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Work and leisure time physical activity assessed using a simple, pragmatic, validated questionnaire and incident cardiovascular disease and all-cause mortality in men and women: The European Prospective Investigation into Cancer in Norfolk prospective population study

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Background The health benefits of physical activity are well established, but the overall amount of physical activity associated with cardiovascular and other health outcomes, and whether the relationships are similar in men and women and at different ages is still debated. This may be partly related to different methods for assessing physical activity. Most studies have focused on leisure time physical activity.

Methods We examined the prospective relationship between usual physical activity, taking into account both leisure and work activity, using a simple, pragmatic, four-point rating scale validated against heart rate monitoring, and cardiovascular disease incidence and total mortality after an average 8 years follow-up in 22 191 community living men and women aged 45–79 years with no known cardiovascular disease or cancer at baseline.

Results The relative risks (95% confidence interval) for all-cause mortality (1553 deaths) for men and women who were moderately inactive, moderately active, and active compared with those who were inactive were 0.83 (0.73–0.95), 0.68 (0.58–0.80), and 0.68 (0.57–0.81), respectively, after adjusting for age, sex, systolic blood pressure, blood cholesterol, cigarette smoking, alcohol intake, diabetes, body mass index, and social class. The relationships were also consistent for cardiovascular disease incidence (3079 events), in subgroups stratified by age, sex, body mass index, smoking status and social class, and after excluding deaths in the first 2 years. The combined scale was more consistently associated with mortality than the individual work and leisure time components separately.

Conclusions When both work and leisure time physical activity patterns are taken into account, using a simple, pragmatic, validated questionnaire feasible for use in clinical and public health practice, even very moderate levels of usual physical activity are associated with significantly reduced risk of mortality and

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cardiovascular disease in men and women in the general population and potential population attributable impact of 14% for inactive compared with active levels. These findings may encourage efforts to increase physical activity levels not only in leisure time but also in usual daily working life.

Keywords physical activity, measurement, mortality, cardiovascular disease, population

The evidence that physical activity is beneficial for cardiovascular health is substantial.[1–8] Nevertheless, an American Heart Association Scientific Statement on exercise, physical activity, and cardiovascular disease, which reviewed the evidence, highlighted several unresolved issues.[9] There is still debate about how much physical activity is required for health benefit and whether the effects of physical activity differ in different population subgroups, for example men and women, or older and younger people.[4,5,10–12] This is partly due to the difficulty in measuring habitual physical activity patterns. Most population studies, in particular, occupationally based cohorts where work-based physical activity may be more homogeneous, rely on assessing leisure time physical activity. However, such leisure time activity may not adequately capture the whole spectrum of habitual physical activity in different population groups, and there may be differences by age, sex, and socioeconomic status. Additionally, while many different instruments for assessing physical activity are available, detailed, validated measurements are difficult to obtain in large population studies, and to apply in clinical and public health practice, whereas simpler questionnaires have not been well validated or are not easily generalizable. We wished to examine the use of a simple, pragmatic questionnaire encompassing both work and leisure time activity that has been validated in a general population of men and women over a wide age range.

It is also unclear how much any apparent health benefit of physical activity is mediated through known risk factors such as obesity, blood pressure, cholesterol, or diabetes as many studies did not measure and adjust adequately for these variables. Additionally, though physical activity appears to be beneficial for other health endpoints including total mortality[1,2,13,14] the relationships are less well documented but essential for understanding and assessing overall risks and benefits.

We present data from a prospective population study examining the relationship between usual physical activity patterns based on a simple questionnaire combining work and leisure time activity, validated using heart rate monitoring over 1 year, and total mortality and incident cardiovascular disease in men and women aged 45–79 years living in the general community.

Methods

The men and women in this analysis were part of EPIC-Norfolk, a prospective population study of 25 663 men and women aged 45–79 years resident in Norfolk, UK who participated in a baseline questionnaire survey and attended a clinic visit. They were recruited from age-sex registers of participating general practices in Norfolk as part of a 10-country collaborative study EPIC, European Prospective Investigation into Cancer and Nutrition, designed to investigate dietary and other determinants of cancer. The EPIC-Norfolk cohort had additional data collection to enable the examination of chronic disease determinants. The participants in this study were recruited by mailing all age eligible persons on participating general practice registers. Because we requested participation of persons willing to provide detailed dietary, biological, and other health data, and to be followed-up over the years, we had a ~45% response rate so participants were not a random population sample. Nevertheless, they were comparable with national population samples with respect to many characteristics including anthropometry, blood pressure, and lipids but with a lower prevalence of current smokers.[15]

At the baseline survey between 1993 and 1997 participants completed a detailed health and lifestyle questionnaire. They were asked about medical history with the question 'Has a doctor ever told you that you have any of the following?' followed by a list of conditions including diabetes, heart attack, stroke, and cancer. Alcohol intake was calculated from questions on amount and type of usual alcohol intake for each day of the week. Smoking history was derived from yes/no responses to the questions 'Have you ever smoked as much as one cigarette a day for as long as a year?' and 'Do you smoke cigarettes now?' Social class was classified according to the registrar general's occupation-based classification scheme into five main categories, with social class I representing professional classes and social class V representing groups such as manual labourers.

