Glasgow Caledonian University

University for the Common Good

Fatigue may contribute to reduced physical activity among older people: an observational study

Egerton, Thorlene; Chastin, Sebastien F. M.; Stensvold, Dorthe; Helbostad, Jorunn L.

Published in:
Journals of Gerontology, Series A

DOI:
10.1093/gerona/glv150

Publication date:
2015

Document Version
Peer reviewed version

Citation for published version (Harvard):
Egerton, T, Chastin, SFM, Stensvold, D & Helbostad, JL 2015, 'Fatigue may contribute to reduced physical activity among older people: an observational study', *Journals of Gerontology, Series A*, vol. 71, no. 5, pp. 670-676. https://doi.org/10.1093/gerona/glv150

Journals of Gerontology: Medical Sciences
cite as: *J Gerontol A Biol Sci Med Sci*, 2015, 1–8
doi:10.1093/gerona/glv150
Advance Access publication September 7, 2015

Research Article

Fatigue May Contribute to Reduced Physical Activity Among Older People: An Observational Study

Thorlene Egerton,[1] Sebastien F. M. Chastin,[2] Dorthe Stensvold,[3] and Jorunn L. Helbostad[1,4]

[1]Department of Neuroscience, Faculty of Medicine, Norwegian University of Science and Technology, Trondheim, Norway. [2]School of Health and Life Science, Institute of Applied Health Research, Glasgow Caledonian University, UK. [3]K.G. Jebsen Center of Exercise in Medicine, Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway. [4]Department of Clinical Services, St. Olav University Hospital, Trondheim, Norway.

Address correspondence to Thorlene Egerton, PhD, Department of Neuroscience, Faculty of Medicine, Norwegian University of Science and Technology, Trondheim N-7489, Norway. Email: thor@sutmap.com

Received February 11 2015; Accepted July 29 2015

Decision Editor: Stephen Kritchevsky, PhD

Abstract

Background. Fatigue is one of the most commonly reported symptoms in primary care and perceived by older people as an overwhelming and distressing experience that restricts their activity and social participation. Self-reported fatigue is complex and multifactorial, with relatively little known about the causes and impacts among older people. This study tested the association between fatigue and objectively measured physical activity in a large cohort of older adults and identified factors that may explain this association.

Methods. Using cross-sectional data from 980 community-living 70- to 77-year-olds, the associations between self-reported fatigue and four physical activity outcomes derived from an accelerometer-based activity monitor were tested. Attenuating effects on the association of age, gender, body mass index (BMI), physical condition, comorbidity, depression, and sleep quality were evaluated.

Results. Nine percent of the sample reported being fatigued. Fatigued individuals had 1,150 fewer steps/day, 9 minutes/day less of moderate–vigorous activity, 12 minutes/day less of daily activity, and 15% fewer counts/minute, when compared with those not fatigued. BMI, physical condition, and comorbidity attenuated the association, and final regression models including these variables explained most (56%–72%) of the association between fatigue and activity.

Conclusions. Fatigue was associated with clinically important reductions in daily physical activity levels of older people. The findings show BMI, physical condition (in particular cardiorespiratory fitness), and comorbidity to be important factors in explaining the fatigue–physical activity association. Modification of these factors may facilitate increases in daily activity levels by lessening fatigue.

Key words: Fatigue—Physical activity—Exercise—Aging—Cardiorespiratory fitness

Fatigue, or tiredness, is one of the most commonly reported symptoms in primary care (1). The prevalence of self-reported fatigue among older people is at least 25% in primary care settings (2) and much higher, up to 98%, in long-term care (3). The type of fatigue referred to in this study is that defined by Ream and Richardson (4) as "A subjective unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion, creating an unrelenting overall condition which interferes with individuals' ability to function to their normal capacity." This type of fatigue is generally agreed to be dynamic in nature, appears to serve no useful purpose, affects functioning and quality of life, and is complex and difficult to describe (5–8). Such fatigue problems often are largely unexplained. Longitudinal studies have shown that fatigue may be present before the onset of disability and morbidity (9,10). Fatigue has also been shown to predict future mortality (11) and has been given by older people as a reason for activity restriction and poor compliance with exercise interventions (12,13). The presence of fatigue may therefore contribute to a cycle of decline.

Sources of fatigue remain unclear and may include aging, obesity, depression, poor sleep, poor physical condition, and/or specific diseases known to lead to fatigue symptoms (14). Fatigue is a cardinal symptom in several diseases (eg, cancer, multiple sclerosis) and is frequently experienced secondary to many other diseases. For this reason, older people with comorbidities are likely to be at higher risk of experiencing fatigue.

All people experience acute fatigue related to physical activity. This activity-related fatigue is for most people a normal experience and is relatively rapidly relieved by rest. However, the level of fatigue is dependent on physical condition such that in deconditioned older people, daily household and self-care tasks may lead to more persistent, overall feelings of fatigue (15). This vulnerability to tiredness from physical activity, as well as poor sleep quality, depression, and comorbidity, may all contribute to fatigue scores (16).

Although there is little known about the relationship between fatigue and physical activity levels in older people, studies have shown a relationship in several disease populations (17–21). An association has been demonstrated between fatigue and self-reported physical activity in cohorts including older people (22). However, self-report activity largely comprises leisure-time activity and exercise and excludes daily activities, which comprise the largest proportion of physical activity accumulated by older people (23). This study aimed to further explore the association in a large cohort of older people using objectively measured daily physical activity. The study objectives were to test the hypotheses that (a) higher levels of self-reported fatigue would be associated with lower levels of physical activity and that (b) high body mass index (BMI), poor physical condition, depression, poor sleep, and higher prevalence of comorbidities would attenuate this association.

