REVIEW

Physical activity and all cause mortality in women: a review of the evidence

Y Oguma, H D Sesso, R S Paffenbarger Jr, I-M Lee

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A computer assisted literature search was performed (Medline, 1966–2000) to examine the association of physical activity with all cause mortality in women. It was concluded that, by adhering to current guidelines for physical activity and expending about 4200 kJ of energy a week, women can postpone mortality. The magnitude of benefit experienced by women is similar to that seen in men.

See end of article for authors' affiliations

Correspondence to:
Dr Oguma, College Alumni Health Study, Department of Epidemiology, Harvard School of Public Health, 677 Huntington Avenue, Boston, MA 02115, USA; yoguma@hsph.harvard.edu

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There is a large body of epidemiological evidence pointing to the health benefits of regular physical activity.[1–3] Among these health benefits is increased longevity or the postponement of premature mortality. Before the last decade, much of the evidence has come from studies conducted in men. For example, a review of the association of physical activity with all cause mortality published in 1997 discussed 13 studies, only three of which included women.[4] Recently, however, several additional studies have examined the relation of physical activity to death rates in women.

A search of the medical literature elicited no systemic reviews of the association of physical activity with all cause mortality specifically in women. We were interested to examine this for several reasons. Although favourable physiological changes resulting from physical activity may be expected to occur in both sexes, the magnitude of benefit for averting premature mortality may be different. Men and women have different patterns of physical activity, with men expending more energy and being more likely to engage in vigorous kinds of activities. Men are also more likely to be physically active in their jobs; women are more likely to be involved in household chores and activities around child rearing. In addition, women go through the menopause, with striking changes in levels of reproductive hormones. Physical activity before and after the menopause may have different influences on subsequent mortality, because the onset of the menopause is associated with a less favourable cardiovascular risk factor profile.

We therefore undertook this review to examine the association of physical activity with all cause mortality in women. In addition to confirming that physical activity is indeed associated with lower death rates in women, we wanted to compare the magnitude of association observed with that seen in studies of men. We also attempted to address practical problems for healthcare providers, such as the amount, intensity, and duration of activity required for postponement of mortality.

METHODS

To identify papers for this review, we conducted a literature search using Medline (US National Library of Medicine) to look for papers published between January 1966 and December 2000. The keywords used were related to physical activity (physical activity, physical fitness, cardiorespiratory fitness, exercise, or walking) and mortality (mortality, death, or fatal outcome).

For inclusion in this review, the papers had to present results specifically for women, use the end point of all cause mortality (rather than cause specific mortality, such as cardiovascular disease mortality), and examine the association of physical activity or fitness with all cause mortality. We excluded review papers and papers not published in the English language because we did not have the facility to translate papers written in other languages. In addition, we checked the reference lists of papers included in this review, as well as review papers not included, to search for other eligible papers not identified by our computerised literature search. By these means, we identified 38 papers.

Two authors independently reviewed each of the papers and summarised the data (table 1). In two circumstances,[5–8] the same data were used to examine the association of physical fitness and all cause mortality in women. We present these data only once in table 1, choosing the publication in which the data were analysed in more detail.[6 8]

RESULTS

A total of 37 prospective cohort studies and one retrospective cohort study that examined the association between physical activity or fitness and all cause mortality in women were identified (table 1). Most of the studies were conducted in western, industrialised countries, with half (19 studies) being based in the United States. The Aerobics Center Longitudinal Study[5–8] and the Framingham Heart Study[9–12] each provided the data for four publications, comprising 21% of the studies reviewed. Sixteen (42%) studies were based in Europe, including five from Finland[13–17] and four from Germany.[18–21] The remaining three studies were based in Canada[22 23] and Israel.[24]

Most (32 (86%)) of the studies focused exclusively on physical activity, while four assessed only physical fitness[6 8 16 25] and another two investigated both physical activity and physical fitness.[14 22] Of the 34 studies investigating physical activity, 13 captured total physical activity and 23 measured leisure time physical activity (the sum

Table 1 Summary of studies examining the association between physical activity or fitness and all cause mortality in women

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Andersen 2000, Denmark[26] 2 prospective cohort studies combined (Copenhagen City Heart Study; Glostrup Population Studies)	13375	20–93	14 (5)†	2881	2 questions on LTPA and OPA in the previous year, with 4 response options for each question, assessed by questionnaire.	v inactive LTPA Light: RR = 0.65, p<0.001 Moderate: RR = 0.59, p<0.001 Vigorous: RR = 0.64, p = 0.20 Among subjects with light, moderate, and heavy LTPA, Sports participation: RR = 0.47 (0.34 to 0.66) v sitting OPA More active OPA: RR = 0.86 (0.74 to 0.99)	Age, educational level, blood pressure, lipid levels, BMI, and smoking Age and educational level	Adjustment for chronic disease did not change findings. Inverse association observed for women aged 20–44, 45–64, and ≥65.
Hirvensalo 2000, Finland[13] Prospective cohort study (Evergreen Project at Jyvaskyla)	718	65–84	8	225	Assessed by interview, using a question with 6 response options, plus questions about participation in a list of sports. Women were then classified as sedentary or active. Mobility was defined as being able to walk 2 km and climb one flight of stairs without difficulty.	v mobile-active Mobile-sedentary: RR = 0.87 (0.55 to 1.40) Impaired-active: RR = 1.72 (1.10 to 2.70) Impaired-sedentary: RR = 2.63 (1.82 to 3.81)	Age, marital status, education, presence of asthma, diabetes, neurological diseases, stroke, mental diseases, CVD, musculoskeletal diseases, smoking, and past physical activity	
Stessman 2000, Israel[24] Prospective cohort study (Jerusalem 70 year Longitudinal Study)	207	70	6	24	1 question on LTPA with 4 response options, assessed by interview.	v <4 hours walking/week Walks about 4 hours/week: RR = 0.28 (0.05 to 1.47) Sports activity ≥2×/week: RR = 0.91 (0.26 to 3.19) Walks ≥1 hour/day: RR = 0.17 (0.02 to 1.53) p for trend = 0.17	Smoking, economic hardship, and pre-existing medical conditions	
Lee 2000, US[30] Prospective cohort study (US Longitudinal Study of Aging)	7527 (both sexes)	≥70	7	2870 (both sexes)	"Compared to other people your age, would you say you are physically more active, less active, or about as active?" "Do you feel that you get as much exercise as you need, or less than you need?"	v a lot more active than peers More active: RR = 0.99 About as active: RR = 1.18, p<0.1 Less active: RR = 1.40, p<0.01 v getting as much exercise as needed Less than needed: RR = 1.05	Sociodemographic characteristics, functioning, diseases, use of services, and self assessed general and mental health	
Haapanen 2000, Northeastern Finland[14] Prospective cohort study	1122	35–63	16	87	Energy expenditure index assessed by questionnaire with 23 questions on LTPA, household chores and commuting. Single-item self assessment of LTPA. Single-item self assessment of physical fitness compared with age-mates. Single-item self assessment of 2 km walking ability. Single-item self assessment of ability to climb several flights of stairs.	v >1500 kcal/week 800.1–1500 kcal/week: RR = 0.59 (0.30 to 1.18) 0–800 kcal/week: RR = 1.27 (0.69 to 2.34) v vigorous activity ≥1/week No or light intensity: RR = 1.61 (0.89 to 2.92) v better physical fitness Similar: RR = 0.82 (0.41 to 1.65) Worse: RR = 1.71 (0.72 to 4.05) v no difficulties walking 2 km At least some difficulties: RR = 1.45 (0.78 to 2.70) v no difficulties climbing stairs At least some difficulties: RR = 2.39 (1.25 to 4.60)	Age, employment status, marital status, perceived health status, smoking, and alcohol consumption	
Dorn 1999, USA[41] Prospective cohort study (Buffalo Blood Pressure Study)	763	15–95	29	276	LTPA and OPA assessed in interview by 28 questions on time spent sleeping, sitting, driving, standing, caring or lifting, walking, gardening, exercising and playing sports.	For every 1 kcal/kg/hour of physical activity, <60 years: RR = 1.05 (0.59 to 1.87) ≥60 years: RR = 1.04 (0.62 to 1.74)	Age, education, smoking, and mean arterial blood pressure	

