction of each of these with follow-up time, as well as
the three-way interaction of physical activity, follow-up
time, and chronic conditions, are displayed in table 4.
Baseline age was inversely associated with body weight, as
each 1-year increase in age was associated with a body
weight lower by approximately 0.75 pound (0.35 kg) in
survivors (beta = –0.78, 95 percent CI: –1.12, –0.45) and
over 1 pound (0.51 kg) in nonsurvivors (beta = –1.12, 95
percent CI: –1.34, –0.91). Hence, older people started off
the follow-up period weighing less than their younger counter-
parts, and the magnitude of this inverse association was
greater among nonsurvivors compared with survivors. The
estimates for follow-up time and its second-order term repre-
sent the markers for aging in this model. The negative
regression coefficients for the linear term in both survivors
(beta = –0.25, 95 percent CI: –0.73, 0.24) and nonsurvivors
(beta = –2.31, 95 percent CI: –3.14, –1.47) and the quadratic
term in survivors (beta = –0.04, 95 percent CI: –0.06, –0.03)
and nonsurvivors (beta = –0.13, 95 percent CI: –0.16, –0.09)
indicate a curvilinear slope for weight loss during follow-up.
Among the survivors, however, the magnitude of weight loss
was significantly dependent upon the presence of a chronic
condition. Survivors with a chronic condition who reported
no physical activity initially lost about 0.5 pound (0.25 kg)
[beta (time) + (time²) + (chronic condition × time) = –0.25 +
–0.04 + –0.34 = –0.63] in the first year of follow-up. Weight
loss over time in the nonsurvivors was not dependent on
a chronic condition. Indeed, nonsurvivors reporting no activity
lost about 2.5 pounds (1.14 kg) [beta = –2.31 + –0.13 + –0.08
= –2.52] in the first year of follow-up. The statistically
significant quadratic term for “time” in the modeling
suggests that the amount of weight loss accelerated in both
survivors and nonsurvivors over the course of follow-up.
Each 1-unit increase in baseline total activity score corre-
sponded to a baseline body weight lower by about 0.25
pound (0.11 kg) in survivors (beta = –0.25, 95 percent CI:
–1.43, 1.92) and about 1 pound (0.45 kg) in nonsurvivors
(beta = –1.03, 95 percent CI: –2.93, 0.87), although these
baseline differences did not reach statistical significance. As
indicated by the interaction term between total activity score
and follow-up time, each 1-unit increase in total activity
score significantly attenuated aging-related weight loss by
nearly 0.1 pound (0.04 kg) per year among the entire cohort
(beta = 0.09, 95 percent CI: 0.02, 0.15). Again, however,
there was marked effect modification by survival status and by chronic disease status, as the parameter estimate for the interaction term among physical activity, follow-up time, and chronic conditions was statistically significant among the survivors (beta = 0.12, 95 percent CI: 0.01, 0.24) but not among the nonsurvivors (beta = –0.10, 95 percent CI: –0.32, 0.12). Thus, among survivors, physical activity attenuates weight loss only in the presence of chronic disease, whereas among nonsurvivors, physical activity significantly attenuates weight loss whether or not chronic disease is present (beta (TAS × time) = 0.18, 95 percent CI: 0.00, 0.37).

Figure 3 presents the parameter estimates for the interaction term of total activity score and follow-up time from the fully adjusted random effects models for the combined cohort and then stratified by survival and chronic disease status, Established Populations for the Epidemiologic Study of the Elderly, 1982–1990. The parameter estimate represents the attenuation of weight loss (pounds/year of aging) per unit of increase in physical activity score at baseline. One pound = 0.45 kg.

### TABLE 4. Parameter estimates* from the random effects model determining the effects of physical activity on aging-related weight change, Established Populations for the Epidemiologic Study of the Elderly, 1982–1994

