What level of physical activity protects against premature cardiovascular death? The Caerphilly study

S Yu, J W G Yarnell, P M Sweetnam, L Murray

MANY studies have shown that physical activity during leisure is associated with a decrease in all cause mortality and may extend life by 1–2 years. Other studies have shown a reduction in premature death caused by cardiovascular disease (CVD) and coronary heart disease (CHD). But the optimal intensity of time physical activity (LTPA) is still unclear. Some studies indicate that only vigorous intensity activity is associated with decreased risk of death; others also show associations with moderate or light intensity activity. Also, studies of leisure physical activity and cancer death have yielded inconsistent findings.

The first aim of the present study was to examine the association of LTPA with all cause mortality and cause specific mortality. It is also useful to know the required level and intensity of activity important in the prevention of premature death. We therefore assessed the effects of energy expenditure in various intensity activities (light, moderate, and heavy) during leisure on the risk of disease specific death in a prospective study of middle aged men in Caerphilly, South Wales, UK. Work related physical activity was also examined.

METHODS
Study population and design
The Caerphilly collaborative heart disease study began in 1979 with the overall objective of examining the determinants and predictive ability of new and classical risk factors for CHD. During the initial recruitment phase (1979–1983) 2512 men aged 45–59 years were examined, representing 90% of the population of men in this age group from the town of Caerphilly and its surrounding villages (total population 40 000). Since then they have been examined at five year intervals. At the first re-examination between 1984 and 1988, when the men were aged 49–54 years, men of the same age who had moved into the defined geographical area were also examined. Work related physical activity was also examined.

Objective: To examine the optimal intensity of leisure time physical activity (LTPA) to decrease the risk of all cause, cardiovascular disease (CVD), and coronary heart disease (CHD) mortality in a population sample of middle aged British men.

Design: Prospective study of middle aged men with an 11 year follow up.

Setting: A whole population sample of men from Caerphilly, South Wales, UK.

Subjects: 1975 men aged 49–64 years without historical or clinical evidence of CHD at baseline examination.

Main outcome measures: All cause, CVD, and CHD mortality.

Results: Total (cumulative) LTPA had a graded, significant relation with all cause, CVD, and CHD mortality but no trend with cancer deaths. When different intensities of activity were considered, light and moderate intensity LTPA had inconsistent and non-significant relations with all cause, CVD, or CHD mortality whether adjusted only for age or for other cardiovascular risk factors. In contrast a significant dose–response relation was found for heavy intensity LTPA for all cause, CVD, and CHD mortality fully adjusted for other risk factors.

Conclusions: These data suggest that, in a population of men without evidence of CHD at baseline, only leisure exercise classified as heavy or vigorous was independently associated with reduced risk of premature death from CVD.

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Abbreviations: AI, activity index; CHD, coronary heart disease; CI, confidence interval; CVD, cardiovascular disease; LSHTM, London School of Hygiene and Tropical Medicine; LTPA, leisure time physical activity; MRFIT, multiple risk factor intervention trial.
example, climbing stairs, swimming, jogging). Four AI scores characterised each person, one for each class of intensity activity and their sum total AI. Because the intensity codes for each specific activity were based predominantly on the experience in middle aged American men, some minor modifications were made to adapt to the leisure activity of British men in this study.

Detailed medical and lifestyle histories were obtained and the LSHTM chest pain questionnaire was administered. A full 12 lead ECG was recorded and height, weight, and blood pressure were measured.

The Health Insurance Plan questionnaire, slightly modified, was used to assess physical activity at work, or previous work if unemployed or retired, by self administration. Job physical activity class was divided into four equally sized groups from low to high occupational physical activity. Subjects who did not answer one or more components of the job physical activity questionnaire were not classified (23 subjects, 1%).

Outcome variables

The mean period of follow up was 10.5 years. Deaths were included until 25 September 1997. All men were flagged with the National Health Service Central Registry and we used death certificates coded according to International classification of diseases, ninth revision (ICD-9). The main outcome measures were mortality from all causes, CVD (ICD-9 codes 390–458), CHD (ICD-9 codes 410–414), and cancer (ICD-9 codes 140–239).

Person years at risk were calculated from the date of examination between 1984 and 1988 to the date of death or 25 September 1997 for men still alive. For analyses of all cause mortality, deaths due to congenital anomalies (ICD-9 codes 740 to 759) and injury and poisoning (ICD-9 codes 800 to 999) were censored for analyses of all cause mortality (seven cases). Of the total cohort of 1975 British men, 252 (13% of all men) died over the follow up period of 10 years. Among these 252, 111 (44%) deaths were caused by CVD, 82 (33%) by CHD, and 98 (39%) by cancer. Deaths resulting from congenital anomalies or injury and poisoning were censored for analyses of all cause mortality (seven cases).