Habitual physical activity was assessed using two questions referring to activity during the past year. The first question asked about usual physical activity at work, classified as four categories: sedentary, standing (e.g. hairdresser, shop assistant, guard), physical work (e.g. plumber, cleaner, nurse), and heavy manual work (e.g. docker, construction worker, bricklayer). The second question asked about the amount of time spent in hours per week in winter and summer separately in two activities: cycling, and other physical exercise (e.g. keep fit, jogging, swimming), (Appendix 1). The average time spent daily in recreational activity per day was estimated as the simple mean of the total hours spent per week in winter and summer, divided by seven. A simple physical activity index was devised to allocate individuals to four ordered categories of overall activity: those who were inactive (sedentary job and no recreational activity); moderately inactive (sedentary job with <0.5 h recreational activity per day or standing job with no recreational activity); moderately active (sedentary job with 0.5–1 h recreational activity per day, or standing job with

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<0.5 h recreational activity per day, or physical job with no recreational activity); and active (sedentary job with >1 h recreational activity per day, or standing job with >1 h recreational activity per day, or physical job with at least some recreational activity, or heavy manual job). (Appendix) This index was validated against heart rate monitoring in 173 individuals over 1 year.[16,17]

A health examination was carried out by trained nurses at a clinic visit. Height and weight were measured with subjects in light clothing without shoes. Body mass index was estimated as weight in kilograms divided by height in metres squared. Blood pressure was measured using an Accutorr non-invasive blood pressure monitor after the participant had been seated for 5 min. The mean of two readings was used for analysis. Non-fasting blood samples were stored in a refrigerator at 4°C until transported within a week of sampling to be assayed at the Department of Clinical Biochemistry, University of Cambridge. Serum total cholesterol, HDL cholesterol, and triglycerides were measured using the RA 1000, (Bayer Diagnostics, Basingstoke, UK) and LDL cholesterol values calculated using the Friedewald formula.[18]

All participants are followed-up for health events. We report results for follow-up to September 2004, an average of ~8 years. All participants have been flagged for death certification at the Office of National Statistics in UK with vital status ascertained on the whole cohort. Death certificates for all decedents were coded by trained nosologists according to the International Classification of Disease (ICD) 9th revision. Cardiovascular death was defined as death with ICD 400–438 as underlying cause and encompasses stroke and coronary heart disease as well as other vascular causes.

Participants admitted to hospital are identified using their unique National Health Service number by data linkage with ENCORE (East Norfolk Health Authority database), which identifies all hospital contacts throughout England and Wales for Norfolk residents. We used standard diagnostic codes to ascertain hospital episodes for cardiovascular disease occurring in the cohort.

Participants were identified as having a cardiovascular disease event during follow-up if they had a hospital admission and/or died with cardiovascular disease as underlying cause of death. Of the 3079 events identified, 535 (17%) of these were fatal events.

The study was approved by the Norwich District Health Authority Ethics Committee and all participants gave signed informed consent.

The present analysis included all men and women aged 45–79 years who had completed the health and lifestyle questionnaire with the questions on physical activity and who attended the health examination. Of the 24 587 with available data, 2396 had a history of heart disease, stroke, or cancer at the baseline visit and were excluded from analysis, leaving 22 191 individuals.

We examined risk factor distributions by physical activity category, then total mortality and cardiovascular disease event rates in these categories. The Cox proportional hazards model was used to determine the relative risks of mortality and cardiovascular disease by physical activity category after adjusting for age, and then for age and other risk factors including body mass index, systolic blood pressure, blood cholesterol concentrations, alcohol intake, cigarette smoking, known diabetes, and social class. We also examined relative risks in subgroups, stratified by sex, age, body mass index, cigarette smoking status, and after excluding those who died within 2 years of follow up. We additionally examined the relative risks for mortality and cardiovascular disease for the work activity and the leisure time activity components of physical activity separately.

Finally, we estimated the population attributable fraction (PAF) for mortality associated with inactivity or moderate inactivity compared with those who were moderately active or active combined. The population attributable risk is a measure of the excess rate of disease in a population, which is attributable to an exposure. The PAF is the estimated proportion by which the incidence rate of the outcome in the entire population could be reduced if the exposure were eliminated assuming causality. PAF was calculated using the formula PAF = Prevalence of exposure * (RR −1)/[(Prevalence of exposure * (RR − 1) + 1] where RR is the relative risk of that physical activity category compared with the moderately active or active group combined.

