Coronary Heart Disease

Occupational, Commuting, and Leisure-Time Physical Activity in Relation to Total and Cardiovascular Mortality Among Finnish Subjects With Type 2 Diabetes

Gang Hu, MD; Johan Eriksson, MD; Noël C. Barengo, MD; Timo A. Lakka, MD; Timo T. Valle, MD; Aulikki Nissinen, MD; Pekka Jousilahti, MD; Jaakko Tuomilehto, MD

Background—Some previous studies have assessed the association between leisure-time physical activity and mortality among patients with diabetes, but the potential effect of occupational and commuting physical activity remains uncertain.

Methods and Results—We prospectively followed up 3316 Finnish participants 25 to 74 years of age with type 2 diabetes. The association of different types of physical activity with mortality was examined with Cox proportional-hazard models. During a mean follow-up of 18.4 years, 1410 deaths were recorded, 903 of which were due to cardiovascular disease (CVD). The multivariate-adjusted (age, sex, study year, body mass index, systolic blood pressure, cholesterol, smoking, and the 2 other types of physical activity) hazard ratios associated with light, moderate, and active work were 1.00, 0.86, and 0.60 (P trend<0.001) for total mortality and 1.00, 0.91, and 0.60 (P trend<0.001) for CVD mortality, respectively. The multivariate-adjusted hazard ratios associated with low, moderate, and high leisure-time physical activity were 1.00, 0.82, and 0.71 (P trend<0.001) for total mortality and 1.00, 0.83, and 0.67 (P trend=0.005) for CVD mortality, respectively. Active commuting had significant inverse associations with total and CVD mortality, but these relations were no longer significant after additional adjustment for occupational and leisure-time physical activity.

Conclusions—Moderate or high levels of physical activity reduce total and CVD mortality among patients with type 2 diabetes. Not only leisure-time physical activity but also occupational and commuting physical activities are important components of a healthy lifestyle among patients with diabetes. (Circulation. 2004;110:666-673.)

Key Words: cardiovascular diseases ▪ diabetes mellitus ▪ exercise

The number of diabetic patients in the world has been estimated to at least double during the next 25 years.1 Cardiovascular disease (CVD) accounts for >75% of total mortality among patients with type 2 diabetes.2 To prevent an increase in CVD mortality in the future, efforts are needed to control this emerging problem of the increasing prevalence of type 2 diabetes. Type 2 diabetes can be prevented or at least postponed by physical activity and a healthy diet.3 Physical activity is too often considered to be physical training or other aerobic activities. In many countries, activities related to commuting or work comprise a considerable proportion of the total physical activity. Even though occupational, commuting, and leisure-time physical activity have been shown to be inversely associated with CVD and total mortality in the general population,4,5 the evidence of such an association among diabetic patients is still scanty.

Clinical trials have shown that physical activity improves levels of CVD risk factors and reduces blood glucose in patients with diabetes.6-7 Some previous studies have indicated that regular leisure-time physical activity is associated with reduced CVD and total mortality among patients with diabetes or impaired glucose tolerance.8-12 However, it is not clear whether other types of physical activities such as occupational and daily commuting physical activity on foot or by bicycle are related to reduced CVD mortality among diabetic patients. The aim of the present study was to examine whether occupational, commuting, or leisure-time physical activity is independently associated with reduced risk of total and CVD mortality among Finnish patients with type 2 diabetes participating in population-based surveys.

Methods

Participants

Six independent population surveys were carried out in 5 geographic areas of Finland in 1972, 1977, 1982, 1987, 1992, and 1997.13 In 1972 and 1977, a randomly selected sample making up 6.6% of the population born between 1913 and 1947 was drawn. Since 1982, the sample has been stratified by area, gender, and 10-year age groups according to the World Health Organization’s Monitoring Trends...
and Determinants in Cardiovascular Disease (WHO MONICA) protocol. Subjects who participated in >1 survey were included only in the first survey cohort. The total sample size of the 6 surveys was 53 166. The participation rate varied by year from 74% to 88%. These surveys were conducted according to the ethics rules of the National Public Health Institute, and the investigations were carried out in accordance with the Declaration of Helsinki.

