SAGE-Hindawi Access to Research
Journal of Aging Research
Volume 2011, Article ID 651931, 10 pages
doi:10.4061/2011/651931

Research Article

Higher Levels and Intensity of Physical Activity Are Associated with Reduced Mortality among Community Dwelling Older People

Eva Hrobonova,[1] Elizabeth Breeze,[2] and Astrid E. Fletcher[3]

[1] *National Health Primary Care Trust Westminster, 15 Marylebone Road, London NW1 5JD, UK*
[2] *Department of Epidemiology and Public Health, University College London, 1-19 Torrington Place, London WC1E 6BT, UK*
[3] *Faculty of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK*

Correspondence should be addressed to Astrid E. Fletcher, astrid.fletcher@lshtm.ac.uk

Received 27 August 2010; Accepted 21 December 2010

Academic Editor: Ben Hurley

Introduction. There is limited evidence on physical activity and mortality in older people. *Methods*. People aged 75–84 years (n = 1449) participating in a randomized trial of health screening in UK general practice were interviewed about their physical activity (PA) and were assessed for a wide range of health and social problems. Mortality data were collected over 7 years of followup. *Results*. Full information on PA and potential confounders was available in 946 people. Those in the highest third of duration of PA had a lower mortality, confounder-adjusted Hazard Ratio (HR) = 0.74, and 95% Confidence Interval (CI) 0.56–0.97, compared to the lowest third. Similar benefits were seen when categorized by intensity of PA, with those in the highest group having a lower mortality, confounder-adjusted HR = 0.61, and 95% CI 0.47–0.79, compared to the lowest category. *Conclusions*. Our results suggest the importance of providing older people with opportunities for physical activity.

1. Introduction

Epidemiological evidence links many chronic diseases to physical inactivity [1, 2]. The benefits of increased physical activity and exercise and the harmful effects of inactivity are well recognized [3, 4]. Although studies of the general population show the positive effect of physical activity on both physical and psychological well-being in adults of all ages, relatively few studies have focused on the older age groups, specifically on those aged 75 years and over. Physical activity and its health effects are more complex in this age group reflecting changing physiology, and the higher likelihood of multiple morbidities. Regular physical activity brings a health benefit in terms of maintaining or increasing strength, power, endurance and flexibility of muscles even in the older elderly [4, 5]. It could be said to be more critical at older ages since everyone will lose strength over time and lack of activity can lead to poor bowel function, falls, and to deterioration in performance of daily activities such as dressing, climbing stairs or rising from a chair. Current public health recommendations for physical activity in the UK are at least 30 minutes of moderate intensity at least five times a week, and these are also recommended for people aged 65 and over [6, 7]. The World Health Organization recommends older people should take at least 30 minutes of aerobic exercise on most, if not all, days and strength training 2 to 3 days a week [8]. Observational studies of adult populations [9–15] have shown reduced or delayed risk of mortality with increased physical activity but included relatively small proportions of the oldest age group. Only four out of 22 large studies covered in a recent review of moderate activity included people aged 75 years and over [15]. This is a fast growing age group in many western countries but with the least evidence on physical activity. Even studies specifically in older people tend not to provide results for people aged 75 years upwards. Thus, more evidence is required for the oldest age group.

We investigated the association of physical activity and mortality in a community-based study of older people aged 75 to 84 years.

2. Methods

The Medical Research Council (MRC) Trial of the Assessment and Management of Older People in the Community was a cluster randomized trial in UK general practice aimed at evaluating the benefit of different approaches to the assessment and management of older people. Details of the MRC trial design and results have been reported elsewhere [16, 17]. The methods are summarized briefly below.

2.1. Study Participants. 106 practices from the MRC General Practice Research Framework were selected to provide a sample representative of the UK mortality experience (Standardized Mortality Ratio) and deprivation level (Jarman score based on the 1991 UK census data). All patients aged 75 years or over on the general practitioner lists were invited to participate in the trial unless they were in long-stay hospital or nursing homes or were terminally ill. Practices were randomised to "universal" or "targeted" assessment. In the "universal" arm all patients were invited to an in-depth assessment by the study nurse, while in the "targeted" arm only selected patients were invited. The in-depth assessment covered a wide range of physical, social, and psychological problems. Practices in the "universal" arm were asked to take part in a separately funded add-on study on nutrition and physical activity, to which 51 out of 53 agreed. In these practices, randomly selected persons aged 75–84 years from the lists of the 51 practices were invited for an interviewer-administered questionnaire on their diet and physical activity and to give a blood sample. Written informed consent was obtained from all participants, and all relevant ethics committees gave approval for the add-on nutrition and physical activity study.

2.2. Data Collection

2.2.1. In-Depth Assessment. Data were collected at the in-depth assessment by the study nurse through interviews and measurements. Sociodemographic data included marital status, living circumstances, frequency of seeing relatives and friends, and housing tenure. We used the MiniMental State examination (MMSE) [18] for cognitive impairment, the Geriatric Depression Scale (GDS) [19] for depression and the Rose Chest Pain questionnaire [20] for angina. Participants were asked whether they had been diagnosed by a doctor for a variety of conditions including cancer, diabetes, stroke and heart attack, hip fracture and emphysema. They were also asked whether they were able to carry out certain activities of daily living (ADL) including cutting toenails, dressing, cooking, doing housework, climbing stairs (with aids if necessary), washing, and walking 50 yards (with aids if necessary). Participants were asked about difficulties in hearing or reading newsprint, current and past smoking behavior, usual alcohol pattern and consumption of wine, beer and spirits over the previous week, and about any recent (in previous six months) serious indicators of poor health: unintentional weight loss (defined as 7 pounds (equivalent to 3.2 kg) or more) and number of falls. Physical measurements included height, weight, waist, and hip circumference, and sitting systolic and diastolic blood pressure. A non fasting blood sample was taken and sent for analysis for a routine biochemical screen and also for cholesterol (total, HDL and LDL). Participants were asked to bring all current medications to the assessment and details were recorded by the study nurse.