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Sherman 1999, USA[9] Prospective cohort study (Framingham Heart Study)	1410	30–62	16	522	Time spent sleeping, resting, or engaging in light, moderate, or heavy physical activity assessed by interview 11–27 years previously and at baseline.	11–27 years previously, per MET-hour/day RR = 1.01 (0.96 to 1.07) At baseline, per MET-hour/day RR = 0.84 (0.76 to 0.93)	Age, systolic blood pressure, total cholesterol, smoking, relative weight, glucose intolerance, LVH, COPD, and cancer	
Villeneuve 1998, Canada[22] Prospective cohort study (Canada Fitness Survey)	8196	20–69	7	502	Average daily energy expenditure in the past 12 months on LTPA estimated from modified Minnesota LTPA questionnaire based on a subset of the 19 most frequently reported activities, in KKD (kcal/kg body weight/day).	v lowest KKD (<0.5) in LTPA 0.5 to <1.5 KKD: RR = 0.94 (0.69 to 1.30) 1.5 to <3.0 KKD: RR = 0.92 (0.64 to 1.34) ⩾3.0 KKD: RR = 0.71 (0.45 to 1.11) v lowest KKD (<0.5) in nonvigorous LTPA among subjects without vigorous (⩽6METs) LTPA 0.5 to <1.5 KKD: RR = 0.97 (0.69 to 1.36) 1.5 to <3.0 KKD: RR = 0.92 (0.64 to 1.34) ⩾3.0 KKD: RR = 0.72 (0.43 to 1.21) Participation in vigorous LTPA RR = 0.71 (0.48 to 1.05)	Age and smoking	
					3 levels of fitness based on Canadian Aerobic Fitness Test.	v recommended fitness level (both sexes) Minimum: RR = 1.02 (0.69 to 1.51) Undesirable: RR = 1.52 (0.72 to 3.18)	Age, sex, and smoking	Sex-specific results not presented for fitness.
Weller 1998, Canada[23] Prospective cohort study (Canada Fitness Survey)	6620	⩾30	7	449	Average daily energy expenditure on all activities estimated from modified Minnesota LTPA questionnaire in KKD (kcal/kg body weight/day).	v lowest KKD quartile (Q1) of leisure activity Q2: RR = 0.91 (0.66 to 1.25) Q3: RR = 0.94 (0.72 to 1.23) Q4: RR = 0.89 (0.67 to 1.17) v lowest KKD quartile (Q1) of non-leisure activity Q2: RR = 0.66 (0.50 to 0.87) Q3: RR = 0.68 (0.51 to 0.89) Q4: RR = 0.71 (0.50 to 0.87)	Age	Adjustment for marital status, educational level, income, self reported health status, and smoking did not change findings
Kujala 1998, Finland[15] Prospective cohort study (Finish Twin Study)	7977	25–64	18	424	3 levels of LTPA plus calculated MET index assessed by questionnaire on type of activity, frequency, duration, and intensity.	v sedentary (both sexes) Occasional exercisers: RR = 0.80 (0.69 to 0.91) Conditioning exercisers: RR = 0.76 (0.59 to 0.98)	Age, sex, smoking, occupation, and alcohol use	Women were free of chronic diseases
						among same sex twin pairs discordant for death, v sedentary (among 148 female twin pairs) Occasional exercisers: RR = 0.66 Conditioning exercisers: RR = 0.24	Age, smoking, occupation, and alcohol use.	
						v lowest MET quintile (Q1) (among 434 twin pairs of both sexes) Q2: RR = 0.85 Q3: RR = 0.72 Q4: RR = 0.68 Q5: RR = 0.60 p for trend = 0.04	Age, sex, smoking, occupation, and alcohol use	