Participants who reported having diabetes on the questionnaire at the baseline survey, had had a hospital discharge diagnosis of diabetes between 1968 and 2001, or were ascertainment as incident cases of drug-treated diabetes from the National Social Insurance Institution’s Drug Register from 1964 through the end of February 1998 were included in the present analysis. Antidiabetic drugs prescribed by a physician are free of charge in Finland and are subject to approval of a physician who reviews each case history. The physician confirms the diagnosis of diabetes by applying the WHO criteria. All participants receiving free medication (either oral antidiabetic agents or insulin) are entered into a register maintained by the Social Insurance Institution. Of the 3494 eligible participants with diabetes, we excluded 51 patients who had type 1 diabetes and 3316 with diabetes between 1968 and 2001, or were ascertained as incident cases of drug-treated diabetes from the National Social Insurance Institution. Of the 3494 eligible participants, 127 who had incomplete data on any required factors. Thus, 3316 participants were included in the present study.

Baseline Measurements

A self-administered questionnaire was mailed to participants. It included questions about smoking, physical activity, and medical history. Physical activity included occupational, commuting, and leisure-time physical activity. A detailed description of the questions is presented elsewhere. These questions were the same as those used in the Nordic countries and similar to those used and validated in the Seven Countries Study. The subjects reported their occupational physical activity according to the following 3 categories: (1) light (physically very easy, sitting office work, eg, secretary), (2) moderate (standing and walking, eg, store assistant, light industrial worker), and (3) active (walking and lifting, heavy manual labor, eg, industrial or farm worker). The daily commuting return journey was categorized into 3 categories: (1) using motorized transportation or no work (0 minutes of walking or cycling), (2) walking or bicycling 1 to 29 minutes, and (3) walking or bicycling for ≥30 minutes. Self-reported leisure-time physical activity was classified into 3 categories: (1) low (almost completely inactive, eg, reading, watching TV, or doing some minor physical activity that was not of a moderate or high level), (2) moderate (some physical activity for ≥4 h/wk, eg, walking, cycling, light gardening, but excluding travel to work), and (3) high (vigorous physical activity for ≥3 h/wk, eg, running, jogging, swimming, and heavy gardening).

At the study site, specially trained research nurses measured blood pressure, height, and weight using a standardized protocol. Body mass index (BMI; weight divided by height squared) was used as a measure of relative body weight. After blood pressure was measured, a venous blood specimen was drawn. Serum total cholesterol was determined by use of the Liebermann-Burchard method in 1972 and 1977 and an enzymatic method (CHOD-PAP, Boehringer Mannheim) since 1982. The enzymatic assay method gave 2.4% lower values than the Liebermann-Burchard method. The cholesterol values from 1972 and 1977 were corrected by this percentage. All samples were analyzed in the same laboratory.

Prospective Follow-Up

The study cohorts were followed up until the end of 2001 through computerized register linkage. Mortality data were obtained from Statistics Finland and were linked with the survey data through the personal identification number. The International Classification of Diseases 8th, 9th, and 10th revisions were used for coding the causes of death. ICD codes 390 through 459 and I00 through I99 were classified as CVD deaths.

Statistical Analysis

Differences in risk factors between groups with different levels of physical activity were tested by use of ANOVA after adjustment for age, sex, and study year. The Cox proportional-hazards model was used to estimate the association of physical activity with the risk of total and CVD mortality. The analyses were first carried out after adjustment for age, sex, and study year and then further for BMI, systolic blood pressure, total cholesterol, smoking, and the other 2 types of physical activity. To avoid the potential bias resulting from severe disease at baseline, additional analyses were carried out, excluding subjects who at baseline were diagnosed with coronary heart disease (CHD), stroke, or heart failure; who may have been physically inactive because of severe disease or disability at baseline; and who died during the first 2 years of follow-up.