Statistical methods

For primary analysis, total, light, moderate, and heavy AI were logarithmically transformed because of their positively skewed distributions. Before taking logarithms, 1.0 was added to each value for total, light, moderate, and heavy AI because zero values were common in some subjects, particularly for heavy AI. This transformation produced a more symmetrical Gaussian distribution and stabilised variances.

The main analyses used a Cox proportional hazards model in survival analysis from the Statistical package for the social sciences (SPSS) with the occurrence, or not, of disease specific mortality as the binary dependent variable. The distributions of total, light, moderate, and heavy AI were each divided into equal thirds and the results are presented as the hazard ratio for each disease category in each third relative to a baseline third, which was always taken as the 20% of men with the lowest levels. For heavy AI, in the first third there were 595 subjects who were inactive for vigorous activity. These subjects were referred to throughout as having the baseline value and, where appropriate, hazards for other thirds of the distribution are shown together with 95% confidence intervals (CIs) estimated from the Cox proportional hazards model.

The tests of linear trend for increasing thirds of total, light, moderate, and heavy AI were performed using Cox proportional hazards model by treating total, light, moderate, and heavy AI as an ordered variable in thirds as described on the relevant tables.

All tests are two sided significance levels of <0.05 calculated from SPSS. Partially missing values were automatically excluded from the analyses.

RESULTS

Of the total cohort of 1975 British men, 252 (13% of all men) died over the follow up period of 10 years. Among these 252, 111 (44%) deaths were caused by CVD, 82 (33%) by CHD, and 98 (39%) by cancer. Deaths resulting from congenital anomalies or injury and poisoning were censored for analyses of all cause mortality (seven cases).

### Table 1 Energy expenditure expressed as activity index (AI, in kcal/day) of physical activity during leisure by activity intensity between 1984 and 1988 in men from Caerphilly, South Wales, UK

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number</th>
<th>Mean</th>
<th>Geometric Mean</th>
<th>Median</th>
<th>Maximum</th>
<th>Q₁</th>
<th>Q₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total AI</td>
<td>1964</td>
<td>366.1</td>
<td>207.3</td>
<td>257.5</td>
<td>2747.2</td>
<td>122.0</td>
<td>486.0</td>
</tr>
<tr>
<td>Light AI</td>
<td>1964</td>
<td>152.1</td>
<td>52.4</td>
<td>81.9</td>
<td>2048.6</td>
<td>23.0</td>
<td>211.9</td>
</tr>
<tr>
<td>Moderate AI</td>
<td>1964</td>
<td>163.9</td>
<td>65.0</td>
<td>83.0</td>
<td>2113.6</td>
<td>29.6</td>
<td>204.2</td>
</tr>
<tr>
<td>Heavy AI</td>
<td>1964</td>
<td>50.1</td>
<td>9.1</td>
<td>8.1</td>
<td>2142.9</td>
<td>0.0</td>
<td>38.9</td>
</tr>
</tbody>
</table>

Q₁, 25th centile; Q₃, 75th centile.

### Table 2 Total energy expenditure of physical activity during leisure time and all cause and selected cause specific mortality during 10 years of follow up

<table>
<thead>
<tr>
<th>Total AI (kcal/day)</th>
<th>Person years</th>
<th>All cause</th>
<th>Cardiovascular disease</th>
<th>Coronary heart disease</th>
<th>Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Rate*</td>
<td>Number</td>
<td>Rate*</td>
</tr>
<tr>
<td>1 (0–161.8)</td>
<td>6804.6</td>
<td>97</td>
<td>14.3</td>
<td>47</td>
<td>6.9</td>
</tr>
<tr>
<td>2 (161.9–395.5)</td>
<td>6954.8</td>
<td>71</td>
<td>10.2</td>
<td>35</td>
<td>5.0</td>
</tr>
<tr>
<td>3 (395.6–2747.2)</td>
<td>6943.7</td>
<td>74</td>
<td>10.7</td>
<td>29</td>
<td>4.2</td>
</tr>
<tr>
<td>Test for trend†</td>
<td></td>
<td>p=0.047</td>
<td>p=0.028</td>
<td>p=0.025</td>
<td>p=0.526</td>
</tr>
<tr>
<td>Total</td>
<td>20703.0</td>
<td>2422</td>
<td>11.7</td>
<td>111</td>
<td>5.4</td>
</tr>
</tbody>
</table>

*The crude mortality rates (1/1000 person years).
†Deaths caused by congenital anomalies and injuries and poisonings were censored at date of death (7 cases, 3% of all deaths).
‡p Value for trend from Cox proportional hazards model with total activity metabolic index (expressed as kcal/day) as an ordered variable from the lowest tertile to the highest tertile.
§AI data missing for three deaths, one of three deaths caused by cancer.
Table 1 presents basic descriptive data at baseline. LTPA measurements were missing for 11 men (0.6% of all men), of whom three had died, one from cancer. The total AI ranged from 0 to 2747.2 kcal/day with a median of 257.5 kcal/day. The medians for light, moderate, and heavy AI were 81.9, 83.0, and 8.1 kcal/day, respectively. The geometric means for total, light, moderate, and heavy AI were 207.3, 52.4, 65.0, and 8.1 kcal/day, respectively. The main energy expenditure during leisure was from light and moderate intensity activity in this population. The energy expenditure in vigorous intensity activity was the lowest, because there were 595 subjects (30% of all men) who reported no heavy intensity activity at all, and those who did take such exercise did so rarely.