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Bath 1998, UK[31] Prospective cohort study (Nottingham Longitudinal Study of Activity and Ageing)	1042 (both sexes)	⩾65	12	369 (women)	Interview asking about outdoor productive activities, indoor productive activities, walking, shopping, leisure activities, strength activities, and flexibility activities.	v high activity Intermediate: RR = 1.22 (0.91 to 1.63) Low: RR = 1.73 (1.28 to 2.33)	Age, health status, smoking, and weight	
Roger 1998, USA[25] (Olmsted county, Minnesota) Retrospective cohort study	741	51 (15)†	6 (2)†	46	Physical fitness determined by maximal exercise test on treadmill, in METs.	For each 1 MET increase workload RR = 0.75 (0.65 to 0.88)	Age and comorbidity	Similar findings were seen when excluding first 3 years of follow up.
Kushi 1997, USA[32] Prospective cohort study (Iowa Women's Healthy Study)	40417	55–69	7	2260	Questionnaire with 2 questions on frequency of moderate and vigorous LTPA. 3-level LTPA index based on combined frequency and intensity.	v rarely/never participating in moderate activity 1/week–few/month: RR = 0.71 (0.63 to 0.79) 2–4/week: RR = 0.63 (0.56 to 0.71) >4/week: RR = 0.59 (0.51 to 0.67) p for trend <0.001 v rarely/never participating in vigorous activity 1/week-few/month: RR = 0.83 (0.69 to 0.99) 2–4 /week: RR = 0.74 (0.59 to 0.93) >4 /week: RR = 0.62 (0.42 to 0.90) p for trend = 0.009 v low activity index Medium: RR = 0.77 (0.69 to 0.86) High: RR = 0.68 (0.60 to 0.77) p for trend <0.001	Age, reproductive factors, alcohol use, total energy intake, smoking, estrogen use, BMI at baseline and 18 years, waist/hip ratio, high blood pressure, diabetes, education level, marital status, and family history of cancer	Similar findings observed when excluding women with CVD or cancer and first 3 years of follow-up. Subjects were post-menopausal women only.
Morgan 1997, UK[33] Prospective cohort study (Nottingham Longitudinal Study of Activity and Ageing)	635	⩾65	10	321	Interview, asking about outdoor productive activities, indoor productive activities, walking, shopping, leisure activities, strength activities, and flexibility activities.	v high activity Intermediate: RR = 1.53 (1.12 to 2.09) Low: RR = 2.07 (1.53 to 2.79)	Age, health status, and smoking	
Fraser 1997, USA[37] Prospective cohort study (Adventist Health Study)	1083	⩾25	9–11	80	2 questions on LTPA (participation in various vigorous activities ⩾15 min, ⩾3×/week) and OPA (5 options).	v no exercise Medium: RR = 0.6 (0.3 to 1.8) Vigorous: RR = 0.5 (0.3 to 1.0)	Age, adventist, smoking, diabetes, high blood pressure, and BMI.	Subjects were black women only. Exclusion of subjects with chronic diseases yielded non-significant RRs of 1.00, 1.08, and 0.96, respectively, for both sexes combined.
Miilunpalo 1997, Northeastern Finland[16] Prospective cohort study	1500	35–63	11	244 (both sexes)	Questionnaire assessing perceived physical fitness compared with similarly aged mates; 3 point scale.	v better Average: RR = 2.21 (0.85 to 5.74) Worse: RR = 3.78 (1.39 to 10.28)	Age, social status, and number of physician contacts	
Schroll 1997, Denmark[34] Prospective cohort study (Nordic Research on Ageing Study)	210	75	5	41	Assessed by interview and categorised into sedentary (hardly any physical activity or mostly sitting with occasional light activity) or physically active (light physical exercise around 2–4 hours/week or more).	v physically active Sedentary: RR = 1.31 p<0.01	None	

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Kampert 1996, USA[5] Prospective cohort study (Aerobics Center Longitudinal Study)	6674	20–88	mean, 8	66	Physical activity assessed by questionnaire on walking, running, and other sports/leisure activities over the past months.	v no reported activities 1–10 min/week: RR = 0.68 (0.39 to 1.17) 11–20 min/week: RR = 0.39 (0.09 to 1.65) ≥21 min/week: RR = 1.14 (0.27 to 4.80) p for trend = 0.22	Age, examination year, smoking, chronic illness, and ECG abnormalities	Fitness data not shown because identical with those of Blair *et al*[6].
Kaplan 1996, USA[38] Prospective cohort study (Alameda County Study)	3299	16–94	28	587	LTPA index assessed using answers to three questions on physical exercise, sports participation, and walking/swimming.	v lowest LTPA tertile (T1) T2: RR = 0.42 T3: RR = 0.22	None	Adjustment for age, sex, ethnicity, education, health conditions, and social isolation still yielded significant inverse associations.
LaCroix 1996, USA[42] (Seattle, Washington) Prospective cohort study	1030	≥65	4	65	LTPA in the previous 2 weeks assessed from Modified Minnesota LTPA questionnaire.	v walked <1 hour/week 1–4 hours/week: RR = 0.83 (0.53 to 1.29) >4 hours/week: RR = 0.91 (0.58 to 1.42)	Age, sex, functional status, smoking status, BMI, chronic disease score, self rated health, and alcohol consumption	Women were without severe disability or heart disease. Sex-specific results were not presented for multivariate analysis. In crude analysis, p for trend in women, <0.01.
Lissner 1996, Sweden[27] (Gothenburg) Prospective cohort study	1405	38–60	20	424	2 questions on LTPA and OPA in the previous year, with 4 response options for each question, assessed by questionnaire in 1968–69 and 1974–75.	v low LTPA in 1968–69 Medium: RR = 0.56 (0.39 to 0.82) High: RR = 0.45 (0.24 to 0.86) v low OPA in 1968–69 Medium: RR = 0.28 (0.17 to 0.46) High: RR = 0.24 (0.14 to 0.43) Compared with no change in LTPA between 1968–1969 and 1974–1975 Increased: RR = 1.11 (0.67 to 1.86) Decreased: RR = 2.07 (1.39 to 3.09)	Age	Women were free of CVD, cancer, and diabetes. Findings little changed with additional adjustment for smoking, alcohol use, education, BMI, waist/hip ratio, diet, blood pressure, blood lipids, and peak expiratory flow.
Mensink 1996, Germany[18] Prospective cohort study (German Cardiovascular Prevention Study)	1212	40–69	mean, 6 range, 5–8	66	Frequency and time spent on 18 leisure activities during the previous 3 months. Each activity assigned a MET score and classified as total activity, LTPA, conditioning activity (excluding walking, cycling, gardening) and sports activity.	v low total activity Moderate: RR = 1.24 (0.60 to 2.58) High: RR = 1.29 (0.58 to 2.85) v low LTPA Moderate: RR = 0.94 (0.51 to 1.75) High: RR = 0.81 (0.44 to 1.49) v low conditioning activity Moderate: RR = 0.38 (0.13 to 1.06) High: RR = 0.80 (0.42 to 1.54) v no sports activity <1 hour/week: RR = 0.38 (0.12 to 1.23) 1–2 hours/week: RR = 0.52 (0.23 to 1.17) >2 hours/week: RR = 0.28 (0.07 to 1.17)	Age, systolic blood pressure, total serum cholesterol, smoking, and BMI	