<table>
<thead>
<tr>
<th>Variable</th>
<th>Combined (n = 2,300)</th>
<th>Survivors (n = 905)</th>
<th>Nonsurvivors (n = 1,395)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parameter estimate</td>
<td>95% CI†</td>
<td>Parameter estimate</td>
</tr>
<tr>
<td>Baseline age</td>
<td>–1.04</td>
<td>–1.21, –0.87</td>
<td>–0.78</td>
</tr>
<tr>
<td>Time</td>
<td>–1.77</td>
<td>–2.19, –1.35</td>
<td>–0.25</td>
</tr>
<tr>
<td>Time²</td>
<td>–0.04</td>
<td>–0.05, –0.02</td>
<td>–0.04</td>
</tr>
<tr>
<td>Age × time</td>
<td>–0.07</td>
<td>–0.08, –0.05</td>
<td>–0.04</td>
</tr>
<tr>
<td>Chronic condition</td>
<td>3.94</td>
<td>1.73, 6.16</td>
<td>9.97</td>
</tr>
<tr>
<td>Chronic condition × time</td>
<td>–0.15</td>
<td>–0.36, 0.06</td>
<td>–0.34</td>
</tr>
<tr>
<td>Total activity score</td>
<td>–0.83</td>
<td>–1.76, 0.10</td>
<td>0.25</td>
</tr>
<tr>
<td>Total activity score × chronic condition</td>
<td>0.09</td>
<td>0.02, 0.15</td>
<td>–0.03</td>
</tr>
<tr>
<td>Total activity score × chronic condition × time</td>
<td>–0.91</td>
<td>–2.76, 0.95</td>
<td>0.12</td>
</tr>
<tr>
<td>Mobility</td>
<td>–3.41</td>
<td>–6.08, –0.74</td>
<td>–6.12</td>
</tr>
<tr>
<td>Mobility × time</td>
<td>0.36</td>
<td>0.09, 0.63</td>
<td>–0.22</td>
</tr>
<tr>
<td>Smoke × time</td>
<td>0.24</td>
<td>–0.02, 0.50</td>
<td>0.23</td>
</tr>
</tbody>
</table>

* Also adjusted for sex, race, education, height, functional disability score, and housing.
† CI, confidence interval.

**FIGURE 3.** Parameter estimates (95% confidence intervals) for the interaction term of physical activity and follow-up time from the fully adjusted random effects model for the combined cohort and then stratified by survival and chronic disease status, Established Populations for the Epidemiologic Study of the Elderly, 1982–1990. The parameter estimate represents the attenuation of weight loss (pounds/year of aging) per unit of increase in physical activity score at baseline. One pound = 0.45 kg.
cohort and then stratified by both survival status and the presence of chronic disease. As indicated, the benefit of physical activity to weight maintenance was evident only among older people with chronic disease, and this relation was most pronounced in those with chronic disease who did not survive the follow-up period.

**DISCUSSION**

The oldest people started off the follow-up period weighing less than their younger counterparts, and the magnitude of this inverse association between age and body weight at baseline was greater among nonsurvivors compared with survivors. Moreover, we observed a curvilinear rate of weight loss over the follow-up period that also varied by survival status and the presence of chronic disease. Survivors with chronic disease who reported no physical activity initially lost about 0.5 pound (0.25 kg), while nonsurvivors reporting no activity lost over 2.5 pounds (1.14 kg) in the first year of follow-up whether or not a chronic condition was present. This aging-related weight loss accelerated over the course of follow-up in both groups, but it was especially pronounced among nonsurvivors. Random effects modeling demonstrated the ability of physical activity to attenuate the rate of aging-related weight loss; however, the relation was observed among only those with chronic disease, and it was most evident in those with chronic disease who did not survive the follow-up period. This relation was independent of other factors known to affect both the ability to be physically active and the ability to maintain a healthy body weight, namely, smoking, and mobility. Together, these results suggest a positive role for even modest levels of physical activity in minimizing the rate of aging- and disease-related weight loss, at least among the less robust members of this cohort.

If we were to consider weight loss a somatic indicator of frailty in older people, it appears that, even among people afflicted with chronic conditions that contribute to frailty, an active lifestyle can attenuate the rate of failure, thereby maintaining some quality of health and function in older age. This particular finding merits future study. On the other hand, a higher physical activity score may simply reflect generally better health practices among older individuals with chronic disease (i.e., greater health services utilization, greater compliance, or a healthier diet), which themselves could have a positive effect on weight maintenance in older age. Unfortunately, we did not measure these other positive health behaviors, and therefore we cannot account for their contribution to this analysis.