2.2.2. Physical Activity. We adapted questions from the Structured Physical Activity Questionnaire used in the Allied Dunbar National Fitness Survey [21]. Predominantly closed format questions were asked about daily activities such as walking (to shops and elsewhere), stair climbing, housework, indoor and outdoor maintenance and "do it yourself" (DIY) activities. Leisure activities such as gardening, sports and dancing were also recorded. Frequency (number of times per week/activity) and duration (in minutes per week) were recorded for most activities. Intensity was recorded for walking and housework and maintenance (speed of walking, light/heavy work). The activity recorded was that of an average week.

The interviews were carried out between 1995 and 1998 in patients' homes by trained staff from the UK Government's Office for National Statistics (ONS). ONS provided date of death and cause of death coded using the International Classification of Diseases, 9th revision (ICD-9) for deaths reported up to September 2002 and 10th revision (ICD-10) after that date.

2.3. Data Preparation. In order to investigate whether greater duration or greater intensity of physical activity (PA) is associated with mortality, we created two measures of physical activity—the total time spent on physical activity per week and the intensity of activities undertaken. The total amount of physical activity in minutes per week was calculated by adding the time (in minutes) spent on individual activities (e.g., walking, light and heavy housework and household maintenance/DIY, sport, and exercise) multiplied by their weekly frequencies. Gardening was recorded as a seasonal activity. In order to calculate minutes spent gardening in an average week in a year, we multiplied the reported time spent on gardening per week in summer/winter by the relevant number of weeks in that particular season and added these together to get the total time spent gardening in a year. Finally, we divided this by the number of weeks per year to get the average time spent gardening per week. The intensity of physical activity was calculated according to the type of activity performed: Category 1—light PA defined as time spent on feet while shopping, light housework and light maintenance, Category 2—moderate PA defined as time spent walking, for example, to shops and elsewhere, and gardening, Category 3—heavy PA defined as time spent on heavy housework, heavy maintenance/DIY, sport and exercise. Since some people performed activities falling into more than one of the above categories, intensity was subsequently recategorized into 3 exclusive categories: "l;ow" (any light PA but not medium or high PA, <60 minutes of moderate PA, no heavy PA), "medium" (≥60 minutes of moderate PA, no heavy PA), "high"(any amount of heavy PA). Total physical activity time in minutes per week was categorized by tertiles.

Data from the in-depth assessment were summarized as follows: body mass index (BMI) (weight/height^2) and waist to-hip ratio (WHR) categorized in sex-specific quintiles; alcohol consumption (total units drunk in the previous week); smoking history (never, ex and current), marital status (single, married, widowed, divorced), housing tenure (owner, rental, and assisted), living alone or with others, seeing people other than spouse (daily, 2-3 times per week, more than twice a week, and rarely), cognitive impairment categorized as normal or mild, moderate and severe (MMSE > 17, >12 and <17, ≤12, resp.), depression (score of >5 on GDS), history of cardiovascular disease (heart attack, stroke, or angina), unable to do >1 ADL, number of falls; and whether taking prescribed medicines or not. The Carstairs local area deprivation score was obtained by linking the participants' postcodes to national census data [22]. We categorized the Carstairs score based on the UK quintiles of distribution.

2.4. Statistical Analysis. Analyses were performed using Stata 10 software using the "svy" command on a weighted sample (pweight command) to take account of the cluster (general practice) sample design. Cox proportional hazards was used to investigate the association of PA with mortality based on deaths reported by ONS up to the end of September 2005. The proportional hazards assumptions for different levels of total physical activity and intensity were tested by plotting the Nelson-Aalen proportional estimates of the hazard function.

Univariable descriptive analysis was first undertaken to describe the relationship between physical activity (total PA and intensity of PA) and mortality. Characteristics of participants by thirds of total PA or by intensity category were examined using tests for linear trend. Potential confounders and possible causal pathways variables from the in-depth assessment were selected *a priori* on their expected relationship with physical activity and mortality.

Analyses were performed for all participants (n = 1449) and also for participants with a full set of physical activity, socioeconomic and health assessment data (n = 946) to allow for full adjustment for potential confounding. Three models were used. Model 1 adjusted for age and sex only. Model 2 adjusted for possible confounders including socioeconomic and psychosocial factors. Variables initially considered for inclusion in model 2 were BMI, WHR, units of alcohol, smoking, GDS, Carstairs index, marital status, housing tenure, living alone, and frequency of contact with people. Model 3 additionally included variables that could be on the causal pathway. Variables initially considered for inclusion in model 3 were: LDL and HDL cholesterol, self reported doctor diagnosis of emphysema, cancer, diabetes, CVD, hip fracture, ADLs hearing and seeing difficulties, number of falls, unintentional weight loss, medication and MMSE. Variables were dropped from the models if the P value was >0.1 and the hazard ratios for physical activity were not changed by more than 5%.