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Blair 1996, USA[6] Prospective cohort study (Aerobics Center Longitudinal Study)	7080	20–88	mean, 8 range, 0.1–19	89	Physical fitness determined by maximal exercise test on treadmill. Subjects classified as low (least fit 20%), moderate (next 40%) and high (most fit 40%) fit.	*v* high fit Low fit: RR = 2.10 (1.36 to 3.26)	Age, examination year, smoking, systolic blood pressure, cholesterol, parental history of CHD, BMI, fasting glucose, abnormal ECG, and chronic illness	Most women were apparently healthy at baseline. 350 had abnormal ECG, and 958 reported a history of chronic illnesses (MI, stroke, hypertension, DM, or cancer).
Ruigómez 1995, Spain[39] Prospective cohort study (Health Interview Survey of Barcelona)	749	⩾65	5	109	Face to face home interviews. Total physical activity estimated from single question and categorised as active ("doing a job that requires a great deal of physical effort" or "walking frequently during the day") or sedentary ("expending most part of their day-time standing up but not walking" or "sitting most of the day").	*v* active Sedentary: RR = 1.30 (0.77 to 2.18)	Age, sex, education, and perceived health status	
Sherman 1994, USA[11] Prospective cohort study (Framingham Heart Study)	1404	50–74	16	319	Time spent sleeping, resting, or engaging in light, moderate, or heavy physical activity assessed by interview. Composite score (physical activity index: PAI) computed as sum of hours per activity level × weight factor based on oxygen consumption.	*v* lowest activity quartile (Q1) Q2: RR = 0.93 (0.70 to 1.23) Q3: RR = 0.65 (0.47 to 0.90) Q4: RR = 0.68 (0.49 to 0.94)	Age, systolic blood pressure, serum cholesterol, smoking, weight, presence or absence of glucose tolerance, LVH, COPD, and cancer	Subjects were free of CVD at the baseline. Excluding first 6 years of follow up yielded similar results.
Sherman 1994, USA[10] Prospective cohort study (Framingham Heart Study)	189	⩾75	10	126	Time spent sleeping, resting, or engaging in light, moderate, or heavy physical activity assessed by interview. Composite score (physical activity index: PAI) computed as sum of hours per activity level × weight factor based on oxygen consumption.	*v* lowest activity quartile (Q1) Q2: RR = 0.70 (0.38 to 1.29) Q3: RR = 0.26 (0.12 to 0.55) Q4: RR = 0.39 (0.20 to 0.77)	Age, systolic blood pressure, serum cholesterol, smoking, weight, presence or absence of glucose tolerance, LVH, COPD, and cancer	Excluding first 6 years of follow up yielded similar results. Subjects were free of CVD at the baseline.
Davis 1994, USA[29] Prospective cohort study (NHANES I Follow-up Study)	3197	45–74	10	673	2 questions with 3 response options each (1) non-recreational activity: "In your usual day, aside from recreation are you physically very active, moderately active, or quite inactive?" (2) recreational activity: "Do you get much, moderate, or little or no exercise in the things you do for recreation?"	*v* very active Inactive — (1) Non-recreational; (2) Recreational 45–54 years: RR: 1.3 (0.5 to 3.3); 0.9 (0.4 to 2.4) 55–64 years: RR: 1.7 (0.8 to 3.7); 2.2 (0.8 to 6.6) 65–74 years: RR: 2.1 (1.5 to 2.8); 1.0 (0.7 to 1.4) Moderately active 45–54 years: RR: 1.2 (0.6 to 2.2); 0.8 (0.3 to 2.3) 55–64 years: RR: 1.3 (0.7 to 2.1); 1.7 (0.6 to 5.2) 65–74 years: RR: 1.2 (1.0 to 1.6); 0.8 (0.5 to 1.1)	Smoking, alcohol, BMI, age, race, education, income, employment status, living arrangement, diet quality, and chronic conditions	
Blair 1993, USA[7] Prospective cohort study (Aerobics Center Longitudinal Study)	3120	mean, 40.9	mean, 8	43	LTPA assessed by questionnaire asking about 18 common activities over the past months. Subjects with no activities were classified as inactive, those who walked, jogged, or ran as highly active, and all others as moderately active.	*v* high LTPA Moderate: RR = 0.75 (0.41 to 1.39) Low: RR = 0.95 (0.54 to 1.70) p for trend = 0.31	Age	Fitness data not shown because identical with those of Blair *et al.*[8]

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Weyerer 1993, Germany[19] Prospective cohort study (Upper Bavarian Field Study)	844	⩾5	5	41	LTPA assessed by interview with single question, "How often do you currently exercise for sports (never, occasionally, or regularly)?"	v regular LTPA Occasional: RR = 1.14 (0.24 to 5.30) Never: RR = 1.51 (0.41 to 5.54)	Age, social class, physical and psychiatric disorders	
Rehm 1993, Germany[20] Prospective cohort study (Upper Bavarian Field Study)	778	⩾15	13	118	LTPA assessed by interview with single question, "How often do you currently exercise for sports (never, occasionally, or regularly)?"	v never Occasional: RR = 0.69 (0.33 to 1.46) Regular: RR = 0.50 (0.20 to 1.25)	Age and physicians' judgment of the severity of somatic disorders within the last year	Differences in sample size from those of Weyerer *et al* (1993)[19] due to available information on vital status.
C-Claude 1993, Germany[21] Prospective cohort study (German Vegetarian Study)	1046	⩾10	11	225 (both sexes)	Total physical activity classified as low, medium and high by self evaluation.	v low physical activity Medium or high: RR = 0.43 (0.22 to 0.82)	Age, adherence to vegetarianism, duration of vegetarianism, and BMI	Similar decreases for CHD, but not cancer mortality.
Rakowski 1992, USA[35] Prospective cohort study (US Longitudinal Study of Aging)	3679	⩾70	5	555	LTPA assessed by responses to questions: "How often do you walk a mile or more at a time, without resting?" and "Do you follow a regular routine of physical exercise?"	v walk ⩾4 days/week 2–3 days/week: RR = 1.72 (1.01 to 2.05) 1 day/week: RR = 1.48 (0.70 to 3.10) <1 day/never: RR = 2.49 (1.64 to 3.80) v have exercise routine No: RR = 1.32 (1.03 to 1.69)	Age, sex, race, education, living arrangement, self rated health, social involvement, heart condition, hypertension, stroke, diabetes, functional status, and BMI	
Blair 1989, USA[8] Prospective cohort study (Aerobics Center Longitudinal Study)	3120	mean, 40.9	mean, 8	43	Physical fitness determined by maximal exercise test on treadmill; women categorszed into quintiles.	v highest fitness quintile (Q5) Q4: RR = 1.07 (0.55 to 2.23) Q3: RR = 1.07 (0.55 to 2.09) Q2: RR = 1.45 (0.80 to 2.62) Q1: RR = 1.98 (1.13 to 3.47) p for trend <0.05	Age, serum cholesterol level, systolic blood pressure, BMI, smoking, parental death from CHD, and serum glucose level	Women were free of chronic diseases and abnormal ECG at baseline.
Garfinkel 1988, USA[40] Prospective cohort study (Cancer Prevention Study II)	496284	mean, 58	2	2865	"How much exercise do you get (work or play)?" with 4 response options.	Exercise inversely related to mortality in both smokers and nonsmokers; exact results not provided.	Age, relative weight	
Lapidus 1986, Sweden[35] (Gothenburg) Prospective cohort study	1424	38–60	12	75	2 questions on LTPA and OPA in the previous year, with 4 response options for each question, assessed by questionnaire.	v 3 highest categories of LTPA or OPA Least active category of LTPA: RR = 1.9 (1.1 to 3.2) Least active category of OPA: RR = 5.2 (2.8 to 9.7)	Age	Women were free of MI.
Salonen 1982, Eastern Finland[17] Prospective cohort study	3784	35–59	7	75	2 questions on LTPA and OPA in the previous year, with 4 response options for each question, assessed by questionnaire.	v 2 highest levels of LTPA or OPA 2 lowest levels of LTPA: RR = 1.6 (1.0 to 2.3) 2 lowest levels of OPA: RR = 2.2 (1.5 to 3.3)	Age, serum cholesterol, diastolic blood pressure, BMI, and smoking	Women were free of AMI, angina, and stroke in the preceding 12 months. 90% confidence intervals provided.