Methods

Participants and Procedures

The data used for this study were collected as part of the Generation 100 study (ClinicalTrials.gov, Identifier: NCT01666340), which was an exercise intervention study carried out in Trondheim, Norway. The primary aim of the Generation 100 study was to evaluate the effects of exercise training on mortality, with secondary aims to investigate the effects on morbidity, physical function, and activity outcomes. All men and women born in the years 1936 to 1942 with a permanent address in the municipality of Trondheim, Norway (n = 6966) were invited to participate in the study. In total, 1,567 older adults were included and randomized to one of two exercise interventions or to a control group (Figure 1). Data from the baseline assessments were used for this study. Assessment included performance-based tests, blood samples, and questionnaires, which included sociodemographic factors, self-reported health status, cardiac risk factors, fatigue, depression, and sleep quality. At baseline, most participants (depending on availability of monitors) were given an ActiGraph GT3X (ActiGraph, Pensacola, FL) tri-axial accelerometer-based device to wear continuously on their right hip (apart from during water-based activities) for 7 consecutive days. The number of people who had valid ActiGraph and data and completed questionnaires determined the sample size for this analysis.

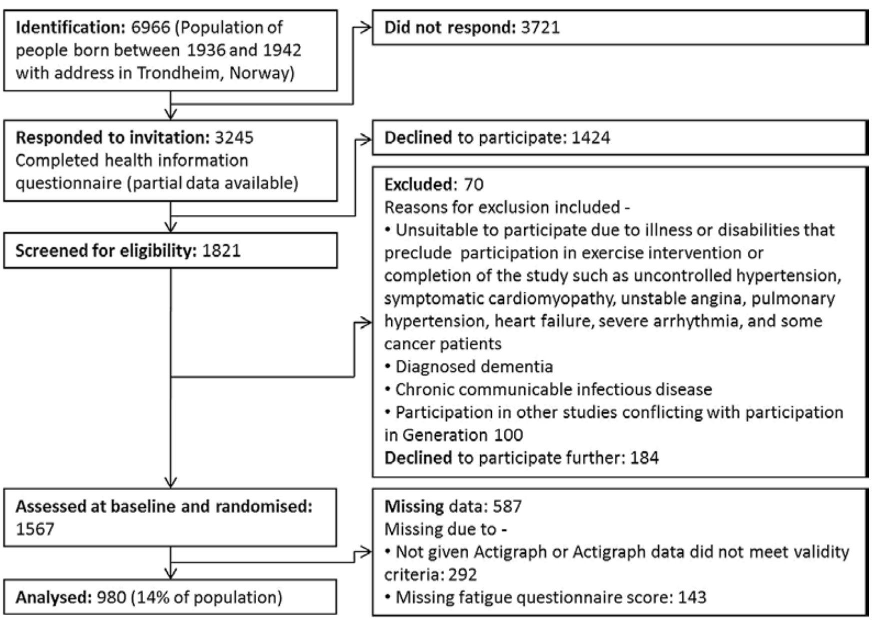

Figure 1. Flow chart of study participants and reasons for noninclusion in the analyses.

All participants gave written informed consent. Ethical approval for the study was granted by the Norwegian Ethical Review Board for Medical and Health Research (REK 2012/381B and 2013/787B). The conduct and reporting of this study were in compliance with the STROBE Statement (24).

Variables

Measurement methods are described briefly in the following section with further details provided as Supplementary Material A. Fatigue was measured using the 7-item Norwegian version of the Fatigue Severity Scale (FSS) (25) (Supplementary Material B). The scale returned scores between 7 (no fatigue) and 49 (extreme fatigue). The psychometric properties of validity, reliability (25), and cross-cultural validity for the Norwegian translation (26) have been reported. The FSS was originally validated in a chronic illness population and has been extensively used in neurological disease and chronic fatigue as well as in a few general population samples (27). Construct validity was endorsed by showing differences between controls and patients and detecting change when fatigue was predicted to change (25). Participants with at least four responses were included, with the average score replacing up to three missing responses. Based on the findings of several previous reports, a cutoff of ≥28 is used to indicate problematic fatigue (28) and has been previously shown to be suitable for distinguishing patients with and without fatigue (25,29,30). Thus, for this analysis, scores from 7 to 27 indicated "no fatigue," whereas scores from 28 to 49 were categorized as "fatigue."

Self-reported health problems (score range 0–9), and the number of prescription medications being taken, were recorded via questionnaires. Depression was measured with the Hospital Anxiety and Depression Scale (31), and a sleep score was calculated from three questions.

Physical condition was assessed using a repeated sit-to-stand task (StS), which measured functional leg strength (32). Average peak speed from five trials was calculated.

Cardiorespiratory exercise testing was carried out to determine VO_{2peak} (mL/kg/min). VO_2 testing began with a 10-minute warm-up on a treadmill (or stationary cycle if walking was difficult or painful). The warm-up was followed by a further 3 minutes at Borg Rating of Perceived Exertion level 11. Load was then increased by one increment (1-km/h increase in speed, 2% increase in inclination, or 10-watt increase if cycling). After 2 minutes at this first load increase, load was then increased when oxygen uptake was stable or approximately every 90 seconds. Load increases were continued until exhaustion (VO_{2peak}) or until the true VO_{2max} was reached. The variables from the gas analyzer were recorded every 10 seconds, and $VO_{2maxpeak}$ was calculated as the average of the three highest consecutive VO_2 values.