Results

Table 1 shows characteristics of the participants according to physical activity category. In both men and women, physical activity was significantly inversely related to age, and cardiovascular risk factors including blood pressure, with lower mean blood pressure levels, cholesterol concentrations, and body mass index. Both the prevalence of diabetes and current smokers were inversely related to physical activity level with lowest prevalence in the active compared with inactive categories. There was a significantly higher proportion of men in manual social classes in the most physically active groups but no consistent social class trend for women.

Table 2 shows sex-specific all-cause mortality and cardiovascular disease incidence rates, which decreased with increasing physical activity category. Age-adjusted relative risks showed a significant linear trend across physical activity categories, apparent for total mortality and for cardiovascular disease incidence. These reduced risks were only slightly attenuated after adjusting for risk factors including age, body mass index, systolic blood pressure, cholesterol, cigarette smoking habit, alcohol intake, known diabetes, and social class. For all-cause mortality, men and women who were moderately inactive had significantly lower relative risks compared with those who were inactive.

Table 3 shows the independent multivariate relationship of physical activity with all-cause mortality and cardiovascular disease incident events in subgroups of the population stratified by age, smoking habit, body mass index, and social class. Being in the moderately active group compared with the inactive group was equivalent to being ~3 years older in terms of mortality risk. Relative risks were also estimated after excluding all those with follow-up time of <2 years. In general, relative risk estimates were consistent in the subgroups except for current smokers for whom relative risks associated with increasing physical activity were not significantly different

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Table 1 Distribution of variables by level of physical activity in 9984 men and 12 207 women aged 45–79 years with no history of heart disease, stroke, or cancer in EPIC Norfolk 1993–97

	Physical activity category				
	Inactive	Moderately inactive	Moderately active	Active	*P*-value Between groups
Men	*n* = 2828	*n* = 2532	*n* = 2320	*n* = 2304	
	Mean (SD)				
Age (years)	62.0 (8.8)	59.3(8.9)	58.1 (8.3)	56.9 (8.1)	<0.001
Body mass index (kg/m^2)	27.0 (3.5)	26.5 (3.3)	26.2 (3.2)	26.3 (3.1)	<0.001
Systolic blood pressure (mm Hg)	140.3(18.4)	137.9 (17.6)	136.3 (17.0)	135.5 (16.7)	<0.001
Diastolic blood pressure (mm Hg)	85.6 (11.6)	85.0 (11.4)	83.9 (10.8)	83.7 (10.5)	<0.001
Cholesterol (mmol/l)	6.10 (1.10)	6.06 (1.13)	6.04 (1.05)	5.98 (1.07)	0.002
LDL-cholesterol (mmol/l)	3.96 (0.98)	3.94 (0.97)	3.92 (0.94)	3.87 (0.96)	0.015
HDL-cholesterol (mmol/l)	1.21 (0.33)	1.22 (0.32)	1.25 (0.34)	1.28 (0.34)	<0.001
Triglycerides (mmol/l)	2.16 (1.28)	2.05 (1.26)	1.98 (1.14)	1.90 (1.11)	<0.001
Alcohol drinking (g/day)	10.8 (13.1)	12.5 (14.4)	11.1 (12.5)	12.5 (13.6)	<0.001
	Per cent (*n*)				
Cigarette smoking habit					
Never	29.2 (820)	35.3(888)	34.6 (798)	36.1 (828)	<0.001
Current	14.3 (401)	11.1 (279)	11.8 (272)	12.1 (277)	
History of diabetes	4.0 (112)	2.9 (74)	2.2 (51)	1.6 (38)	<0.001
Manual social class	38.3 (1061)	28.2 (702)	47.4 (1082)	56.6 (1287)	<0.001
Women	*n* = 3463	*n* = 3997	*n* = 2767	*n* = 1980	
	Mean (SD)				
Age (years)	62.3 (9.0)	58.7 (8.6)	56.7 (8.1)	55.7 (7.7)	<0.001
Body mass index (kg/m^2)	27.08 (4.7)	26.2 (4.2)	25.8 (4.1)	25.6 (3.8)	<0.001
Systolic blood pressure (mm Hg)	138.7 (19.4)	133.9 (18.4)	131.9 (18.4)	130 2(17.6)	<0.001
Diastolic blood pressure (mm Hg)	83.1 (11.4)	81.1 (11.0)	80.2 (11.1)	79.2 (10.7)	<0.001
Cholesterol (mmol/l)	6.54 (1.20)	6.34 (1.21)	6.25 (1.19)	6.12 (1.13)	<0.001
LDL-cholesterol (mmol/l)	4.20 (1.09)	4.04 (1.07)	4.00 (1.08)	3.87 (1.04)	<0.001
HDL-cholesterol (mmol/l)	1.54 (0.42)	1.56 (0.42)	1.59 (0.42)	1.61 (0.42)	<0.001
Triglycerides (mmol/l)	1.80 (1.00)	1.63 (1.00)	1.55 (0.90)	1.45 (0.81)	<0.001
Alcohol drinking (units/day)	4.2 (6.1)	5.2 (6.8)	5.3 (6.5)	5.3 (6.3)	<0.001
	Per cent (*n*)				
Cigarette smoking habit					
Never	54.2 (1854)	58.2 (2305)	57.6 (1581)	56.9 (1120)	0.008
Current	12.6(431)	10.8 (427)	11.3 (311)	9.9 (196)	
History of diabetes	2.5 (86)	1.6 (60)	0.8 (23)	0.7 (13)	<0.001
Manual social class	41.0 (1359)	35.5 (1390)	38.8 (1–53)	43.9 (854)	0.04