Table 1 continued

Author and year, country study design	No of women	Age (years)	Duration (years)*	No of deaths	Assessment of physical activity	Main results‡	Factors adjusted for	Other comments
Wingard 1982, USA[36] Prospective cohort study (Alameda County Study)	2496	30–69	9	160	Based on the frequency (often, sometimes, never) and presumed strenuousness of leisure time participation in active sports, swimming or long walks, physical exercises, gardening and/or hunting and classified as active or inactive.	*v* active Inactive: RR = 1.7 p = 0.01	Age, race, socioeconomic status, occupation, use of health services, weight status, sleeping patterns, and church or group membership.	
Kannel 1979, USA[12] Prospective cohort study (Framingham Heart Study)	2311	35–69	14	269	Time spent sleeping, resting, or engaging in light, moderate, or heavy physical activity assessed by interview. Composite score (physical activity index: PAI) computed as sum of hours per activity level × weight factor based on oxygen consumption.	p>0.05 for association of PAI with mortality.	Age, systolic blood pressure, smoking, serum cholesterol, glucose intolerance, and LVH.	

*Maximum duration of the study unless otherwise specified; †mean (SD); ‡values in parentheses are 95% confidence intervals.
AMI, Acute myocardial infarction; BMI, body mass index; CHD, coronary heart diseases; COPD, chronic obstructive pulmonary diseases; CVD, cardiovascular diseases; DM, diabetes mellitus; ECG, electrocardiogram; LTPA, leisure time physical activity; LVH, left ventricular hypertrophy; MET, metabolic equivalent; MI, myocardial infarction; OPA, occupational physical activity; RR, relative risk.

exceeds 34 because some studies had both measures). Only six of the 23 studies that measured leisure time physical activity also measured occupational physical activity[17 26–28] or non-recreational physical activity.[23 29] Of the studies examining physical fitness, three used a maximal exercise test on a treadmill.[6 8 25]

Are higher levels of physical activity or fitness associated with lower death rates in women?

The first question we sought to answer was whether women who are physically active or physically fit postpone mortality compared with their less active or less fit peers. Of the 38 studies included in this review, 23 reported significant inverse associations between physical activity (or physical fitness) and death rate in at least one subgroup.[6 8–11 14–17 21 23 25–36] Another nine studies observed at least a 20% difference in death rates between the most and least active women, which was not statistically significant during the period of study.[18–20 22 24 37–40] The lack of statistical significance may have been due, in part, to the small number of deaths in these studies. In the remaining six studies, investigators reported less than a 20% difference in death rates during follow up between the most and least active (or fit) women.[5 7 12 13 41 42]

We calculated the median relative risk, comparing the most with the least active (or fit) women, from all 38 studies to estimate an average magnitude of effect of physical activity or fitness on mortality. For all 38 studies, the median relative risk was 0.66 (table 2)—that is, the most active or fit women in these studies were 34% less likely, on average, to die during the period of study. We then estimated the median relative risk separately for studies of total physical activity, leisure time physical activity, occupational or non-recreational physical activity, and physical fitness. Based on 11 studies, the median relative risk for women who were most active with regard to total physical activity, compared with those who were least active, was 0.75.[9–11 18 21 23 30 34 37 39 41] For leisure time physical activity (23 studies), the corresponding median relative risk was 0.66.[5 7 13–15 17–20 22–24 26–29 31–33 35 36 38 42] This figure was 0.54 for occupational or non-recreational physical activity (six studies),[17 23 26–29] and 0.55 for physical fitness (six studies).[6 8 14 16 22 25] Because the latter two estimates were based on only a small number of studies, there is less confidence in these values.

Is the magnitude of association similar to that seen in men?

To examine whether the association of physical activity or fitness with all cause mortality in women is of similar magnitude to that seen in men, we conducted a similar exercise for studies conducted in men (reviewed in references 4, 43, 44; and references 6, 9, 13, 14, 16, 17, 20, 21, 29–31, 36, 37, 39, 45, 46). The median relative risk for all cause mortality in men, comparing most active with least active, was 0.65 based on all studies of men that we identified (n = 67). For studies of total physical activity, this was 0.66 (17 studies), for leisure time physical activity, it was 0.70 (30 studies), for occupational or non-recreational physical activity, it was 0.65 (10 studies), and for physical fitness, it was 0.55 (10 studies). These data indicate similar associations in both sexes.

Is there a dose-response relation?

To assess whether a dose-response relation exists, we examined papers in which investigators categorised subjects into at least three levels of physical activity or fitness. We identified 28 such studies. Sixteen of these showed evidence (not always statistically evaluated by the authors) of an inverse dose-response relation between physical activity (or fitness) and all cause mortality in at least one subgroup of subjects (table 1).[8 9 15 16 19 20 22 25 27 29–33 37 38] Of the remaining 12 studies, eight reported data compatible with a J shaped or

Table 2 Relative risks* (RR) of all cause mortality in women according to physical activity or physical fitness

	No of studies†	Median RR*
All studies	38	0.66
Studies of physical activity	34	0.68
Total physical activity	13	0.75
Leisure time physical activity	23	0.66
Occupational or non-recreational physical activity	6	0.54
Studies of physical fitness	6	0.55

*Comparing most with least active or fit women. These data exclude references 12 and 40, because RRs were not provided.
†No of studies do not sum to total because studies may have assessed more than one dimension of physical activity or fitness.

reverse J shaped curve,[5 7 10 11 14 23 26 42] and four observed non-significant associations of physical activity with all cause mortality.[18 24 35 41]

For a more formal examination of the dose-response relation, we assessed studies that performed statistical tests for a trend of declining all cause death rates with increasing volume of physical activity (or fitness). Of 13 studies identified, eight observed significant p values for trend.[8–11 15 23 25 32] The remaining five studies reported non-significant trends.[5 7 24 41 42]

How much physical activity is required?