The ActiGraph GT3X records acceleration as activity counts and provides an estimate of the intensity of free-living bodily movement (particularly ambulatory movement). Activity counts correlate well with energy expenditure when walking at different speeds and gradients (33). Recorded data were downloaded using ActiLife software (ActiGraph, Pensacola, FL) and processed at an epoch duration of 10 seconds (Supplementary Material A).

The following outcomes representing free-living physical activity levels were derived:

1. *Steps per day*: The number of steps was divided by the number of valid days for daily ambulatory activity.
2. *Minutes of moderate and vigorous physical activity (MVPA) per day.* Counts per epoch were summed for each minute of valid data to indicate minute-by-minute physical activity intensity related to energy expenditure. The number of minutes per day that the counts per minute (CPM) was greater than 1,952 (34) was calculated. This value provides an estimation of moderate and higher intensity physical activity. The validity of using this cut point (absolute level of activity intensity) for identifying MVPA for older people with lower fitness has been questioned (35). However, it is a commonly used cut point and would undoubtedly represent higher intensity of activity for older people.
3. *Minutes of daily physical activity (DPA) per day*: The number of minutes per day that the CPM was greater than 760 (36) was calculated. This value was used to provide an estimation of daily activity. Time spent at 760 CPM or more represents activity above a light level in adult populations (34) and was considered to be an appropriate cut point for estimation of health-enhancing daily activity of older people.
4. *Average CPM*. Average CPM was used as it gives a reasonable estimation of the overall energy expenditure of participants.

Statistical Analysis

Each outcome was compared between groups according to whether or not they had fatigue and (where data were available) whether or not they were included in this study, using *t* tests, Mann–Whitney *U* tests, and Chi-squared tests as appropriate. The associations between fatigue and the four physical activity outcomes were tested using univariable linear regression analyses (Step 1 models) in SPSS Statistics 21 (IBM Corp, Armonk, NY). The models were then individually adjusted for each of gender, age, BMI, StS speed, VO_{2peak}, comorbidity (the number of prescription medications and health problems), depression, and sleep score (Step 2 models). Medications and health problems were expected to covary and were therefore entered together. Variables that were found to modify the association between fatigue and physical activity in these Step 2 models were entered into a final multivariable model together with fatigue (Step 3 models) to determine the extent to which the fatigue–physical activity association could be explained. Colinearities in the final models were checked using variance inflation factors (scores >5 indicated substantial colinearity). Residuals were inspected for normality of distribution and outliers.

An additional sensitivity analysis was carried out to ascertain the robustness of the results. The crude association between fatigue and physical activity (Step 1 models) was repeated including the participants who had fatigue and physical activity data available, but were omitted from the main analysis because of other missing outcomes.

Results

Descriptive data are shown in Table 1. Of the 980 participants analyzed, 9% reported fatigue as defined by a score of ≥28 on the FSS. The proportion of women was higher in the group reporting fatigue than in the group not reporting fatigue. Of the 442 people who answered the questionnaires but did not have activity data, 57 (13%) reported fatigue. Those not included in the analysis were also slightly older, more likely to be obese, and had slower StS speed than those included (Table 1).

For all activity outcomes, fatigue was associated with lower levels of physical activity (results of Step 1 models shown in Table 2 and Figure 2). BMI, StS speed, VO_{2peak}, and the number of prescription medications all attenuated the association. Depression, sleepiness, and the number of self-reported health problems had minimal effect on the association (results of Step 2 models provided in

Table 1. Descriptive Data for All Participants in the Study, and Participants Separated According to Fatigue. Data Are Also Shown for Those Not Included in the Analysis Due to Missing Outcome Variables

	Participants	Fatigue	No Fatigue	Others Not in Analysis
	(*n* = 980)	(*n* = 87)	(*n* = 893)	
Age, mean ± *SD* years*	73.4 ± 1.9	73.7 ± 2.0	73.4 ± 1.9	73.8 ± 2.0 (*n* = 1797)
Gender, *n* (%) female*,†	471 (48%)	54 (62%)	417 (47%)	1112 (54%) (*n* = 2049)
BMI, mean ± *SD*†	25.9 ± 3.4	26.7 ± 4.3	25.8 ± 3.3	26.2 ± 4.7 (*n* = 1916)
BMI: Underweight, *n* (%)	29 (3%)	4 (5%)	25 (3%)	64 (3%) (*n* = 1916)
BMI: Overweight, *n* (%)	454 (46%)	41 (47%)	413 (46%)	841 (44%) (*n* = 1916)
BMI: Obese, *n* (%)*,†	111 (11%)	18 (21%)	93 (10%)	278 (15%) (*n* = 1916)
StS peak speed, mean ± *SD* m/s*	1.08 ± 0.23	0.97 ± 0.25	1.09 ± 0.23	1.02 ± 0.25 (*n* = 631)
VO_{2peak} (mL/kg/min), mean ± *SD*†	29.1 ± 6.6	25.5 ± 6.7	29.5 ± 6.4	27.6 ± 6.2 (*n* = 584)
Number of self-reported health problems, mean ± *SD*†	2.1 ± 1.7	2.9 ± 2.1	2.0 ± 1.6	2.3 ± 1.9 (*n* = 598)
Number of prescribed medications, mean ± *SD*†	2.1 ± 1.8	2.7 ± 2.1	2.0 ± 1.8	2.3 ± 2.1 (*n* = 522)
Depression, mean ± *SD* (HAD depression subscale)†	9.7 ± 2.3	11.2 ± 2.6	9.6 ± 2.2	9.8 ± 2.4 (*n* = 616)
Sleep score, mean ± *SD*†	5.2 ± 1.4	6.1 ± 1.5	5.1 ± 1.3	5.1 ± 1.4 (*n* = 567)
Steps/day, mean ± *SD*†	6466 ± 2385	5413 ± 2202	6563 ± 2379	6341 ± 2395 (*n* = 272)
Minutes >1,952 CPM/day, mean ± *SD*†	37 ± 21	29 ± 20	38 ± 21	35 ± 20 (*n* = 293)
Minutes >760 CPM /day, mean ± *SD*†	92 ± 35	81 ± 38	93 ± 35	90 ± 35 (*n* = 293)
Average CPM, mean ± *SD*†	213 ± 87	183 ± 75	216 ± 88	205 ± 82 (*n* = 293)
Fatigue ≥28, % (FSS)*	8.9%	N/A	N/A	57, 13% (*n* = 442)