3. Results

Of the 2959 people randomly sampled, 2040 were eligible to take part in the physical activity survey, 587 did not respond and 1453 completed the interview. A further 4 subjects with insufficient data were excluded from the analysis at the data cleaning stage. Compared to responders, nonresponders were more likely to be women (63% of nonresponders compared to 55% of responders) ($P < .01$) and current smokers (16% of nonresponders compared to 11% of responders) ($P < .01$); the mean ages were similar in non responders (79.4 years) compared to responders (79.0 years). In analyses adjusting for age and sex, there were no differences by response for BMI, history of CVD, cancer, hip fracture, weight loss, alcohol consumption, difficulty with ADLs, marital status or living alone. Nonresponders had slightly higher GDS scores (2.2 in nonresponders compared to 1.9 in responders) ($P = .03$) and slightly lower MMSE scores (25.6 in nonresponders compared to 26.3 in responders) ($P = .03$). There was no differences in the mortality rates between responders and non responders either in crude analyses or analyses adjusted for age, sex and smoking. There were 946 participants with complete data on baseline characteristics and confounding factors (65% of the people who completed the interview). The characteristics of this subsample were similar to those in the full sample (n = 1449) (Table 1). The median followup time for mortality was 7.8 years. Of those with data on all characteristics 453 (47.9%) had died by the end of September 2005 (Table 2). Nearly a half (49.8%) of the total sample and a similar proportion (49.2%) of the subsample reported levels of moderate or high physical activity which were less than the current UK minimum recommendations of 5 × 30 minutes per week. Apart from other daily physical activities, 25% of the sample total and 24% of the subsample did sport and exercise, mainly weekly exercises/keep fit at home, dancing, cycling, swimming, class exercises/keep fit supervised classes, golf, and various others as listed in the physical activity questionnaire.

In univariable analysis, age, history of stroke and CVD, depression, ability to perform activities of daily living, and taking medications were all inversely significantly associated ($P < .01$) with both total duration of and intensity of PA (Tables 3 and 4). In addition, intensity of PA was inversely associated with cognitive impairment and emphysema. There were increasing proportions of homeowners across increasing thirds of total duration or intensity of PA ($P < .001$). Longer duration and greater intensity of PA were associated with greater proportions in the least deprived (as defined by Carstairs) areas and smaller proportions in the most deprived areas. Total duration of any physical activity was strongly associated with thirds of intensity; those in the highest intensity group had the highest duration of physical activity ($P < .0001$) (Table 4).

Table 1: Characteristics of all persons in the PA study and of those with full data.

	$n - x$[1]	All eligible persons ($N = 1449$)	Complete data ($N = 946$)
Age[2]	1444	79.3 (75.0, 86.6)	79.2 (75.1, 86.6)
Men (%)	1449	45.0	45.0
BMI (kg/m^2)[3]	1370	26.5 ± 4.3	26.4 ± 4.2
Home owner (%)	1410	64.5	65.5
Systolic blood pressure (mm Hg)[4]	1413	148.8 ± 21.5	148.4 ± 21.3
Current smoker (%)	1415	10.0	9.2
History of CVD[5]	1407	24.2	22.7
History of Emphysema	1411	1.8	1.8
History of Cancer (%)[6]	1406	7.8	8.6
Diabetes (%)	1415	7.2	6.3
Hip fracture (%)	1410	2.7	2.2
Recent weight loss (%)	1405	2.3	2.6
MMSE score <12/<17[7]	1417	2.9	2.0
GDS score >5[8]	1417	6.9	6.8
Unable to do >1ADL[9]	1416	21.4	18.4
On prescribed Medication (%)	1371	81.6	81.4

[1] Not all 1449 participants had a complete data set on all characteristics, reported values are based on the complete records.
[2] Mean, interquartile range in parenthesis.
[3] $\overline{x}$ ± SD.
[4] $\overline{x}$ ± SD of average of 2 readings while sitting.
[5] History of heart attack, stroke or angina.
[6] Excluding skin cancer.
[7] MiniMental State Examination (MMSE) <12 if language section could not be completed, otherwise <17.
[8] 15 item Geriatric Depression Score (GDS).
[9] ADL: Activities of Daily Living.

Table 2: Study participants, person-years at risk, number of deaths and crude death rate by tertile of total duration of PA, and category of intensity.

$N = 946$	Total PA			Intensity of PA		
	Tertile 1	Tertile 2	Tertile 3	Low	Moderate	Heavy
Person years[1]	6.1 (2.9)	6.9 (2.7)	7.3 (2.4)	5.9 (3.0)	6.7 (2.7)	7.2 (2.5)
Deaths (%)	187 (41.3)	139 (30.7)	127 (28.1)	138 (30.5)	137 (30.2)	178 (39.3)
Crude death rate[2]	98.0	65.7	50.1	111.8	69.5	53.3

[1] $\overline{x}$ ± SD Time at risk /person.
[2] Per 1000 person years.

We observed an inverse trend for all cause mortality with both total PA and with the intensity of PA after adjusting for age and sex (Model 1) (Table 5). The associations were attenuated slightly but remained significant when adjusted for confounders (Model 2) and further attenuated after additionally adjusting for confounders and possible causal pathway variables (Model 3). In Model 3, those in the highest third of total PA or highest intensity of PA had Hazard Ratios (HR) of 0.74, 95% Confidence Interval (CI) (0.56, 0.97) and HR of 0.61, 95% CI (0.47, 0.79), respectively (Table 5). We ran a sensitivity analysis to examine the effect of excluding people in the highest intensity group who had less than 60 minutes high-intensity activity per week ($n = 102$). The results were essentially unchanged from the model that included all people in that group. The results for the full sample ($n = 1449$) in models 1 and 2 were similar to the results for both models when only the subsample of participants with full data ($n = 946$) was used (data not shown).