To address this question, we first investigated the volume (amount) of energy expenditure associated with significantly lower death rates in women. Because physical activity was assessed very differently in the various studies, it was difficult to compare volume of energy expenditure across studies. We attempted to make comparisons across studies by estimating the volume of energy expenditure as kJ (1 kcal ≈ 4.2 kJ) or MET hours (1 MET is the energy expended while resting quietly; it is equivalent to 4.2 kJ/kg body weight per hour) in studies in which sufficient data were provided.

Significantly lower death rates were observed at these approximate volumes of energy expenditure: 1050–6720 kJ/week (250–1600 kcal/week) or 0.5–3.5 MET hours/day[32]; 2100 kJ/week (500 kcal/week) or 1 MET hour/day[9 27]; 2100–2940 kJ/week (500–700 kcal/week) or 1.0–1.5 MET hours/day[26]; 4200 kJ/week (1000 kcal/week) or 2.2 MET hours/day[15]; 5460 kJ/week (1300 kcal/week) or 2.8 MET hours/day[23]; 5880 kJ/week (1400 kcal/week) or 3 MET hours/day[11]; 9660 kJ/week (2300 kcal/week) or 5 MET hours/day.[10]

We next examined what intensity of physical activity is required for lower death rates. Few studies collected or analysed data on intensity of physical activity, precluding firm conclusions. In the Iowa Women's Health Study,[32] participation in moderate intensity physical activity was associated with lower death rates. However, in the Canada Fitness Survey,[22] non-vigorous physical activity was not associated with lower death rates, but an inverse association, of borderline significance, was observed with vigorous physical activity. In the Copenhagen City Heart Study,[26] participation in sports was associated with additional risk reduction among women who were already participating in other activities of light, moderate, or vigorous intensity.

Several studies examined frequency[20 32 35] or duration[5 18 42] of physical activity in relation to all cause mortality. However, because these studies did not control for the volume of energy expenditure, the findings on frequency or duration essentially reflect the findings for volume of energy expended. Therefore, the independent associations with frequency or duration could not be evaluated in this review.

Is there effect modification by age?

Finally, we were interested in whether physical activity was beneficial for all cause mortality in both younger and older women. We identified 11 studies[9 14–17 26–29 32 41] in which data were presented separately for women aged <65 years at baseline and 13 studies[10 13 24 26 29–35 39 42] in which data were provided for those aged ⩾65 years at baseline. In women aged <65 and ⩾65 years, the median relative risk comparing most active with least active women was 0.67 and 0.58, respectively. The use of other age cut off points—for example, 55 or 60 years—produced similar relative risks for both younger and older women. In six studies, investigators provided findings separately for women of different ages, ranging from 20 to ⩾75 years.[20 26 29 32 41 42] In all but one study[29] the magnitude of risk reduction was lower among older women than among younger women.

DISCUSSION

There is clear evidence from 38 studies conducted primarily in the United States and Europe that physically active women postpone mortality compared with inactive women. Formal meta-analysis using raw data from investigators is beyond the scope of this review; instead we conducted a systematic qualitative review using published data. This review indicates that the median risk reduction over the period of study is 34%, a magnitude of association that closely parallels that for men.

Most studies reviewed reported at least a 20% difference in death rate between the most active and least active women, and most results were statistically significant. In the six studies that did not find an association, physical assessments may not have been sufficiently precise or valid. Although many other studies also suffered from similar limitations in physical activity measurement, they still reported significant results. Therefore the reported findings are likely to underestimate the magnitude of the true association.

Although 28 studies classified women into at least three levels of physical activity, allowing for assessment of dose-response, only 13 formally tested for a trend of declining all cause mortality with increasing levels of physical activity. Eight observed significant inverse trends. Future studies of physical activity and mortality in women need to use measurements that allow a more detailed analysis of dose-response effects. Whether the apparent inverse association follows a linear or non-linear trend also merits consideration, as few studies have examined this.

Because the prevalence of physical inactivity is high,[3 47] an issue of public health importance is the minimum amount of physical activity required to postpone early mortality in women. Few published studies have provided specific estimates of energy expenditure, again highlighting the need for better quantitative assessments of physical activity in epidemiological research. We converted various measures of physical activity to kJ/week or kcal/week, assuming the average body weight of a woman to be 65 kg. On the basis of studies from which volume of energy expenditure could be estimated, an energy expenditure of about 4200 kJ/week (1000 kcal/week) seemed to be sufficient to avert premature mortality.

This level of physical activity is in line with recommendations from various US organisations that had based these targets primarily on data in men.[1–3] In fact, a few studies suggest that even lower levels of energy expenditure may be associated with significant reduction in all cause mortality in women.[9 26 27 32]

We also attempted to assess the role of physical activity intensity in postponing mortality in women. Studies of physical activity intensity and mortality in women are limited and inconsistent in their findings. For example, the Iowa Women's Study separately examined moderate and vigorous activity, noting an inverse association between moderate intensity physical activity and mortality.[32] The inverse association with vigorous intensity physical activity was only of borderline significance, presumably because few women undertook vigorous activities. However, Villeneuve *et al*[22] reported from the Canada Fitness Survey that non-vigorous leisure time physical activity in subjects with no vigorous leisure time physical activity was not associated with death rate. Further studies are needed to clarify the role of physical activity intensity in postponing mortality in women. Studies of physical activity intensity and risk of coronary heart disease in women have yielded more consistent findings. For example, the Nurses' Health Study[48] and Women's Health Study[49] both indicate that moderate intensity activities are associated with lower risk of coronary heart disease. No papers have examined whether, with the same level of energy expenditure, activity bouts of shorter duration (and greater frequency) or longer duration (and lesser frequency) have different effects on all cause mortality in women. Several intervention studies have shown that total physical activity may be more important than duration or frequency for coronary risk factors,[50 51] and large scale observational studies are necessary to confirm or refute these findings for clinical end points such as premature mortality.

When we examined the association of physical activity with death rates in women of different ages, we observed that higher levels of physical activity reduce death rates in both younger and older women. These benefits across all ages of women extend beyond just a reduction in premature mortality. Ferrucci *et al*[52] notes that higher levels of physical activity are also associated with fewer years of disability before death, helping women to live more enjoyable lives.