Notes: BMI = body mass index; CPM = counts per minute; FSS = Fatigue Severity Scale; HAD = Hospital Anxiety and Depression scale; StS = sit-to-stand task. BMI underweight = <20, BMI overweight = 25–30, BMI obese = >30, self-reported health problems score range 0–12, HAD depression score range 7–28, sleep score range 3–9, FSS score range 7–49, Fatigue = FSS ≥ 28.

*$p < .05$ for test of difference between participants in analysis and others not included in analysis, using *t* test, Mann–Whitney *U* test or chi-squared test as appropriate.

†$p < .05$ for test of difference between participants with and without fatigue.

Supplementary Material C). The final Step 3 multivariable models therefore included BMI, StS speed, VO_{2peak}, and the number of prescription medications as covariates, and the adjusted fatigue–activity association explained around two thirds (56%–72%) of the unadjusted effect (results shown in Table 2).

For steps/day, the R^2 for fatigue in was .018 ($p < .001$), thus explaining less than 2% of the variation in steps/day. However, being fatigued was associated with 1,150 fewer steps/day, 17% less than the nonfatigue group's daily average (Table 2). The estimate was significant, but imprecise: 95% confidence interval (CI) approximately −1,700 to −600.

Fatigue was associated with about 9 minutes/day (24%) less MVPA and 12 minutes/day (13%) less DPA (Table 2). The R^2 for MVPA/day and DPA/day were .014 ($p < .001$) and .009 ($p = .002$), respectively. Average CPM was 33 counts (about 15%) lower among those reporting fatigue. R^2 was .012 ($p = .001$).

In all the models, the variance inflation factor scores were below 2.0, and the residuals were nearing normal distribution and considered acceptable.

Sensitivity Analysis

The repeat of the univariable linear regression analysis between fatigue and physical activity, which included the participants ($n = 120$) who had fatigue and physical activity data but were missing other outcomes (total $n = 1100$), showed that fatigue was associated with 1,172 fewer steps/day (β −.138, 95% CI −1689, −655), 8.6 minutes less of MVPA/day (β −.118, 95% CI −12.9, −4.3), 13.7 minutes less of DPA/day (β −.111, 95% CI −20.9, −6.4), and the average CPM was reduced by 35 counts (β −.114, 95% CI −52, −17). Eleven people (9%) in this added group reported fatigue. The point estimates were similar to the unadjusted associations in the main analysis supporting the primary findings.

Table 2. Results of Univariable (Step 1 Models) and Multivariable Regression Analyses With the Association Between Fatigue (Fatigue Severity Scale score ≥28/49) and Physical Activity Attenuated by the Confounders BMI, Physical Capacity (StS peak speed and VO_{2peak}), and Comorbidity (number of prescription medications; Step 3 models)

	Steps/day		Minutes MVPA/day		Minutes DPA/day		Average CPM	
	B	β	*B*	β	*B*	β	*B*	β
	(95% CI)	(*p* value)	(95% CI)	(*p* value)	(95% CI)	(*p* value)	(95% CI)	(*p* value)
Step 1 models								
Fatigue	−1,150	−.134	−8.8	−.118	−12.1	−.097	−33.4	−.109
	(−1,703, −598)	(<.001)	(−13.4,−4.1)	(<.001)	(−19.8, −4.3)	(.002)	(−52.6, −14.3)	(.001)
Step 3 models	(Adjusted R^2 = .193)		(Adjusted R^2 = .184)		(Adjusted R^2 = .122)		(Adjusted R^2 = .194)	
Fatigue	−514	−.060	−3.2	−.042	−4.2	−.034	−9.4	−.030
	(−1,026, −3)	(.049)	(−7.5,1.1)	(.149)	(−11.6, 3.3)	(.271)	(−27.0,8.2)	(.297)
BMI	−115	−.166	−0.9	−.141	−0.8	−.077	−3.6	−.142
	(−159, −71)	(<.001)	(−1.2,−0.5)	(<.001)	(−1.4, −0.1)	(.017)	(−5.1,−2.1)	(<.001)
StS peak speed, m/s	−294	.029	3.6	.040	1.4	.009	10.5	.028
	(−1,031, 443)	(.434)	(−2.7, 9.8)	(.262)	(−9.4, 12.2)	(.800)	(−15.1, 36.1)	(.422)
$VO_{2peak,}$ mL/kg/min	122	.335	1.0	.310	1.5	.272	4.3	.321
	(94, 150)	(<.001)	(0.8, 1.2)	(<.001)	(1.0, 1.9)	(<.001)	(3.3,−5.3)	(<.001)
No. of prescription medications	−77	−.058	−0.6	−.053	−1.6	−.083	−3.6	−.075
	(−159, 6)	(.069)	(−1.3, 0.1)	(.087)	(−2.9, −0.4)	(.010)	(−6.5,−0.7)	(.016)