Table 2 shows the crude mortality of all cause death and cause specific death according to thirds for total LTPA at baseline during a 10 year follow up. In all cases except for cancer mortality, men in the least active group had the highest mortality across the thirds. Men in the group immediately below those who did take such exercise did so rarely.

Table 3 shows these results. Hazard ratios for total activity were lower than those for all causes and CVD mortality in the highest thirds of total activity. Full adjustment for multiple risk factors in addition tends to increase the size of the hazard ratios slightly.

Table 4 shows the relation between work related activity and all cause mortality and cause specific mortality by thirds of all cause mortality and cause specific mortality by thirds of all causes and CVD mortality. Hazard ratios for higher levels of total activity are lower and show a significant trend with increasing levels of activity for all causes and CVD mortality. Hazard ratios for CHD mortality are lower than those for all causes and CVD mortality in the higher thirds of total activity. Full adjustment for multiple risk factors in addition tends to increase the size of the hazard ratios slightly.

Table 5 shows the relation between leisure time physical activity and cause specific mortality by thirds of all causes and CVD mortality. Hazard ratios for higher levels of total activity are lower and show a significant trend with increasing levels of activity for all causes and CVD mortality. Hazard ratios for CHD mortality are lower than those for all causes and CVD mortality in the higher thirds of total activity. Full adjustment for multiple risk factors in addition tends to increase the size of the hazard ratios slightly.

Table 6 shows the relation between leisure time physical activity and cause specific mortality by thirds of all causes and CVD mortality. Hazard ratios for higher levels of total activity are lower and show a significant trend with increasing levels of activity for all causes and CVD mortality. Hazard ratios for CHD mortality are lower than those for all causes and CVD mortality in the higher thirds of total activity. Full adjustment for multiple risk factors in addition tends to increase the size of the hazard ratios slightly.

Table 3

<table>
<thead>
<tr>
<th>Cause</th>
<th>Total activity tertile (kcal/day)</th>
<th>p Value for trend*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (0.0–161.6)</td>
<td>2 (161.8–395.3)</td>
</tr>
<tr>
<td>All causes</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td>CVD</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td>CHD</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*p Value for trend from Cox proportional hazards model with total activity metabolic index (kcal/day) as an ordered variable from the lowest to the highest tertile.
†Adjusted for age, diastolic blood pressure, and body mass index as continuous variables, smoking status (never smoked, previously smoked, or currently smokes cigars, pipe, or 1–14, 15–24, or ≥25 cigarettes per day), social class (manual), family history of CHD among first degree relatives before age 55, history of diabetes mellitus in the past five years, and job physical activity class (accumulated score 1–8, 9–12, 13–16, and 17–19).

Table 4

<table>
<thead>
<tr>
<th>Cause</th>
<th>Combined light and moderate activity tertile (kcal/day)</th>
<th>p Value for trend*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (0.0–133.0)</td>
<td>2 (133.1–342.6)</td>
</tr>
<tr>
<td>All causes</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td>CVD</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td>CHD</td>
<td>Age adjusted†</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Fully adjusted†</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*p Value for trend from Cox proportional hazards model with combined light and moderate activity metabolic index (kcal/day) as an ordered variable from the lowest to the highest tertile.
†Adjusted for age and heavy intensity activity (expressed as AI (kcal/day) and logarithmic scale) as continuous variables.
‡Adjusted for age and heavy intensity activity (expressed as AI (kcal/day) and logarithmic scale) as continuous variables, and variables listed in footnote in table 3.
employment for each man. Some 48% of men had retired or were unemployed and results were adjusted for employment status. There was no evidence of any association between job physical activity and all cause, CVD, CHD, and cancer deaths. All analyses were repeated to include 30 men who died within two years who were initially excluded. The pattern and significance of the results were essentially unchanged.