from inactive smokers. However, the numbers of current smokers were relatively small, compared with other subgroups.

For men and women combined, the 28% prevalence of those who were inactive and 29% prevalence of those who were moderately inactive contributed 14% [95% confidence interval (95% CI) 10–18%] and 6% (95% CI 2–8%), respectively, of the population attributable risk fraction for total mortality compared with those who were moderately active or active.

Table 4 shows the age and sex, and age and multivariate adjusted relative risks for all-cause mortality and cardiovascular disease incidence by the separate work and recreational components of the combined physical activity score. While, generally, there was an inverse association for both the separate work and recreational components with mortality and cardiovascular disease, the associations were less consistent both for statistical significance and for clear dose–response relationships compared with the combined work and leisure scale. Compared with the combined scale, there was substantial misclassification for both work and recreational scales; for example, 5470 men and women who had low scores on the leisure scale (<1 h daily) scored as moderately active or active on the combined work and leisure scale, and 4950 men and women who reported sedentary or standing occupations scored as moderately active or active on the combined work and leisure scale.

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Table 2 Rates* and age-adjusted relative risks[a] for all-cause mortality and incident fatal and non-fatal cardiovascular disease by category of physical activity in 9984 men and 12 207 women aged 45–79 years with no history of heart disease, stroke, or cancer in EPIC-Norfolk 1993–2004

	Physical activity category			
	Inactive	Moderately inactive	Moderately active	Active
Men	*n* = 2828	*n* = 2532	*n* = 2320	*n* = 2304
All-cause mortality (*n* = 930/9984)				
Rate/100 (*n* of events)	13.8 (391)	9.8 (241)	6.7 (156)	5.9 (135)
Age-adjusted relative risk (95% CI)	1	0.84 (0.71–0.96)	0.65 (0.54–0.77)	0.65 (0.53–0.79)
Age and risk factor adjusted relative risk (95% CI)	1	0.89 (0.75–1.06)	0.69 (0.56–0.84)	0.68 (0.54–0.84)
Cardiovascular disease incidence (*n* = 1669/9964)				
Rate/100 (*n* of events)	22.4 (633)	16.5 (417)	14.1 (327)	12.2 (292)
Age-adjusted relative risk (95% CI)	1	0.80 (0.71–0.91)	0.73 (0.64–0.83)	0.71 (0.67–0.82)
Age and risk factor adjusted relative risk (95% CI)	1	0.88 (0.77–1.00)	0.79 (0.68–0.91)	0.74 (0.64–0.86)
Women	*n* = 3463	*n* = 3997	*n* = 2767	*n* = 1980
All-cause mortality (*n* = 623/12 207)				
Rate/100 (*n* of events)	8.6 (299)	4.5 (181)	3.1 (86)	2.9 (57)
Age-adjusted relative risk (95% CI)	1	0.71 (0.57–0.86)	0.60 (0.47–0.77)	0.62 (0.46–0.83)
Age and risk factor adjusted relative risk (95% CI)	1	0.76 (0.61–0.93)	0.69 (0.53–0.90)	0.68 (0.49–0.94)
Cardiovascular disease incidence (*n* = 1410/12 207)				
Rate/100 (*n* of events)	16.8 (582)	11.3 (453)	9.0 (249)	6.4 (126)
Age-adjusted relative risk (95% CI)	1	0.84 (0.74–0.95)	0.75 (0.65–0.88)	0.57 (0.47–0.88)
Age and risk factor adjusted relative risk (95% CI)	1	0.98 (0.85–1.12)	0.94 (0.80–1.11)	0.69 (0.56–0.86)

* $P < 0.001$ for linear trend across physical activity categories for all endpoints.

[a] Age-adjusted relative risks using Cox regression; risk factors are body mass index, systolic blood pressure, blood cholesterol, cigarette smoking habit, alcohol intake, known diabetes, and social class.