Note: BMI = body mass index; CPM = counts per minute; DPA = daily physical activity; MVPA = moderate–vigorous physical activity, StS = sit-to-stand task.

Discussion

The study found significant associations between self-reported fatigue and all the physical activity outcomes examined in this community-living sample of 70- to 77-year-olds. Although the predictive ability of fatigue seems small, it represents around 1,000 fewer steps/day, 9 fewer minutes/day of MVPA, 12 fewer minutes/day of DPA, and 16% less energy expenditure. These values are clinically important given current knowledge of the health and well-being benefits of physical activity for older people. Walking less than 5,000 steps/day has been consistently associated with lower health-related quality of life, greater prevalence of cardiometabolic risk factors, and deleterious body composition indicators (37). Half of the people who reported fatigue in this study had a daily step count of below 5,000 (Figure 2), compared with only 28% of those not fatigued. For older people, every minute of higher intensity activity may be important (38), and many older people fail to reach the recommended 150 minutes MVPA/week. Recent evidence points to the value of lower intensity exercise to offset the negative effects of sedentary behavior (23,39,40), especially in populations at risk of both low compliance to moderate–intensity exercise recommendations and compensatory behaviors that can negate the effect of MVPA on some health outcomes (41). Finally, studies of free-living energy expenditure show protective effects of higher levels of expenditure regardless of type or intensity of the activity on mortality rate (23).

The association was attenuated by BMI, physical condition (both functional leg muscle strength and VO_{2peak}), and the number of prescription medications, a marker of comorbidity. These variables explained approximately two thirds of the association between fatigue and physical activity. In the final models, fatigue no longer had any independent association with activity. The attenuation of the association by physical condition supports our hypothesis that some of the fatigue reported by older people may be due to exercise-related fatigue in deconditioned people. Declines in strength, cardiorespiratory fitness, biomechanical efficiency (eg, because of high body mass (42)), and postural stability may result in activities of daily living requiring larger proportions of physical and energy reserves (15), and this in turn may result in the perception of persistent physical fatigue (5,43). The association between a measure representing available energy and physical activity levels was shown to be particularly strong for those with the lowest fitness (44). Thus in those with perceived limitations in available energy (fatigue) and/or real limitations (physical decondition), accumulation of physical activity may be particularly unappealing or challenging. In this scenario, fatigue may lie on a causal pathway between physical condition and physical activity. In the final model with both StS speed and VO_{2peak}, StS speed was no longer independently associated with activity, suggesting that cardiovascular fitness was the key physical condition predictor.

Although a substantial portion of the association between fatigue and physical activity is explained by physical condition, in particular cardiorespiratory fitness, there appear to be other factors that also attenuate the relationship. BMI may be an important modifier for similar reasons to physical condition. Excessive weight leads to biomechanical inefficiency during daily tasks (45), and studies suggest high levels of body fat may have a direct influence on limiting mobility (42). Larger proportions of physical reserves would be needed for daily activities, and therefore, higher levels of fatigue may be experienced by people with overweight and obesity. Alternatively, because obesity is associated with a chronic inflammatory response where adipose tissue is a key component in the abnormal production of cytokines and acute-phase reactants, and in the activation of pro-inflammatory signaling pathways (46,47), obesity may also be related to fatigue because of increased inflammation (14).

Aging processes are thought to be responsible for some unexplained fatigue among older people (5,48). Chronological age had a small association with both activity and with fatigue in this study. Age may have explained more of the association between fatigue and physical activity if this study had included a wider age range. Contrary to our expectations, the fatigue–activity association was not explained or modified by depression or poor sleep quality. Both are known to be closely related to self-reported fatigue (2,49), however, they appear to play a lesser role in predicting physical activity levels than fatigue.