To define more accurately the activity level associated with a reduction in risk of death or cardiovascular death, we divided the men according to fifths of the distribution of heavy intensity activity. Two of the other studies that exercise of light or moderate intensity reduces risk of CHD with very few men engaging in heavy intensity activity. Five hundred and ninety five men did no heavy intensity activity during leisure at baseline during 10 years follow up

<table>
<thead>
<tr>
<th>Cause</th>
<th>Heavy activity tertile (kcal/day)</th>
<th>p Value for trend*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All causes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted†</td>
<td>1 (0.0–0.6)</td>
<td>0.88 (0.66 to 1.18)</td>
</tr>
<tr>
<td>Fully adjusted‡</td>
<td>1 (0.0–0.6)</td>
<td>0.87 (0.65 to 1.17)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause</th>
<th>Job physical activity*</th>
<th>p Value for trend†</th>
</tr>
</thead>
<tbody>
<tr>
<td>All causes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted†</td>
<td>1 (1–8)</td>
<td>1.31 (0.92 to 1.87)</td>
</tr>
<tr>
<td>Fully adjusted‡</td>
<td>1 (1–8)</td>
<td>1.38 (0.95 to 2.00)</td>
</tr>
</tbody>
</table>

*Job physical activity (expressed as job physical activity class, accumulated scores from low to high occupational physical activity) was divided into four equally sized groups.
†p Value for trend from Cox proportional hazard model with job physical activity as a ordinal variable (1, 2, 3, or 4 for four groups from low to high occupational physical activity).
‡Adjusted for total leisure activity (logarithmic scale), employment status (employed versus unemployed or retired) and variables listed in footnote in table 3.

DISCUSSION

The purpose of this study was to examine the relation between habitual physical activity and all cause and cause specific mortality. We also assessed the effect of exercise at different levels of energy expenditure during leisure (light, moderate, and heavy) on all cause and disease specific mortality in middle aged British men.

We found strongly significant inverse associations between heavy LTPA and all cause, CVD, and CHD mortality after adjustment for either age or multiple risk factors, but neither LTPA of moderate nor of light intensity was consistently associated with all cause or cause specific mortality. Job related physical activity was not associated with all cause or cardiovascular mortality.

Current guidelines in the UK recommend that adults accumulate at least 30 minutes of moderately intensive activity (such as brisk walking) on at least five days a week, which are similar to those recommended for US adults by the Surgeon General. However, the number of studies that show that exercise of light or moderate intensity reduces risk of CHD is small. The largest study to show that moderate intensity activity is protective (MRFIT (multiple risk factor intervention trial)) is based on 12 866 men selected from 415–18 and 3 416 US men initially screened and screened who were at relatively high levels of energy expenditure during leisure (light, moderate, and heavy) on all cause and disease specific mortality in middle aged British men.

The findings of other cohort studies relate to increases in physical activity during middle age, which suggests that the type of population studied has a bearing on the generalisability of our present results. The present report supports the findings of other cohort studies that habitual leisure exercise of vigorous intensity is associated with significantly reduced risk of all cause and cardiovascular death.
In additional analyses we examined risk of deaths by fifths of the distribution of men in this cohort according to their level of vigorous intensity leisure activity. Forty per cent of men reported no or very little vigorous activity while those in the upper fifth of the distribution (at 54 kcal/day or above) had a 10 year reduced risk of death of 47% and of a coronary death of 62%. In the next highest fifth (at 16–53 kcal/day) there was a 16% reduction in the risk of death and a 27% reduction in the risk of coronary death.

An energy expenditure of 54 kcal/day corresponds to an average of nine minutes of jogging or doubles tennis per day or seven minutes of climbing stairs, but this level and intensity of activity was achieved by only one fifth of our population. In contrast subsequent risk was not reduced in men in the upper third of the distribution of light and moderate intensity activity. A gain of an energy expenditure of 343 kcal/day or more (table 4) equivalent to over one and a half hours of walking for pleasure or one hour of ballroom dancing a day.

The strengths of this study were a well defined prospective design, mid to long term follow up, and standardised and validated assessment of physical activity. One limitation is that we measured physical activity during leisure only at the baseline survey and did not have information about changes of physical activity over time. This can cause misclassification of physical activity over time. Additionally, the bias in this type of study may be due to the possibility that men who had low levels of LTPA at baseline were already sick and that illness was the cause rather than the result of lack of physical activity. To reduce this potential source of bias we excluded from these analyses men with diagnosed myocardial infarction, angina, or probable ECG ischaemia or men who died during the first two years of follow up. Extending the exclusion period to four years did not alter the pattern of results. Finally, physical activity was measured by a self administered questionnaire, and despite the use of a previously validated LTPA questionnaire there was undoubtedly some misclassification, particularly as the initial validation was undertaken in a North American sample. This misclassification most likely would attenuate the observed relative risks, especially for light and moderate intensity activity, and the true association may be stronger.

In conclusion, these data support the view that significant health benefits can be obtained by LTPA. We and others have especially for light and moderate intensity activity, and the true reduction in the risk of mortality most likely would attenuate the observed relative risks, principally from CVD and CHD, in middle aged men who have no evidence of pre-existing CHD.

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