Several limitations of the studies reviewed need to be considered. The assessment of physical activity was often based on instruments developed for men. For example, care of children and household chores were often not accounted for. In the Canada Fitness Survey, Weller *et al*[23 53] observed that, for women, non-leisure time physical activity comprised most (82%) of their daily energy expenditure. In this study, investigators did not find an association between physical activity and death rates when examining only leisure time energy expenditure. However, after taking into account non-leisure activities, an inverse relation was present. This underscores the importance of assessing non-leisure activities, such as those mentioned above. The challenge is to develop reliable and valid instruments for measuring such activities.

Another limitation is that residual confounding by other lifestyle and dietary habits may be a plausible explanation for an inverse association between physical activity and mortality. Physically active women are likely to be healthy in other ways such as eating behaviour, body weight, and smoking. However, many studies did adjust for potential confounders, and continued to observe significant inverse associations. As all the studies reviewed are observational epidemiological studies, a causal relation cannot be definitely established. However, randomised clinical trials, which provide more rigorous data for cause and effect inferences, are unlikely to be conducted because of the lack of feasibility in maintaining compliance with physical activity over the long term needed in studies of mortality.

We also had difficulty assessing minimum levels of physical activity required for averting premature mortality. Different cut off points for physical activity were used, not all of which allowed interpretation of the amount of physical activity required.

We were interested in the association of physical activity and death rates in women before and after the menopause, but no studies provided this information. When we examined older women separately using the cut off points of 65, 60, or 55 years, as proxies for identifying postmenopausal women, we found that postmenopausal women also showed inverse associations between physical activity and death rates.

Finally, changes in physical activity were typically not considered in the studies reviewed. Lissner *et al*[27] reported that those who decreased their physical activity level were at increased mortality risk relative to those who maintained activity levels. Recent results from the Nurses' Health Study (not included in this review because the study was published outside the time window for inclusion) also support these findings.[54]

Physical inactivity is pervasive: more than 60% of American women do not engage in the recommended amount of physical activity, and 25% are not active at all.[3] Similar levels of inactivity are observed in England: according to the Health Survey for England in 1994,[47] 60% of women were underactive and 20% were inactive. This is unfortunate, as the present review adds to the list of benefits associated with physical activity in postponing premature mortality in women. This review also supports current physical activity guidelines of at least 30 minutes of physical activity of moderate intensity on most, preferably all, days of the week.[1–3 55] Although these guidelines were developed primarily from data in men, this review supports its applicability for women as well.

Take home message

Although earlier studies have been conducted primarily in men, studies over the last 10 or 20 years provide convincing evidence that physical activity can also avert premature mortality in women. Following current recommendations of at least 30 minutes of moderate intensity physical activity on most days of the week can postpone mortality in women, as well as men.

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Authors' affiliations

Y Oguma, H D Sesso, I-M Lee, Department of Epidemiology, Harvard School of Public Health, 677 Huntington Avenue, Boston, MA 02115, USA

R S Paffenbarger Jr, Division of Epidemiology, Stanford University School of Medicine, Stanford, CA, USA

REFERENCES

1 **Physical activity and cardiovascular health**. NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. *JAMA* 1996;**276**:241–6.
2 **Pate RR**, Pratt M, Blair SN, *et al*. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 1995;**273**:402–7.
3 **US Department of Health and Human Services**. *Physical activity and health: a report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Preventions, and National Center for Chronic Disease Prevention and Health Promotion, 1996.
4 **Lee IM**, Paffenbarger RS, Hennekens CH. Physical activity, physical fitness and longevity. *Aging (Milano)* 1997;**9**:2–11.
5 **Kampert JB**, Blair SN, Barlow CE, *et al*. Physical activity, physical fitness, and all-cause and cancer mortality: a prospective study of men and women. *Ann Epidemiol* 1996;**6**:452–7.