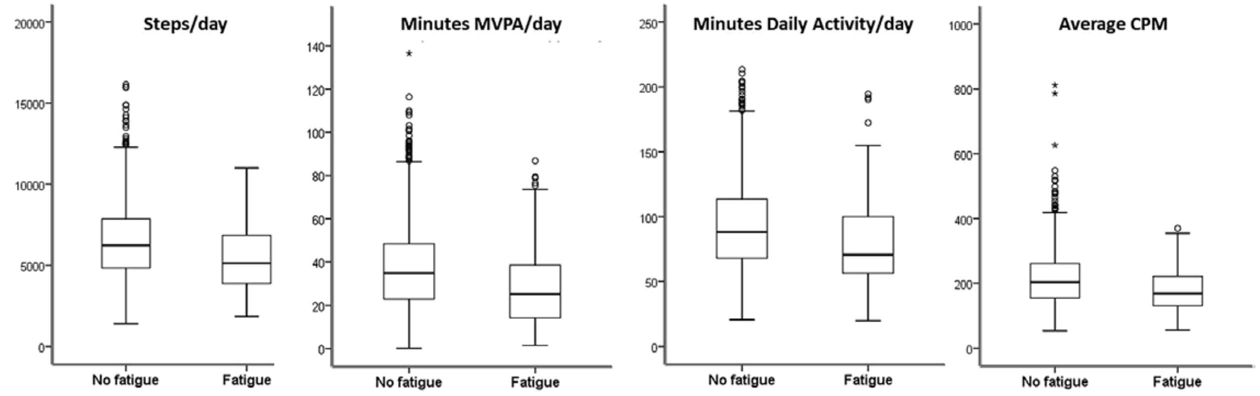

Figure 2. Activity outcomes for the cohort grouped according to whether they reported fatigue.

The associations found in the present study do not confirm whether fatigue is a cause of lower physical activity levels or a result of inactivity. Our approach in this study takes the view that fatigue could be a determinant of physical activity. It is well known that genetic factors contribute significantly to cardiorespiratory fitness (50), the largest explanatory variable in this study. However, it is possible that reduced activity could lead to loss of physical capacity and hence increased inactivity-related fatigue through a reversed causal pathway. Repeated measures over time would strengthen considerably our appreciation of the relationship between fatigue and physical activity. Further to this, self-reported fatigue can fluctuate over time (9), and understanding how changes in physical activity patterns relate to fluctuations in fatigue report warrant further investigation.

There are many determinants of physical activity not included in our models (51). In our study, we included factors we hypothesized would have an influence on whether or not an older person reports fatigue in order to assess the influence of these factors on the association between fatigue and physical activity. Fatigue may lead to lower motivation to be physically active and motivational factors have been shown to play an important role in determining physical activity levels of older people (51). In addition, studies on patients with osteoarthritis (18,52) have demonstrated that the relationship between fatigue and physical activity is moderated by coping strategies and self-efficacy. Central mechanisms such as psychosocial and motivational factors may therefore be important in understanding the relationship between fatigue and physical activity found in this study and warrant further research.

The sample in this study cannot be considered representative of all older people. Participants were a relatively healthy sample of the population in this community, as people unwilling or unable for health reasons to participate in a physical activity program were excluded. In addition, the sample included in the analysis appeared to be a slightly healthier subsample of the Generation 100 cohort. The recruitment strategy is a potential source of bias. People who avoid physical activity because of fatigue may have been less likely to volunteer. The effect of this bias may have been simply to reduce the proportion of the sample with fatigue. However, if the sample included a bias toward those who have a tendency to "carry on regardless of their fatigue," the size of the association between fatigue and activity levels may have been underestimated.

The relatively healthy sample with low prevalence of fatigue affects the external validity of the findings to older people in poorer health. It is important to recognize that the relationship between fatigue and physical activity may be quite different for people with disabilities, people with significant chronic disease, and those living in noncommunity settings. In this group, physical activity participation would be challenged by many additional factors than those facing community-living older adults, such as movement difficulties, pain, and opportunity. The impact of fatigue for these groups should not be inferred from the presented findings.

The clinically important findings from this study are firstly that fatigue among generally well-functioning older people appears to be associated with physical activity, and secondly that BMI, physical condition (in particular VO_{2peak}), and comorbidity (specifically prescription medication usage) are potentially modifiable factors that appear to explain most of this association. Reducing BMI among those with overweight or obesity and/or improving cardiovascular fitness may ameliorate some of the impact of fatigue on activity levels. In addition, management of fatigue symptoms that result from disease processes, and avoiding combinations of medications that can cause the fatigue, may be important in preventing fatigue from restricting physical activity participation. Such efforts may assist in interrupting or delaying a fatigue-induced cycle of decline.

Supplementary Material

Supplementary material can be found at: http://biomedgerontology.oxfordjournals.org/

Funding

This work was supported by the K.G. Jebsen Center for Exercise in Medicine, the Health Authorities of Mid-Norway, Norwegian Women's Health Association [T. E.] and the Norwegian Extra Foundation for Health, and Rehabilitation through EXTRA funds [T. E.].

Acknowledgments

The authors wish to thank the Generation 100 Study group for collecting and sharing the data. They also thank all the participants.

Conflict of Interest

None to declare.

References

1. Wijeratne C, Hickie I, Brodaty H. The characteristics of fatigue in an older primary care sample. *J Psychosom Res*. 2007;62:153–158. doi:10.1016/j.jpsychores.2006.09.011