Discussion

In this population of middle-aged and older men and women, increasing level of usual physical activity was strongly and independently associated with lower subsequent all-cause mortality and cardiovascular disease incident events, with an ~30% lower risk in the most active group compared with those who were inactive. However, even those who were moderately inactive compared with those who were inactive had 20% significantly lower all-cause mortality. While increasing physical activity was associated with lower levels of known cardiovascular risk factors including blood pressure, cholesterol, lower diabetes, and smoking prevalence, the reduced mortality and cardiovascular risks were only slightly attenuated by adjustment for age and these risk factors.

It is possible that people who are already ill are less likely to be physically active. However, individuals with known serious chronic disease, namely cancer, heart disease, and stroke, were excluded from these analyses. It is possible that there were still people with preclinical disease or other chronic diseases such as musculoskeletal conditions, which might be associated with increased mortality risk and lower physical activity levels. Nevertheless, the relationships were also consistent after excluding all those who had an event within 2 years of the baseline. In addition, when the separate components of physical activity were considered, those in the heavy manual labour category or the highest recreational physical activity categories, where the reverse causality argument might be expected to apply most strongly, did not in fact show the lowest relative mortality risk compared with the other categories. The relationships were also consistent after stratification for major potential confounders such as smoking habit, alcohol intake, body mass index, age, and social class. Though we cannot exclude residual confounding from other factors not considered here such as diet, these findings are consistent with the substantial existing evidence from epidemiological and clinical studies indicating that physical activity is beneficial for health.

Though there is overwhelming consensus about the health benefits of physical activity, the current study addresses a number of issues that are still not completely resolved. It has been difficult to quantify the levels and type of physical activity required for benefit on cardiovascular disease or mortality outcomes, and to compare directly findings for men and women or different age groups, as many cohorts have been restricted with respect to age, gender, occupation, or social class. For example, early studies suggested that vigorous activity at least three times a week was necessary to confer cardiovascular benefit,[5] though later work has indicated that lower levels of physical activity such as walking may be cardioprotective.[4,19] Other studies have suggested that the relationship between physical activity and mortality may be different in men and women or at different ages. For example a review suggested good evidence for an inverse linear dose–response relationship between volume of physical activity and all-cause mortality rates in men and women, suggesting

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Table 3 Relative risks (RRs) age, sex, and risk factor adjusted[a] for all-cause mortality and incident fatal and non-fatal cardiovascular disease in pre-specified subgroups by category of physical activity in 8638 men and 10 652 women[b] aged 45–79 years with no history of heart disease, stroke, or cancer in EPIC-Norfolk 1993–2004