Several cross-sectional analyses using population-based databases have demonstrated an inverse graded association between age and body weight among populations aged more than 65 years (1–4). Data from the present analysis of the New Haven EPESE cohort confirm this cross-sectional trend and verify its continuation throughout older ages (i.e., beyond 75 years). Cross-sectional data may not accurately reflect the true longitudinal relation between age and body weight, however, as they are unable to minimize the contribution of selective survival and, therefore, may underestimate the true effect of aging on weight loss. Longitudinal analysis of repeated weight assessments using a random effects model reduces the bias caused by selective survival, since it allows for the inclusion of body weight data collected in individuals who were eventually lost to death during the follow-up. On the other hand, including sicker, frailer people in the estimation of longitudinal change may exaggerate these changes with age among the entire cohort. For example, if frailer, older people are unable to be physically active and are losing weight secondary to chronic disease, the benefits of physical activity to attenuated weight loss may be overestimated among the entire cohort. We addressed this issue by stratifying the analysis by survival status and chronic disease status, as well as by adjusting for the confounding influences of age, smoking, and mobility. Moreover, persons who were excluded at baseline because of missing weight or other information had significantly more chronic conditions and functional disability compared with those remaining for study in 1982. Thus, we are confident that the sickest members of the EPESE New Haven cohort were excluded at baseline from any analyses and, therefore, could not have influenced the results.

Unfortunately, there have been few longitudinal studies of body weight loss in older people; however, the studies that do exist confirm that body weight decreases with aging after about the seventh decade (5–9, 12, 37). Biracial data from the Charleston Heart Study (8) of people aged 65–74 years at baseline show a median weight loss of 29 pounds (13 kg) over 25 years of follow-up, which corresponded to a rate of 1.1 pounds (0.55 kg) per year. Among the combined New Haven EPESE cohort, we observed an average loss greater than 1.5 pounds per year (0.55 and 2.52 pounds in survivors and nonsurvivors, respectively) that was not dependent on sex. Dey et al. (9) showed that Swedish adults lost weight between the ages of 70 and 80 years at a rate between 0.5 and 1.76 pounds/year (0.23–0.80 kg/year), which was also in agreement with our analysis.

To our knowledge, this is the first longitudinal study to determine the relation between physical activity and weight loss in an older cohort. We hypothesize that, in older age, physical activity may be less effective in preventing the excess accumulation of body fat and more instrumental in preserving lean mass, thereby attenuating weight loss and consequent frailty. To date, however, there is little evidence from population-based studies demonstrating an ability of physical activity to preserve entirely lean mass in old age. A cross-sectional analysis of subjects over 60 years using doubly labeled water to measure energy expenditure from physical activity revealed that a physically active lifestyle does not appear to prevent the aging-related decline in fat-free mass (38); rather, it can only attenuate this decline in varying degrees. Likewise, Forbes (39) reviewed data from several small longitudinal studies and concluded that, when an underlying weight loss occurs, exercise alone cannot reverse the loss of lean mass.

There are several other limitations to the analysis that must be noted. First, we relied on the self-report of body weight, which could have been either under- or overreported for any given subject. However, to the extent to which the tendency to under- or overreport body weight remained constant within each individual over time, the potential bias is mini-
mized in analyses of serial assessments such as ours. Second, the accuracy of recall of physical activity is problematic in any study, especially in studies of older people. Nevertheless, the use of crude categories of activity (e.g., walking, gardening/housework, physical exercises, and active sports/swimming) with simple interval responses in the New Haven EPESE cohort has previously demonstrated predictive validity (32, 33). Finally, dietary intake has a strong influence on the relation between physical activity and weight change. No information was collected on diet and, therefore, we cannot account for its contribution to weight loss with aging in this particular cohort of older people.

These findings suggest that body weight decreases with age in older individuals and that physical activity plays an important role in minimizing this rate of weight loss, although the degree to which this occurs varies significantly by survival and chronic disease status. Indeed, this relation was not apparent in healthy survivors and was most apparent in those with chronic disease who did not survive the follow-up period. Thus, even among trailer, older people, a physically active lifestyle in older age can minimize the weight loss that often accompanies chronic disease, thereby maintaining some degree of health and function toward the end of the life span.

ACKNOWLEDGMENTS

Supported by grant NIA AG-00153 to Dr. Kasl and by grant AG-17163 to Dr. DiPietro. The authors gratefully acknowledge the contributions of the Yale Health and Aging Project research staff. They would also like to thank Dr. Theodore Holford and Dr. Steven N. Blair for their thoughtful contributions to the manuscript.

REFERENCES