2. Hickie IB, Hooker AW, Hadzi-Pavlovic D, Bennett BK, Wilson AJ, Lloyd AR. Fatigue in selected primary care settings: sociodemographic and psychiatric correlates. *Med J Aust*. 1996;164:585–588.
3. Liao S, Ferrell BA. Fatigue in an older population. *J Am Geriatr Soc*. 2000;48:426–430. doi:10.1111/j.1532-5415.2000.tb04702.x
4. Ream E, Richardson A. Fatigue: a concept analysis. *Int J Nurs Stud*. 1996;33:519–529. doi:0020-7489(96)00004-1
5. Alexander NB, Taffet GE, Horne FM, et al. Bedside-to-Bench conference: research agenda for idiopathic fatigue and aging. *J Am Geriatr Soc*. 2010;58:967–975. doi:10.1111/j.1532-5415.2010.02811.x
6. Trendall J. Concept analysis: chronic fatigue. *J Adv Nurs*. 2000;32:1126–1131. doi:10.1046/j.1365-2648.2000.01583.x
7. Woo K. Fatigue in COPD. *Nurse Pract*. 1995;20:11.
8. Yu DS, Lee DT, Man NW. Fatigue among older people: a review of the research literature. *Int J Nurs Stud*. 2010;47:216–228. doi:10.1016/j.ijnurstu.2009.05.009
9. Avlund K, Pedersen AN, Schroll M. Functional decline from age 80 to 85: influence of preceding changes in tiredness in daily activities. *Psychosom Med*. 2003;65:771–777. doi:10.1097/01.PSY.0000082640.61645.BF
10. Ekmann A, Petersen I, Mänty M, Christensen K, Avlund K. Fatigue, general health, and ischemic heart disease in older adults. *J Gerontol A Biol Sci Med Sci*. 2013;68:279–285. doi:10.1093/gerona/gls180
11. Moreh E, Jacobs JM, Stessman J. Feeling tired predicts functional status, physical activity, and mortality in elderly people. *J Am Geriatr Soc*. 2009;57:742–743. doi:10.1111/j.1532-5415.2009.02214.x
12. Cooper KM, Bilbrew D, Dubbert PM, Kerr K, Kirchner K. Health barriers to walking for exercise in elderly primary care. *Geriatr Nurs*. 2001;22:258–262. doi:10.1067/mgn.2001.119470
13. Wilcox S, Der Ananian C, Abbott J, et al. Perceived exercise barriers, enablers, and benefits among exercising and nonexercising adults with arthritis: results from a qualitative study. *Arthritis Rheum*. 2006;55:616–627. doi:10.1002/art.22098
14. Valentine RJ, Woods JA, McAuley E, Dantzer R, Evans EM. The associations of adiposity, physical activity and inflammation with fatigue in older adults. *Brain Behav Immun*. 2011;25:1482–1490. doi:10.1016/j.bbi.2011.06.002
15. Richardson CA, Glynn NW, Ferrucci LG, Mackey DC. Walking energetics, fatigability, and fatigue in older adults: the study of energy and aging pilot. *J Gerontol A Biol Sci Med Sci*. 2015;70:487–494. 10.1093/gerona/glu146
16. Eldadah BA. Fatigue and fatigability in older adults. *PM R*. 2010;2:406–413. doi:10.1016/j.pmrj.2010.03.022
17. Larkin L, Kennedy N. Correlates of physical activity in adults with rheumatoid arthritis: a systematic review. *J Phys Act Health*. 2014;11:1248–1261. doi:10.1123/jpah.2012-0194
18. Murphy SL, Kratz AL, Williams DA, Geisser ME. The Association between symptoms, pain coping strategies, and physical activity among people with symptomatic knee and hip osteoarthritis. *Front Psychol*. 2012;3:326. doi:10.3389/fpsyg.2012.00326
19. Waschki B, Spruit MA, Watz H, et al. Physical activity monitoring in COPD: compliance and associations with clinical characteristics in a multicenter study. *Respir Med*. 2012;106:522–530. doi:10.1016/j.rmed.2011.10.022
20. Elbers R, van Wegen EE, Rochester L, et al. Is impact of fatigue an independent factor associated with physical activity in patients with idiopathic Parkinson's disease? *Mov Disord*. 2009;24:1512–1518. doi:10.1002/mds.22664
21. Tawashy AE, Eng JJ, Lin KH, Tang PF, Hung C. Physical activity is related to lower levels of pain, fatigue and depression in individuals with spinal-cord injury: a correlational study. *Spinal Cord*. 2009;47:301–306. doi:10.1038/sc.2008.120
22. Moreh E, Jacobs JM, Stessman J. Fatigue, function, and mortality in older adults. *J Gerontol A Biol Sci Med Sci*. 2010;65:887–895. doi:10.1093/gerona/glq064
23. Manini TM, Everhart JE, Patel KV, et al. Daily activity energy expenditure and mortality among older adults. *JAMA*. 2006;296:171–179. doi:10.1001/jama.296.2.171
24. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Epidemiology*. 2007;18:800–804. doi:10.1097/EDE.0b013e3181577654
25. Krupp LB, LaRocca NG, Muir-Nash J, Steinberg AD. The Fatigue Severity Scale. Application to patients with multiple sclerosis and systemic lupus erythematosus. *Arch Neurol*. 1989;46:1121–1123.
26. Lerdal A, Wahl A, Rustøen T, Hanestad BR, Moum T. Fatigue in the general population: a translation and test of the psychometric properties of the Norwegian version of the Fatigue Severity Scale. *Scand J Public Health*. 2005;33:123–130. doi:10.1080/14034940410028406
27. Whitehead L. The measurement of fatigue in chronic illness: a systematic review of unidimensional and multidimensional fatigue measures. *J Pain Symptom Manage*. 2009;37:107–128. doi:10.1016/j.jpainsymman.2007.08.019
28. Valko PO, Bassetti CL, Bloch KE, Held U, Baumann CR. Validation of the Fatigue Severity Scale in a Swiss cohort. *Sleep*. 2008;31:1601–1607.
29. Bakshi R, Miletich RS, Henschel K, et al. Fatigue in multiple sclerosis: cross-sectional correlation with brain MRI findings in 71 patients. *Neurology*. 1999;53:1151–1153. doi:10.1212/WNL.53.5.1151
30. Flachenecker P, Kümpfel T, Kallmann B, et al. Fatigue in multiple sclerosis: a comparison of different rating scales and correlation to clinical parameters. *Mult Scler*. 2002;8:523–526. doi:10.1191/1352458502ms839oa
31. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand*. 1983;67:361–370. doi:10.1111/j.1600-0447.1983.tb09716.x
32. Helbostad JL, Sletvold O, Moe-Nilssen R. Effects of home exercises and group training on functional abilities in home-dwelling older persons with mobility and balance problems. A randomized study. *Aging Clin Exp Res*. 2004;16:113–121. doi:10.1007/BF03324539
33. Hansen BH, Bortnes I, Hildebrand M, Holme I, Kolle E, Anderssen SA. Validity of the ActiGraph GT1M during walking and cycling. *J Sports Sci*. 2014;32:510–516. doi:10.1080/02640414.2013.844347
34. Freedson PS, Melanson E, Sirard J. Calibration of the computer science and applications, Inc. accelerometer. *Med Sci Sports Exerc*. 1998;30:777–781. doi:10.1097/00005768-199805000-00021
35. Gorman E, Hanson HM, Yang PH, Khan KM, Liu-Ambrose T, Ashe MC. Accelerometry analysis of physical activity and sedentary behavior in older adults: a systematic review and data analysis. *Eur Rev Aging Phys A*. 2014;11:35–49. doi:10.1007/s11556-013-0132-x
36. Matthew CE. Calibration of accelerometer output for adults. *Med Sci Sports Exerc*. 2005;37:S512–S522. doi:10.1249/01.mss.0000185659.11982.3d
37. Tudor-Locke C, Craig CL, Thyfault JP, Spence JC. A step-defined sedentary lifestyle index: <5000 steps/day. *Appl Physiol Nutr Metab*. 2013;38:100–114. doi:10.1139/apnm-2012-0235
38. Swain DP, Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *Am J Cardiol*. 2006;97:141–147. doi:10.1016/j.amjcard.2005.07.130
39. Duvivier BM, Schaper NC, Bremers MA, et al. Minimal intensity physical activity (standing and walking) of longer duration improves insulin action and plasma lipids more than shorter periods of moderate to vigorous exercise (cycling) in sedentary subjects when energy expenditure is comparable. *PLoS One*. 2013;8:e55542. doi:10.1371/journal.pone.0055542
40. Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined moderate intensity lifestyle activity and cardiometabolic health. *Prev Med*. 2011;52:358–360. doi:10.1016/j.ypmed.2011.01.030
41. Meijer EP, Westerterp KR, Verstappen FT. Effect of exercise training on total daily physical activity in elderly humans. *Eur J Appl Physiol Occup Physiol*. 1999;80:16–21. doi:10.1007/s004210050552
42. Visser M, Harris TB, Langlois J, et al. Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. *J Gerontol A Biol Sci Med Sci*. 1998;53:M214–M221. doi:10.1093/gerona/53A.3.M214
43. Schrack JA, Zipunnikov V, Goldsmith J, et al. Assessing the "physical cliff": detailed quantification of age-related differences in daily patterns of physical activity. *J Gerontol A Biol Sci Med Sci*. 2014;69:973–979. doi:10.1093/gerona/glt199
44. Schrager MA, Schrack JA, Simonsick EM, Ferrucci L. Association between energy availability and physical activity in older adults. *Am J Phys Med Rehabil*. 2014;93:876–883. doi:10.1097/PHM.0000000000000108
45. Ko S, Stenholm S, Ferrucci L. Characteristic gait patterns in older adults with obesity–results from the Baltimore Longitudinal Study of Aging. *J Biomech*. 2010;43:1104–1110. doi:10.1016/j.jbiomech.2009.12.004