	Physical activity category			
	Inactive	Moderately inactive	Moderately active	Active
All-cause mortality (*n* of events/*N*)				
All (1553/22 191)				
Age and sex adjusted RR	1	0.78 (0.69–0.88)	0.63 (0.54–0.73)	0.63 (0.54–0.75)
Age, sex and risk factor adjusted RR	1	0.83 (0.73–0.95)	0.68 (0.58–0.80)	0.68 (0.57–0.81)
Age <65 years (481/15 335)				
Age and sex adjusted RR	1	0.94 (0.74–1.19)	0.73 (0.57–0.95)	0.71 (0.54–0.92)
Age, sex and risk factor adjusted RR	1	1.01 (0.78–1.31)	0.81 (0.62–1.07)	0.82 (0.62–1.09)
Age >65 years (*n* = 1072/6856)				
Age and sex adjusted RR	1	0.73 (0.63–0.85)	0.60 (0.50–0.72)	0.62 (0.40–0.77)
Age, sex and risk factor adjusted RR	1	0.77 (0.66–0.91)	0.65 (0.53–0.79)	0.64 (0.50–0.80)
Current non-smokers (*n* = 1289/19 418)				
Age and sex adjusted RR	1	0.79 (0.69–0.90)	0.62 (0.53–0.73)	0.62 (0.51–0.74)
Age, sex and risk factor adjusted RR	1	0.83 (0.72–0.96)	0.67 (0.56–0.79)	0.64 (0.53–0.78)
Current smokers (*n* = 246/2594)				
Age and sex adjusted	1	0.81 (0.59–1.12)	0.79 (0.55–1.12)	0.85 (0.57–1.26)
Age, sex and risk factor adjusted	1	0.79 (0.56–1.12)	0.80 (0.54–1.17)	0.93 (0.59–1.38)
Body mass index <27 kg/m^2 (*n* = 874/13 788)				
Age and sex adjusted	1	0.77 (0.66–0.91)	0.65 (0.54–0.79)	0.69 (0.56–0.85)
Age, sex and risk factor adjusted	1	0.83 (0.69–0.99)	0.70 (0.57–0.86)	0.75 (0.60–0.94)
Body mass index ⩽27 kg/m^2 (*n* = 673/8358)				
Age and sex adjusted	1	0.82 (0.68–0.98)	0.62 (0.49–0.78)	0.56 (0.43–0.73)
Age, sex and risk factor adjusted	1	0.84 (0.69–1.03)	0.67 (0.52–0.87)	0.59 (0.44–0.79)
Social class non-manual (811/12 915)				
Age and sex adjusted	1	0.82 (0.69–0.96)	0.67 (0.55–0.82)	0.69 (0.56–0.88)
Age, sex and risk factor adjusted	1	0.85 (0.71–1.01)	0.71 (0.57–0.88)	0.74 (0.58–0.94)
Social class manual (663/8788)				
Age and sex adjusted	1	0.81 (0.67–0.98)	0.61 (0.49–0.72)	0.56 (0.44–0.72)
Age, sex and risk factor adjusted	1	0.80 (0.65–0.99)	0.65 (0.51–0.82)	0.62 (0.47–0.80)
Follow-up time ⩾2 years (*n* = 1360/21 988)				
Age and sex adjusted	1	0.81 (0.71–0.92)	0.63 (0.53–0.73)	0.63 (0.53–0.75)
Age, sex and risk factor adjusted	1	0.85 (0.74–0.98)	0.68 (0.57–0.81)	0.68 (0.56–0.82)
Incident fatal and non-fatal cardiovascular disease				
All (3079/22 191)				
Age and sex adjusted RR	1	0.82 (0.75–0.90)	0.74 (0.67–0.82)	0.66 (0.59–0.74)
Age, sex and risk factor adjusted RR	1	0.92 (0.84–1.01)	0.85 (0.76–0.94)	0.73 (0.65–0.83)
Age <65 years (*n* = 1365/15 335)				
Age and sex adjusted	1	0.75 (0.65–0.86)	0.71 (0.62–0.82)	0.63 (0.54–0.73)
Age, sex and risk factor adjusted	1	0.87 (0.74–1.01)	0.87 (0.74–1.01)	0.74 (0.62–0.87)
Age ⩾65 years (*n* = 1714/6856)				
Age and sex adjusted	1	0.87 (0.77–0.97)	0.74 (0.64–0.85)	0.67 (0.57–0.80)
Age, sex and risk factor adjusted	1	0.95 (0.84–1.08)	0.81 (0.70–0.94)	0.73 (0.61–0.88)
Current non-smokers (*n* = 2617/19 418)				
Age and sex adjusted	1	0.87 (0.79–0.95)	0.76 (0.68–0.85)	0.68 (0.60–0.77)
Age sex and risk factor adjusted	1	0.96 (0.87–1.06)	0.86 (0.76–0.96)	0.73 (0.66–0.85)
Current smokers (*n* = 424/2594)				
Age and sex adjusted	1	0.64 (0.50–0.82)	0.73 (0.50–0.94)	0.69 (0.51–0.94)

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Table 3 continued

	Physical activity category			
	Inactive	Moderately inactive	Moderately active	Active
Age, sex and risk factor adjusted	1	0.69 (0.52–0.90)	0.81 (0.61–1.07)	0.68 (0.49–0.94)
Body mass index <27 (*n* = 1565/1378)				
Age and sex adjusted	1	0.82 (0.73–0.93)	0.78 (0.68–0.89)	0.69 (0.59–0.81)
Age, sex and risk factor adjusted	1	0.91 (0.79–1.04)	0.85 (0.74–0.99)	0.74 (0.63–0.88)
Body mass index <27 (*n* = 1508/8358)				
Age and sex adjusted	1	0.86 (0.76–0.97)	0.74 (0.64–0.86)	0.67 (0.57–0.79)
Age, sex and risk factor adjusted	1	0.94 (0.82–1.07)	0.84 (0.72–0.98)	0.73 (0.61–0.88)
Social class non-manual (1607/12 915)				
Age and sex adjusted	1	0.86 (0.76–0.97)	0.74 (0.64–0.86)	0.70 (0.60–0.83)
Age, sex and risk factor adjusted	1	0.91 (0.81–1.03)	0.82 (0.71–0.96)	0.76 (0.64–0.91)
Social class manual (1366/8788)				
Age and sex adjusted	1	0.82 (0.72–0.95)	0.72 (0.62–0.84)	0.59 (0.50–0.70)
Age, sex and risk factor adjusted	1	0.88 (0.76–1.02)	0.82 (0.70–0.96)	0.65 (0.55–0.78)
Follow time >2 years (*n* = 2992/21 968)				
Age and sex adjusted	1	0.82 (0.75–0.90)	0.74 (0.67–0.82)	0.66 (0.59–0.74)
Age, sex and risk factor adjusted	1	0.93 (0.84–1.02)	0.85 (0.76–0.94)	0.71 (0.65–0.83)

[a] Age-adjusted relative risks using Cox regression; risk factors are body mass index, systolic blood pressure, blood cholesterol, cigarette smoking habit, alcohol intake, known diabetes, and social class.