4. Discussion

In our study, we found that both higher levels of physical activity (PA) and higher relative intensity of PA were associated with lower mortality. This inverse trend was apparent after adjusting for a wide range of confounders. Ill health, discomfort, fear of adverse effects, and well-meaning efforts of others to protect older persons from potential

Table 3: Characteristics of the study participants by tertile of total duration of PA (min/wk).

PA total $N = 946$	Tertile 1 313	Tertile 2 302	Tertile 3 331	P value (r trend)
Cutoffs (min of PA/wk)	<370	371, 802	805, 3644	
Median	180	560	1136	
Mean	173	567	1312	
Age (mean)	79.68	79.20	78.72	.002
Men (%)	45.9	45.8	44.4	.73
BMI (kg/m^2)	19.5	13.7	17.9	.71
Lowest fifth (%)				
LDL (mean)[1]	4.51 ± 1.5	4.58 ± 1.6	4.74 ± 1.5	.18
HDL (mean)[1]	1.18 ± 0.52	1.22 ± 0.45	1.23 ± .5	.07
Systolic blood pressure[2]	148.47 ± 32	145.99 ± 29	150.56 ± 30	.42
Diastolic blood pressure[2]	73.97 ± 18	74.77 ± 18	75.40 ± 16	.25
Carstairs (1,5%)[3]	17.0, 15.9	26.0, 7.6	24.1, 5.0	.006
Single (%)	5.5	8.7	6.0	.98
Home owner (%)	53.7	69.3	74.7	<.001
Lives alone (%)	47.2	47.7	43.6	.58
Current smoker (%)	12.4	6.5	8.0	.16
Emphysema (%)	2.4	1.8	1.2	.19
Cancer (%)[4]	8.1	9.7	7.5	.75
Diabetes (%)	8.5	6.0	3.9	.039
CVD[5]	32.5	23.3	16.4	<.001
Hip fracture (%)	3.5	1.3	0.9	.059
Recent weight loss (%)	3.8	2.7	1.0	.026
MMSE score <12/<17[6]	3.5	0.8	0.9	.030
GDS score >5[7]	13.0	4.1	4.3	<.001
Unable to do >1 ADL[8]	35.3	14.2	5.3	<.001
Medication (%)	89.8	83.1	71.3	<.001

[1] $\overline{x}$ ± SD.
[2] $\overline{x}$ ± SD of average of 2 readings while sitting.
[3] Carstairs deprivation index, quintiles 1&5.
[4] Excluding skin cancer.
[5] History of heart attack, stroke, or angina.
[6] MimiMental State Examination (MMSE) <12 if language section could not be completed, otherwise <17.
[7] 15 item Geriatric Depression Score (MMSE).
[8] ADL: Activities of Daily Living.

harm all potentially contribute to activity limitations. Since ill health may also be a consequence of low physical activity we included variables in a third model, which we conjectured to be possible consequences of physical activity such as hip fracture, falls, and history of heart attack. After adjustment for potential confounders as well as possible causal pathways variables (comorbidities) a significant trend of lower mortality with increased levels of duration and intensity of PA persisted.

Observational studies in the general adult population which included people aged 75 years and over have found a reduced risk of mortality with increased physical activity in both older women and men [9, 13, 14]. The evidence has been inconsistent as to the levels of physical activity required to maximize health benefit. A recent systematic review of the benefits of moderate activity found a 19% reduction in mortality risk with 2.5 hours per week compared to no activity. The additional survival benefit from 7 hours activity per week was fairly small (24%) [15]. Interestingly the benefit was somewhat stronger in the older age group (65 years and over) compared to the younger age groups. Other studies have been conducted specifically in the older age group [23–26]. It is problematic to make a direct comparison between these studies and ours due to different methods of assessment and categorization of physical activity, different length of followup,and lack of stratified analysis by age 75

Table 4: Characteristics of the study participants by category of intensity of PA.

Intensity $N = 946$	Low 219 (light + <60 min/wk of moderate PA)	Medium 275 (>60 min/wk of moderate, no heavy PA)	High 452 (heavy PA, any amount/wk)	P value (r trend)
Median	120	188	120	
Mean	228	293	188	
Total duration of PA				
Median	130	275	803	$P < .0001$
Age (mean)	79.89	79.34	78.77	<.000
Men (%)	37.2	49.2	47.0	.14
BMI (kg/m^2)	20.8	16.8	15.6	.22
Lowest fifth (%)				
LDL (mean)[1]	4.63 ± 1.58	4.61 ± 1.5	4.61 ± 1.5	.93
HDL (mean)[1]	1.16 ± .54	1.24 ± .49	1.22 ± .48	.34
Systolic blood pressure[2]	147.06 ± 33	148.33 ± 32	149.41 ± 27	.253
Diastolic blood pressure[2]	73.74 ± 18	74.33 ± 19	75.43 ± 16	.079
Carstairs[3] (%)	17.9, 15.8	23.4, 10.7	23.7, 5.6	.019
Single (%)	6.5	9.7	4.9	.12
Home owner (%)	55.7	63.4	72.6	<.001
Lives alone (%)	46.8	45.9	45.8	.88
Current smoker (%)	11.7	8.0	8.3	.39
Emphysema (%)	4.0	1.5	0.9	.012
Heart attack (%)	16.7	13.0	8.2	.001
Stroke (%)	13.0	6.3	4.8	<.001
Cancer[4] (%)	6.4	7.1	10.1	.10
Diabetes (%)	9.8	5.4	4.7	.019
CVD[5]	34.7	24.3	18.5	<.001
Hip fracture (%)	2.4	2.1	1.5	.35
Recent weight loss (%)	3.0	2.4	2.4	.72
MMSE score <12/<17[6]	4.8	1.7	0.2	<.001
GDS score >5[7]	10.1	4.1	4.9	<.001
Unable to do >1ADL[8]	43.0	11.3	10.0	<.001
Medication (%)	91.5	79.8	76.9	.001