6 **Blair SN**, Kampert JB, Kohl HW, 3rd, *et al*. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA* 1996;**276**:205–10.
7 **Blair SN**, Kohl HW, Barlow CE. Physical activity, physical fitness, and all-cause mortality in women: do women need to be active? *J Am Coll Nutr* 1993;**12**:368–71.
8 **Blair SN**, Kohl HW, 3rd, Paffenbarger RS, Jr, *et al*. Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989;**262**:2395–401.
9 **Sherman SE**, D'Agostino RB, Silbershatz H, *et al*. Comparison of past versus recent physical activity in the prevention of premature death and coronary artery disease. *Am Heart J* 1999;**138**:900–7.
10 **Sherman SE**, D'Agostino RB, Cobb JL, *et al*. Does exercise reduce mortality rates in the elderly? Experience from the Framingham Heart Study. *Am Heart J* 1994;**128**:965–72.
11 **Sherman SE**, D'Agostino RB, Cobb JL, *et al*. Physical activity and mortality in women in the Framingham Heart Study. *Am Heart J* 1994;**128**:879–84.
12 **Kannel WB**, Sorlie P. Some health benefits of physical activity. The Framingham Study. *Arch Intern Med* 1979;**139**:857–61.
13 **Hirvensalo M**, Rantanen T, Heikkinen E. Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. *J Am Geriatr Soc* 2000;**48**:493–8.
14 **Haapanen-Niemi N**, Miilunpalo S, Pasanen M, *et al*. Body mass index, physical activity and low level of physical fitness as determinants of all-cause and cardiovascular disease mortality-16 y follow-up of middle-aged and elderly men and women. *Int J Obes Relat Metab Disord* 2000;**24**:1465–74.
15 **Kujala UM**, Kaprio J, Sarna S, *et al*. Relationship of leisure-time physical activity and mortality: the Finnish twin cohort. *JAMA* 1998;**279**:440–4.
16 **Miilunpalo S**, Vuori I, Oja P, *et al*. Self-rated health status as a health measure: the predictive value of self-reported health status on the use of physician services and on mortality in the working-age population. *J Clin Epidemiol* 1997;**50**:517–28.
17 **Salonen JT**, Puska P, Tuomilehto J. Physical activity and risk of myocardial infarction, cerebral stroke and death: a longitudinal study in Eastern Finland. *Am J Epidemiol* 1982;**115**:526–37.
18 **Mensink GBM**, Deketh M, Mul MDM, *et al*. Physical activity and its association with cardiovascular risk factors and mortality. *Epidemiology* 1996;**7**:391–7.
19 **Weyerer S**. Effects of physical inactivity on all-cause mortality risk in Upper Bavaria. *Percept Mot Skills* 1993;**77**:499–505.
20 **Rehm J**, Fichter MM, Elton M. Effects on mortality of alcohol consumption, smoking, physical activity, and close personal relationships. *Addiction* 1993;**88**:101–12.
21 **Chang-Claude J**, Frentzel-Beyme R. Dietary and lifestyle determinants of mortality among German vegetarians. *Int J Epidemiol* 1993;**22**:228–36.
22 **Villeneuve PJ**, Morrison HI, Craig CL, *et al*. Physical activity, physical fitness, and risk of dying. *Epidemiology* 1998;**9**:626–31.
23 **Weller I**, Corey P. The impact of excluding non-leisure energy expenditure on the relation between physical activity and mortality in women. *Epidemiology* 1998;**9**:632–5.
24 **Stessman J**, Maaravi Y, Hammerman-Rozenberg R, *et al*. The effects of physical activity on mortality in the Jerusalem 70-Year-Olds Longitudinal Study. *J Am Geriatr Soc* 2000;**48**:499–504.
25 **Roger VL**, Jacobsen SJ, Pellikka PA, *et al*. Prognostic value of treadmill exercise testing: a population-based study in Olmsted County, Minnesota. *Circulation* 1998;**98**:2836–41.
26 **Andersen LB**, Schnohr P, Schroll M, *et al*. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med* 2000;**160**:1621–8.
27 **Lissner L**, Bengtsson C, Bjorkelund C, *et al*. Physical activity levels and changes in relation to longevity. A prospective study of Swedish women. *Am J Epidemiol* 1996;**143**:54–62.
28 **Lapidus L**, Bengtsson C. Socioeconomic factors and physical activity in relation to cardiovascular disease and death. A 12 year follow up of participants in a population study of women in Gothenburg, Sweden. *Br Heart J* 1986;**55**:295–301.
29 **Davis MA**, Neuhaus JM, Moritz DJ, *et al*. Health behaviors and survival among middle-aged and older men and women in the NHANES I Epidemiologic Follow-up Study. *Prev Med* 1994;**23**:369–76.
30 **Lee Y**. The predictive value of self assessed general, physical, and mental health on functional decline and mortality in older adults. *J Epidemiol Community Health* 2000;**54**:123–9.
31 **Bath PA**, Morgan K. Customary physical activity and physical health outcomes in later life. *Age Ageing* 1998;**27**(suppl 3):29–34.
32 **Kushi LH**, Fee RM, Folsom AR, *et al*. Physical activity and mortality in postmenopausal women. *JAMA* 1997;**277**:1287–92.
33 **Morgan K**, Clarke D. Customary physical activity and survival in later life: a study in Nottingham, UK. *J Epidemiol Community Health* 1997;**51**:490–3.
34 **Schroll M**, Avlund K, Davidsen M. Predictors of five-year functional ability in a longitudinal survey of men and women aged 75 to 80. The 1914-population in Glostrup, Denmark. *Aging (Milano)* 1997;**9**:143–52.
35 **Rakowski W**, Mor V. The association of physical activity with mortality among older adults in the Longitudinal Study of Aging (1984–1988). *J Gerontol* 1992;**47**:M122–9.
36 **Wingard DL**. The sex differential in mortality rates: demographic and behavioral factors. *Am J Epidemiol* 1982;**115**:205–16.
37 **Fraser GE**, Sumbureru D, Pribis P, *et al*. Association among health habits, risk factors, and all-cause mortality in a black California population. *Epidemiology* 1997;**8**:168–74.
38 **Kaplan GA**, Strawbridge WJ, Cohen RD, *et al*. Natural history of leisure-time physical activity and its correlates: associations with mortality from all causes and cardiovascular disease over 28 years [see comments]. *Am J Epidemiol* 1996;**144**:793–7.
39 **Ruigómez A**, Alonso J, Anto JM. Relationship of health behaviours to five-year mortality in an elderly cohort. *Age Ageing* 1995;**24**:113–9.
40 **Garfinkel L**, Stellman SD. Mortality by relative weight and exercise. *Cancer* 1988;**62**:1844–50.
41 **Dorn JP**, Cerny FJ, Epstein LH, *et al*. Work and leisure time physical activity and mortality in men and women from a general population sample. *Ann Epidemiol* 1999;**9**:366–73.
42 **LaCroix AZ**, Leveille SG, Hecht JA, *et al*. Does walking decrease the risk of cardiovascular disease hospitalizations and death in older adults? *J Am Geriatr Soc* 1996;**44**:113–20.
43 **Lee I-M**, Skerrett PJ. Physical activity and all-cause mortality: what is the dose-response relation? *Med Sci Sports Exerc* 2001;**33**:S459–71.
44 **Paffenbarger RS**, Lee IM. Physical activity and fitness for health and longevity. *Res Q Exerc Sport* 1996;**67**:S11–28.
45 **Kristal-Boneh E**, Harari G, Melamed S, *et al*. Association of physical activity at work with mortality in Israeli industrial employees: the CORDIS study. *J Occup Environ Med* 2000;**42**:127–35.
46 **Smith GD**, Shipley MJ, Batty GD, *et al*. Physical activity and cause-specific mortality in the Whitehall study. *Public Health* 2000;**114**:308–15.
47 **Gray R**. 6. Physical activity. In: Colhoun H, Prescott-Clarke P, eds. *Health Survey for England 1994. A survey carried out on behalf of the department of health*. London: HMSO, 1996:175–203.
48 **Manson JE**, Hu FB, Rich-Edwards JW, *et al*. A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. *N Engl J Med* 1999;**341**:650–8.
49 **Lee I-M**, Rexrode KM, Cook NR, *et al*. Physical activity and coronary heart disease in women. Is "no pain, no gain" passe? *JAMA* 2001;**285**:1447–54.
50 **DeBusk RF**, Stenestrand U, Sheehan M, *et al*. Training effects of long versus short bouts of exercise in healthy subjects. *Am J Cardiol* 1990;**65**:1010–3.
51 **Murphy MH**, Hardman AE. Training effects of short and long bouts of brisk walking in sedentary women. *Med Sci Sports Exerc* 1998;**30**:152–7.
52 **Ferrucci L**, Izmirlian G, Leveille S, *et al*. Smoking, physical activity, and active life expectancy. *Am J Epidemiol* 1999;**149**:645–53.
53 **Weller IM**, Corey PN. A study of the reliability of the Canada Fitness Survey questionnaire. *Med Sci Sports Exerc* 1998;**30**:1530–6.
54 **Rockhill B**, Willett WC, Manson JE, *et al*. Physical activity and mortality: a prospective study among women. *Am J Public Health* 2001;**91**:578–83.
55 **Killoran A**, Fentem P, Casperson C, *et al*. *Moving on: international perspectives on promoting physical activity*. London: Health Education Authority, 1994.