[b] Numbers do not always total 1553 deaths/22 191 people exactly because of missing data for some variables.

that energy expenditure of ~1000 kcal a week (−1) [4200 kJ/week (−1)] is associated with 20–30% reduction in risk of all-cause mortality. However, it was unclear whether <1000 kcal a week might be associated with lower risk. Owing to limited data, it was also unclear whether vigorous-intensity activity conferred additional benefit beyond its contribution to volume of physical activity, when compared with moderate-intensity physical activity.[19]

Part of the difficulty revolves around the measurement of physical activity. Most previous studies have assessed only leisure time physical activity and this may not capture the full range of activity in daily life, especially as patterns of leisure time and, just as importantly, non-leisure time physical activity differ by sex, age, social class, or occupation. While detailed questionnaires on physical activity and possible physiological measures such as 24 h heart rate monitoring or energy expenditure may be necessary to obtain more specific quantified estimates of different dimensions of physical activity including frequency, intensity, duration, and total amount, as well as aerobic and resistance activity in individuals,[20–22] such intensive measurements are not feasible in large population studies. Conversely simple questionnaires that have been used have not been well validated. Our aim in creating the physical activity index was to develop a simple and pragmatic tool for easily classifying physical activity. We expressly did not go down the road of converting reported physical activity into energy expenditure units such as METs or kJ in these particular analyses as we believe that such a conversion based on this short questionnaire would not be valid and create an impression of spurious precision as to the estimated energy expenditure requirements and dose–response required to achieve risk reduction. We wished to use a simple but comprehensive index incorporating both work and leisure time activity with a descriptive label that was easily understood. Additionally, the other advantage of the index is the ease with which it can be assessed and computed in daily life. In clinical and public health practice, it is not practical to use a physical activity questionnaire which requires complex data entry and computation. Nevertheless, this index has been previously demonstrated in validation studies with objective heart rate monitoring in individuals followed over 1 year to be linearly related to true activity. In the current analyses, we now also demonstrate that this index predicts total mortality and cardiovascular disease incidence. Large random measurement associated with this index is likely to result in underestimation of any relationship.

Additionally much previous work has been based in occupational groups or confined to one sex or a more narrow age range. The current population-based study encompassed the whole range of work and leisure patterns and was able to compare men and women, and different ages using the same scale. Using this scale, the significantly lower mortality in those who were moderately inactive compared with those who were inactive suggests that even relatively modest increases in work or leisure time activity may be associated with benefit. At least for all-cause mortality, there were no significant differences between those who were moderately active and those who were active. Some of the differences in dose–response relationship in the current compared with findings from past studies may relate to the total measure of physical activity used in the current study incorporating work activity compared with use of only leisure time activity in previous studies. The weaker and less consistent associations between the separate work and leisure components compared with the combined score and

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Table 4 Relative risks (RR) age, sex and risk factor adjusted[a] for all-cause mortality and incident fatal and non-fatal cardiovascular disease by separate work and recreational components of the physical activity score in 8638 men and 10 652 women aged 45–79 years with no history of heart disease, stroke, or cancer in EPIC-Norfolk 1993–2004

	Relative risks (95% confidence intervals)			
By work activity	Sedentary (n = 12 137)	Standing (n = 5633)	Physical (n = 3873)	Heavy manual (n = 548)
All-cause mortality (1553 events)				
Age and sex adjusted	1	0.84 (0.74–0.96)	0.71 (0.60–0.84)	0.88 (0.61–1.28)
Age, sex and risk factor adjusted	1	0.86 (0.75–0.99)	0.73 (0.62–0.88)	0.91 (0.62–1.33)
Incident fatal and non fatal cardiovascular disease (3079 events)				
Age and sex adjusted RR	1	0.64 (0.58–0.70)	0.67 (0.60–0.75)	0.80 (0.62–1.02)
Age, sex and risk factor adjusted RR	1	0.69 (0.63–0.76)	0.69 (0.62–0.78)	0.78 (0.60–1.01)
By recreational physical activity	None (N = 11 143)	Up to 0.5 h daily (n = 7147)	0.5–1 h daily (n = 2767)	More than 1 h daily (n = 1134)
All-cause mortality (1553 events)				
Age and sex adjusted	1	0.69 (0.61–0.78)	0.72 (0.60–0.87)	0.79 (0.63–1.01)
Age, sex and risk factor adjusted	1	0.76 (0.66–0.97)	0.78 (0.64–0.95)	0.82 (0.63–1.06)
Incident fatal and non-fatal cardiovascular disease (3079 events)				
Age and sex adjusted	1	0.95 (0.78–0.92)	0.84 (0.74–0.96)	0.71 (0.59–0.85)
Age, sex and risk factor adjusted	1	0.96 (0.88–1.05)	0.95 (0.84–1.09)	0.76 (0.64–0.94)

[a] Age-adjusted relative risks using Cox regression; risk factors are body mass index, systolic blood pressure, blood cholesterol, cigarette smoking habit, alcohol intake, known diabetes, and social class.

health endpoints suggest that it is necessary to assess total physical activity.