[1] $\overline{x}$ ± SD.
[2] $\overline{x}$ ± SD of average of 2 readings while sitting.
[3] Carstairs deprivation index, quintiles 1&5.
[4] Excluding basal cell carcinoma.
[5] History of heart attack, stroke, or angina.
[6] MiniMental State Examination (MMSE) <12 if language section could not be completed, otherwise <17.
[7] 15 item Geriatric Depression Score (GDS).
[8] ADL: Activities of Daily Living.

years and over. The UK Nottingham Longitudinal Study on Activity and Ageing measured customary physical activity (type, frequency, and duration) in people aged 65 years and over categorized as low, intermediate, and high [23]. Relative to the high group, an increased 47% 12 year mortality risk was observed in men for the "intermediate" group and a 75% increased mortality for the "low" group. The increased risk was observed only for the low-activity group for women. A prospective study conducted in the US of community dwelling people aged 65 years and over found that walking more than 4 hours/week was associated with a 27% reduced risk of death [27]. However, this association was substantially diminished by adjustment for cardiovascular risk factors and measures of general health status. Other studies in older people have reported improved survival from any level of physical activity compared to none [24], or a mortality

Table 5: Hazard ratios (95% CI, P value) by tertile of total PA and category of intensity referent to the first tertile/category.

MODEL		Total PA			Intensity		
		T1	T2	T3	Low	Medium	High
	$N = 946$[1]	313	302	331	219	275	452
(1) (adjusted for age and sex)		1	0.66	0.54	1	0.57	0.45
	CI		(0.50, 0.87)	(0.40, 0.71)		(0.41, 0.79)	(0.37, 0.55)
	P value		0.004	0.0001		0.001	0.000001
	P trend		0.0001			0.0000001	
(2) (adjusted for age, sex and potential confounders[2])		1	0.73	0.58	1	0.61	0.50
	CI		(0.55, 0.96)	(0.43, 0.80)		(0.44, 0.85)	(0.40, 0.62)
	P value		0.025	0.001		0.004	0.00001
	P trend		0.001			0.00001	
(3) (adjusted for age, sex, potential confounders and possible causalpathways[3])		1	0.84	0.74	1	0.74	0.61
	CI		(0.60, 1.17)	(0.56, 0.97)		(0.51, 1.07)	(0.47, 0.79)
	P value		0.3	0.04		0.1	0.001
	P trend		0.04			0.001	

[1] Participants with complete data on all variables in the models.
[2] BMI, smoking status, Carstairs, GDS, marital status, living alone, housing tenure.
[3] BMI, smoking status, MMSE score, Carstairs, GDS, marital status, living alone, housing tenure, HDL, diastolic BP, history of emphysema, cancer, CVD, diabetes, hip fracture, ADLscore, weight, loss, and medication.

benefit from 3 or more hours per week of activity of at least moderate-intensity compared to none, even among frail people [26] and a lower mortality rate over 10 months among frail people who did at least 2 hours activity a week [28]. A US-based study of people aged 65 years and over found those who walked more than 4 hours per week had a lower mortality although this was significant only among persons aged 75 years and older [27]. Bembom et al. concluded that the benefits of at least 22.5 metabolic equivalents (MET) hours per week could be greater for people aged 75 and over than for aged 54–74 years, but they had little detail on physical activity [25].

We had no information on previous leisure activities in our study. Other studies have shown that the greatest declines in physical activity over time are associated with the highest mortality rates in men but not in women [29], but that increasing leisure time activities even in later life is beneficial [30, 31]. The levels of habitual physical activity (of moderate or high intensity) in our study based on a community sample of people aged 75–84 years are reasonably high for this age group with half of participants achieving the current recommendation of at least 5×30 minutes of moderate physical activity per week. The Health Survey for England (HSE) reported that 72% of men and 82% of women aged 75 and over do not achieve at least 30 minutes per day on one- to four- days a week of at least moderate intensity [32]. Direct comparison between our study and the Health Survey for England is not possible, because we did not measure frequency. The closest comparison is that 42% of participants in our study managed less than 120 minutes of at least moderate physical activity per week. This difference may be partly accounted for by the fact that the HSE categorized heavy housework and outdoor maintenance/DYI as moderate activity for the survey population of all ages. Our judgment was that for people aged 75 years and over, intensity of heavy housework as defined in our study (e.g., scrubbing floors on knees, moving furniture, spring cleaning, and polishing brass) and outdoor maintenance/DIY (e.g., washing, polishing and repairing the car, carpentry, erecting a fence or shed, brick/concrete laying, moving heavy loads,etc.) requires energy expenditure justifying inclusion in the heavy-intensity of PA category. Other studies in Europe which have included either domestic and DIY activities [33] or leisure time activities [14] have reported higher levels of PA in older people with up to two thirds of participants reporting moderate or high levels of physical activities.