46. Tilg H, Moschen AR. Adipocytokines: mediators linking adipose tissue, inflammation and immunity. Nature reviews. *Immunology*. 2006;6:772–783. doi:10.1038/nri1937
47. Wellen KE, Hotamisligil GS. Inflammation, stress, and diabetes. *J Clin Invest*. 2005;115:1111–1119. doi:10.1172/JCI25102
48. Avlund K. Fatigue in older adults: an early indicator of the aging process? *Aging Clin Exp Res*. 2010;22:100–115. doi:10.1007/BF03324782
49. Lim W, Hong S, Nelesen R, Dimsdale JE. The association of obesity, cytokine levels, and depressive symptoms with diverse measures of fatigue in healthy subjects. *Arch Intern Med*. 2005;165:910–915. doi:10.1001/archinte.165.8.910
50. Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Med Sci Sports Exerc*. 2001;33:S446–S451. doi:10.1097/00005768-200106001-00013
51. Franco MR, Tong A, Howard K, et al. Older people's perspectives on participation in physical activity: a systematic review and thematic synthesis of qualitative literature. *Br J Sports Med*. 2015. doi:10.1136/bjsports-2014-094015
52. Sperber N, Hall KS, Allen K, DeVellis BM, Lewis M, Callahan LF. The role of symptoms and self-efficacy in predicting physical activity change among older adults with arthritis. *J Phys Act Health*. 2014;11:528–535. doi:10.1123/jpah.2012-0030