Controlled trials as well as observational studies have reported that physical activity improves levels of classical cardiovascular disease risk factors including lower blood pressure, more favourable lipid profile, lower obesity levels, and improved glucose tolerance.[4,5,8,10–12,23–27] As expected, we also found strong relationships between level of physical activity and these risk factors. However, more surprisingly, the relationship of physical activity with cardiovascular disease incidence and total mortality in this cohort was only somewhat attenuated and still apparent after adjustment for these risk factors. Physical activity has been reported to have more wide-ranging physiological effects apart from those documented for conventional cardiovascular risk factors, such as effects on endothelial function, inflammation, haemostasis, and even endogenous sex hormone levels.[28–30] While there may have been imperfect adjustment for the classical risk factors, given the large measurement error in assessment of physical activity, this suggests that the apparent health benefits of physical activity may be substantial and may have physiological benefits additional to those for classical cardiovascular risk factors.

Since over a quarter of this British population were inactive, the PAF of 14% suggests that even relatively modest increases in work or leisure time physical activity may have substantial impact on population health. This PAF is likely to be larger in countries such as the US where the prevalence of inactivity is likely to be greater than in this British population.

Conclusions

A simple pragmatic questionnaire encompassing both work and leisure time physical activity validated in the general population can feasibly be used in clinical and public health practice. When both work and leisure time physical activity patterns are taken into account, using this simple questionnaire, even very moderate levels of usual physical activity are associated with significantly reduced risk of mortality and cardiovascular disease in men and women, and various population subgroups stratified by age, body mass index, and social class. While randomized primary prevention trials are desirable, their feasibility for health outcomes such as mortality is questionable. In the interim, these findings may encourage efforts to increase physical activity levels not only in leisure time but also in usual daily working life.

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Contributors

Kay-Tee Khaw, Nick Day, Sheila Bingham, and Nick Wareham are principal investigators in the EPIC-Norfolk population study. Nick Wareham and Rupert Jakes developed and validated the physical activity measures and scales. Ailsa Welch is responsible for nutritional data involved in the physical activity validation and calibration studies. Robert Luben is responsible for data management, record linkage, and computing overall. Kay-Tee Khaw conducted the data analyses and wrote the paper with the co-authors.

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KEY MESSAGES

- A simple, pragmatic index encompassing both work and leisure activity, and feasible for use in general practice has been previously validated against energy expenditure.
- This simple index predicts cardiovascular disease incidence and mortality in a prospective population study.
- This index appears robust in different population subgroups stratified by age, sex, smoking, body mass index, and social class.
- These findings may encourage efforts to increase physical activity in the population. Even being moderately inactive compared with inactive is associated with demonstrable significant differences in future risk.

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Appendix

Table A1 Description of physical activity categories

Category	Description
Inactive	Sedentary job and no recreational activity
Moderately inactive	Sedentary job with <0.5 h recreational activity per day or standing job with no recreational activity
Moderately active	Sedentary job with 0.5–1 h recreational activity per day or Standing job with 0.5 h recreational activity per day or Physical job with no recreational activity
Active	Sedentary job with >1 h recreational activity per day or Standing job with >1 h recreational activity per day or Physical job with at least some recreational activity or Heavy manual job

These categories are derived from the two questions following.

EPIC Physical activity questions from which total physical activity score derived

1. We would like to know the type and amount of physical activity involved in your work.

   Please tick what best corresponds to your present activities from the following four possibilities

___	Sedentary occupation	You spend most of your time sitting (such as in an office)
___	Standing occupation	You spend most of your time standing or walking. However, your work does not require intense physical efforts (e.g. shop assistant, hairdresser, guard, etc.)
___	Physical work	This involves some physical effort including handling of heavy objects and use of tools (e.g. plumber, cleaner, nurse, sports instructor, electrician, carpenter, etc.)
___	Heavy manual work	This involves very vigorous physical activity including handling of very heavy objects (e.g. docker, miner, bricklayer, construction worker, etc.)

2. In a typical week during the past 12 months, how many hours did you spend on each of the following activities? (Put '0' if none)

   Cycling, including cycling to work and during leisure time

   In summer ___ hours per week

   In winter ___ hours per week

   Other physical exercise such as keep fit, aerobics, swimming, jogging

   In summer ___ hours per week

   In winter ___ hours per week

   Hours per day of recreational activity computed from [(mean of summer and winter hours per week cycling) + (mean of summer and winter hours per week other physical exercise)]/7.

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