Data on PA in our study covered a large range of typical activities in older people and took account of widely varying intensities and frequencies. Low level everyday mobility activities as well as shorter bouts of activities (e.g., time spent on feet in shops and stair climbing) were recorded. These are not usually counted in other studies such as the HSE even though some activities, such as hoovering, are included in the UK Department of Health recommendations. It is controversial whether domestic activity has health benefits [33]. Domestic activity and shopping were included in a category of "consumptive" activity that did not predict mortality among people aged 70 and over during a 10–13 year follow-up after the analyses were adjusted for demographic factors, education, comorbidity, and physical and cognitive functioning [34]. On the other hand, in a wider agegroup there was some indication of reduction in all-cause mortality for men and women over an average follow-up of 8 years [35]. Some authors have suggested that psychosocial pathways, such as stress, may limit the benefits of domestic work [34], at least for some groups [36]. It is possible that our study participants were more health conscious and active than in the HSE survey. This could further explain the overall higher levels of PA achieved by our study subjects. In view of this, the intensity variable may be considered a better measure of PA performed. We categorized people in the high-intensity group on the basis of performing any high-intensity activity. We found no difference in models that excluded or included people with less than an hour's heavy activity a week.

We used questions adapted from the Allied Dunbar National Fitness Survey. We could not identify any validation studies conducted on the survey instrument. Discriminant validity was suggested in our study by the predictive association with thirds of physical activity and health status. Similar to other studies which used questionnaire methods to assess physical activity, we cannot exclude errors in the reporting of physical activity, for example, due to recall problems, over reporting due to perceived social desirability and the collection of data at a single point in time. However, results of assessment by a seven-day physical activity recall interview administered in a community health survey, a randomized clinical trial, and two worksite health promotion programmes suggest that physical activity recall provides useful estimates of habitual physical activity for research in epidemiological and health education studies [37]. Moreover, self-report has some advantages over objective measures in that the latter often have to exclude those in the worst physical state [26].

Undertaking physical activity is a complex behavior. Descriptive variables may be meaningfully partitioned into various categories as long as they are mutually exclusive of each other [38]. In preparation for constructing new summary measures of PA from the questionnaire we conducted a structured review of the literature specific to the question of categorizing self-reported physical activity into relevant derived physical activity variables in older people. This work was further supported by conducting an overview of the exercise physiology of old age. The most frequent categorization of PA found was by total quantity (in minutes per week) and by intensity, frequency, and type of PA (e.g., walking). From the point of view of the older person the most problematic measurement is the intensity of activity undertaken. The frequently used classification of physical activity by rate of energy expenditure using energy expenditure values in METs based on young adults can be misleading due to the bigger effort, and thus higher energy expenditure, required in older age to accomplish given tasks. We have, therefore, taken the approach used mainly in Scandinavian studies where physical activity is graded in levels using a modified version of the scale developed by Grimby [14, 39, 40]. We categorized participants into categories of "inactive" (engage in no or very few activities of only light intensity of not more than 30 minutes/week), "lightly active" (engage in light- and moderate-intensity activities up to one hour/week), "moderately active" (engage in light and moderate intensity activities up to 2.5 hours/week), "active" (engage in moderate physical activities for more than 2.5 hours/week and including at least 30 minutes of heavy intensity activity or active exercise/week) and "highly active" (engage in moderate physical activity for more than 4 hours/week or heavy intensity activity or exercise for over 2 hours/week). However, given the relatively high volume of physical activity performed by participants in our study and reduction in our original sample size due to incomplete data on confounders and co-morbidities, we categorized physical activity into tertiles by total amount of PA and three mutually exclusive categories of intensity (low, medium, and high) described in detail in the methods section.

There are a number of limitations in our study. Although we took account of a large number of potential confounders there may be other unmeasured confounders which could have attenuated our results. People with higher levels and intensity of physical activity had fewer health problems than those with the lowest levels. In common with other observational studies of physical activity in older people, it is difficult to establish whether poor health is a consequence of low physical activity or whether low physical activity is a consequence of poor health. Since poor health is associated with mortality, we controlled for this by including the major health conditions in our models. Although we did not have information on the severity of some conditions such as emphysema or angina, we included a measure of functional limitation (ADL) as a proxy indicator of poor health. We did not have any objective measures of physical activity. Using data from the US NHANES survey, Troiano et al. found differences in levels of physical activity based on self-report compared with accelerometers suggesting over estimation by study participants [41]. However, as noted by the authors, accelerometry may underestimate physical activity because it does not take account of activities such as bicycling, swimming, and upper body activities.

Our results do not apply to people in long-stay hospital or nursing homes (an exclusion criterion for the trial) in whom physical activity levels are likely to be substantially different from the community sample. The response rate in our study was 71% and nonresponders were more likely to be women and current smokers. However, there were no other major differences in health measures between responders and nonresponders, and the mortality rates were similar. The 35% of responders who did not have full data on possible confounders were similar to those with full data. Moreover, the Model 1 and 2 mortality estimates for those with incomplete data were essentially the same as those with complete data.

Our results for people aged 75 to 84 years support the existing evidence that physical activity is beneficial and is associated with improved survival in those aged 75 years and over. Regular physical activity and/or exercise enable older people to retain higher levels of functional capacity (notably cardiovascular and neuromuscular function) and possibly slow the age-related decline in cognitive function. The benefits of increased levels of exercise in relation to mortality found by us and in previous studies apply to a range of daily activities and are by no means specific to structured exercise. Our study also shows that doing more strenuous physical activity (as well as light and moderate) has benefits in terms of survival. Significant natural reduction in muscle mass and consequent loss of strength is a natural irreversible process. However, considerable strength improvement of existing muscle mass with vigorous training is possible into the ninth decade of age [42]. Since muscle strength is crucial to mobility, performing heavy physical activity will also undoubtedly lead to increased self-sufficiency in older age and there is a case for making resistance training a core component of disability postponing programmes for the elderly.

Although we were not able to report on the frequency of exercise below the weekly time unit and cannot, therefore, say with certainty how many times per week physical activity should be performed, the nature of our observations about daily customary activities suggests that activity took place on most, if not all, days. If customary physical activity such as housework, gardening, shopping, and walking is the main or sole component of physical activity for older people, it should be emphasized that increased activity (above the current recommended level) has considerable longevity benefit. While recommendations for older people appropriately focus on the provision and promotion of physical activity classes [6], this should be integrated with an approach which additionally emphasizes home-based activities.

Acknowledgments

The MRC Trial of assessment and management of older people was funded by the Medical Research Council, the Department of Health, and the Scottish Office, Grant no. G9223939. The add-on nutrition and physical activity study was funded by the UK National Health Service Research and Development Programme.

References

[1] C. K. Roberts and R. J. Barnard, "Effects of exercise and diet on chronic disease," *Journal of Applied Physiology*, vol. 98, no. 1, pp. 3–30, 2005.

[2] S. G. Wannamethee and A. G. Shaper, "Physical activity in the prevention of cardiovascular disease: an epidemiological perspective," *Sports Medicine*, vol. 31, no. 2, pp. 101–114, 2001.

[3] R. R. Pate, M. Pratt, S. N. Blair et al., "Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine," *Journal of the American Medical Association*, vol. 273, no. 5, pp. 402–407, 1995.

[4] W. D. McArdle, F. I. Katch, and V. L. Katch, *Exercise Physiology : Energy, Nutrition, and Human Performance*, Lippincott Williams & Wilkins, Philadelphia, Pa, USA, 6th edition, 2006.

[5] J. J. Keysor, "Does late-life physical activity or exercise prevent or minimize disablement? A critical review of the scientific evidence," *American Journal of Preventive Medicine*, vol. 25, supplement 2, pp. 129–136, 2003.

[6] A. Young and S. Dinan, "Activity in later life," *British Medical Journal*, vol. 330, no. 7484, pp. 189–191, 2005.

[7] "At least five a week: evidence on the impact of physical activity and its relationship to health, in Physical Activity, Health Improvement and Prevention," Report from the Chief Medical Officer, Department of Health, London, UK, 2004.

[8] WHO, *Keep Fit for Life: Meeting the Nutritional Needs of Older Persons*, World Health Organization, Geneva, Switzerland, 2002.

[9] L. B. Andersen, P. Schnohr, M. Schroll, and H. O. Hein, "All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work," *Archives of Internal Medicine*, vol. 160, no. 11, pp. 1621–1628, 2000.

[10] F. C. H. Bijnen, E. J. M. Feskens, C. J. Caspersen, N. Nagelkerke, W. L. Mosterd, and D. Kromhout, "Baseline and previous physical activity in relation to mortality in elderly men: the Zutphen Elderly Study," *American Journal of Epidemiology*, vol. 150, no. 12, pp. 1289–1296, 1999.

[11] A. A. Hakim, H. Petrovitch, C. M. Burchfiel et al., "Effects of walking on mortality among nonsmoking retired men," *New England Journal of Medicine*, vol. 338, no. 2, pp. 94–99, 1998.

[12] L. Kilander, L. Berglund, M. Boberg, B. Vessby, and H. Lithell, "Education, lifestyle factors and mortality from cardiovascular disease and cancer. A 25-year follow-up of Swedish 50-year-old men," *International Journal of Epidemiology*, vol. 30, no. 5, pp. 1119–1126, 2001.

[13] Y. Oguma, H. D. Sesso, R. S. Paffenbarger, and I. M. Lee, "Physical activity and all cause mortality in women: a review of the evidence," *British Journal of Sports Medicine*, vol. 36, no. 3, pp. 162–172, 2002.

[14] P. Schnohr, H. Scharling, and J. S. Jensen, "Changes in leisure-time physical activity and risk of death: an observational study of 7,000 men and women," *American Journal of Epidemiology*, vol. 158, no. 7, pp. 639–644, 2003.

[15] J. Woodcock, O. H. Franco, N. Orsini, and I. Roberts, "Non-vigorous physical activity and all-causemortality: systematic review and meta-analysis of cohort studies," *International Journal of Epidemiology*. In press.

[16] A. E. Fletcher, D. A. Jones, C. J. Bulpitt, and A. J. Tulloch, "The MRC trial of assessment and management of older people in the community: objectives, design and interventions [ISRCTN23494848]," *BMC health services research*, vol. 2, no. 1, p. 21, 2002.

[17] A. E. Fletcher, G. M. Price, E. S. W. Ng et al., "Population-based multidimensional assessment of older people in UK general practice: a cluster-randomised factorial trial," *The Lancet*, vol. 364, no. 9446, pp. 1667–1677, 2004.

[18] M. F. Folstein, S. E. Folstein, and P. R. McHugh, ""Mini mental state". A practical method for grading the cognitive state of patients for the clinician," *Journal of Psychiatric Research*, vol. 12, no. 3, pp. 189–198, 1975.

[19] J. I. Sheikh and J. A. Yesavage, "Geriatric Depression Scale (GDS): recent evidence and development of a shorter version," *Clinical Gerontologist*, vol. 37, pp. 819–820, 1986.

[20] G. A. Rose, "The diagnosis of ischaemic heart pain and intermittent claudication in field surveys," *Bulletin of the World Health Organization*, vol. 27, pp. 645–658, 1962.

[21] "Allied Dunbar national fitness survey. Main findings," S.l.]: Allied Dunbar[in association with]Health Education Authority[and]Sports Council. p. 160, 1992.

[22] V. Carstairs and R. Morris, *Deprivation and Health in Scotland*, Aberdeen University Press, Aberdeen, UK, 1991.

[23] P. A. Bath and K. Morgan, "Customary physical activity and physical health outcomes in later life," *Age and Ageing*, vol. 27, supplement 3, pp. 29–34, 1998.

[24] K. Ueshima, K. Ishikawa-Takata, T. Yorifuji et al., "Physical activity and mortality risk in the Japanese elderly. A cohort study," *American Journal of Preventive Medicine*, vol. 38, no. 4, pp. 410–418, 2010.

[25] O. Bembom, M. Van Der Laan, T. Haight, and I. Tager, "Leisure-time physical activity and all-cause mortality in an elderly cohort," *Epidemiology*, vol. 20, no. 3, pp. 424–430, 2009.

[26] R. E. Hubbard, N. Fallah, S. D. Searle, A. Mitnitski, and K. Rockwood, "Impact of exercise in community-dwelling older adults," *PLoS ONE*, vol. 4, no. 7, Article ID e6174, 2009.

[27] A. Z. LaCroix, S. G. Leveille, J. A. Hecht, L. C. Grothaus, and E. H. Wagner, "Does walking decrease the risk of cardiovascular disease hospitalizations and death in older adults?" *Journal of the American Geriatrics Society*, vol. 44, no. 2, pp. 113–120, 1996.

[28] F. Landi, M. Cesari, G. Onder, F. Lattanzio, E. M. Gravina, and R. Bernabei, "Physical activity and mortality in frail, community-living elderly patients," *Journals of Gerontology—Series A Biological Sciences and Medical Sciences*, vol. 59, no. 8, pp. 833–837, 2004.

[29] L. A. Talbot, C. H. Morrell, J. L. Fleg, and E. J. Metter, "Changes in leisure time physical activity and risk of all-cause mortality in men and women: the Baltimore Longitudinal Study of Aging," *Preventive Medicine*, vol. 45, no. 2-3, pp. 169–176, 2007.

[30] L. Byberg, H. Melhus, R. Gedeborg et al., "Total mortality after changes in leisure time physical activity in 50 year old men: 35 Year follow-up of population based cohort," *British Journal of Sports Medicine*, vol. 43, no. 7, p. 482, 2009.

[31] S. G. Wannamethee, A. G. Shaper, and M. Walker, "Changes in physical activity, mortality, and incidence of coronary heart disease in older men," *The Lancet*, vol. 351, no. 9116, pp. 1603–1608, 1998.

[32] *Health Survey for England*, HMSO, London, UK, 1993.

[33] D. A. Lawlor, M. Taylor, C. Bedford, and S. Ebrahim, "Is housework good for health? Levels of physical activity and factors associated with activity in elderly women. Results from the British Women's Heart and Health Study," *Journal of Epidemiology and Community Health*, vol. 56, no. 6, pp. 473–478, 2002.

[34] P. L. Klumb and H. Maier, "Daily activities and survival at older ages," *Journal of Aging and Health*, vol. 19, no. 4, pp. 594–611, 2007.

[35] E. Stamatakis, M. Hamer, and D. A. Lawlor, "Physical activity, mortality, and cardiovascular disease: is domestic physical activity beneficial? The Scottish Health Survey—1995, 1998, and 2003," *American Journal of Epidemiology*, vol. 169, no. 10, pp. 1191–1200, 2009.

[36] M. Asztalos, K. Wijndaele, I. De Bourdeaudhuij et al., "Specific associations between types of physical activity and components of mental health," *Journal of Science and Medicine in Sport*, vol. 12, no. 4, pp. 468–474, 2009.

[37] S. N. Blair, W. L. Haskell, and P. Ho, "Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments," *American Journal of Epidemiology*, vol. 122, no. 5, pp. 794–804, 1985.

[38] C. J. Caspersen, K. E. Powell, and G. Christenson, "Physical activity, exercise and physical fitness: definitions and distinctions for health-related research," *Public Health Reports*, vol. 100, no. 2, pp. 126–131, 1985.

[39] T. Rantanen and E. Heikkinen, "The role of habitual physical activity in preserving muscle strength from age 80 to 85 years," *Journal of Aging and Physical Activity*, vol. 6, no. 2, pp. 121–132, 1998.

[40] S. Sihvonen, T. Rantanen, and E. Heikkinen, "Physical activity and survival in elderly people: a five-year follow-up study," *Journal of Aging and Physical Activity*, vol. 6, no. 2, pp. 133–140, 1998.

[41] R. P. Troiano, D. Berrigan, K. W. Dodd, L. C. Mâsse, T. Tilert, and M. Mcdowell, "Physical activity in the United States measured by accelerometer," *Medicine and Science in Sports and Exercise*, vol. 40, no. 1, pp. 181–188, 2008.

[42] M. A. Fiatarone, E. C. Marks, N. D. Ryan, C. N. Meredith, L. A. Lipsitz, and W. J. Evans, "High-intensity strength training in nonagenarians. Effects on skeletal muscle," *Journal of the American Medical Association*, vol. 263, no. 22, pp. 3029–3034, 1990.