Results

During the average follow-up of 18.4 years, 1410 deaths were recorded, of which 903 (64%) were due to CVD. General
Among Subjects With Type 2 Diabetes

TABLE 2. HRs of Total and Cardiovascular Mortality According to Occupational, Commuting, and Leisure-Time Physical Activity

<table>
<thead>
<tr>
<th>Characteristics of the Study Population at Baseline</th>
<th>Deaths, n Person-years</th>
<th>Model 1 (n=3316)</th>
<th>Model 2 (n=3316)</th>
<th>Model 3 (n=3316)</th>
<th>Model 4 (n=2596)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>793 25 549</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>250 13 216</td>
<td>0.77 (0.67–0.89)</td>
<td>0.80 (0.69–0.93)</td>
<td>0.86 (0.74–1.00)</td>
<td>0.89 (0.74–1.06)</td>
</tr>
<tr>
<td>Active</td>
<td>367 22 305</td>
<td>0.58 (0.51–0.66)</td>
<td>0.59 (0.52–0.67)</td>
<td>0.60 (0.52–0.69)</td>
<td>0.67 (0.57–0.78)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Walking or cycling to and from work, min/d</td>
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<tr>
<td>0</td>
<td>928 33 530</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1–29</td>
<td>271 15 581</td>
<td>0.79 (0.69–0.91)</td>
<td>0.82 (0.71–0.94)</td>
<td>0.91 (0.79–1.05)</td>
<td>0.95 (0.81–1.12)</td>
</tr>
<tr>
<td>≥30</td>
<td>211 11 959</td>
<td>0.71 (0.61–0.83)</td>
<td>0.75 (0.64–0.87)</td>
<td>0.88 (0.75–1.04)</td>
<td>0.96 (0.80–1.15)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.21</td>
</tr>
<tr>
<td>Leisure-time physical activity</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>741 27 974</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>597 28 072</td>
<td>0.82 (0.73–0.91)</td>
<td>0.84 (0.75–0.93)</td>
<td>0.82 (0.73–0.91)</td>
<td>0.86 (0.75–0.98)</td>
</tr>
<tr>
<td>High</td>
<td>72 5024</td>
<td>0.66 (0.52–0.85)</td>
<td>0.73 (0.57–0.94)</td>
<td>0.71 (0.56–0.92)</td>
<td>0.72 (0.55–0.95)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>&lt;0.001</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>0.18</td>
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<td>Cardiovascular mortality</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Occupational physical activity</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>517 25 549</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>161 13 216</td>
<td>0.80 (0.67–0.96)</td>
<td>0.84 (0.70–1.01)</td>
<td>0.91 (0.75–1.10)</td>
<td>0.94 (0.74–1.18)</td>
</tr>
<tr>
<td>Active</td>
<td>225 22 305</td>
<td>0.58 (0.48–0.68)</td>
<td>0.59 (0.50–0.69)</td>
<td>0.60 (0.50–0.71)</td>
<td>0.69 (0.57–0.85)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
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<tr>
<td>Walking or cycling to and from work, min/d</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>609 33 530</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1–29</td>
<td>165 15 581</td>
<td>0.78 (0.65–0.92)</td>
<td>0.81 (0.67–0.96)</td>
<td>0.89 (0.75–1.07)</td>
<td>0.97 (0.79–1.20)</td>
</tr>
<tr>
<td>≥30</td>
<td>129 11 959</td>
<td>0.69 (0.57–0.84)</td>
<td>0.74 (0.61–0.90)</td>
<td>0.86 (0.70–1.06)</td>
<td>0.94 (0.74–1.19)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>0.27</td>
<td>0.87</td>
</tr>
<tr>
<td>Leisure-time physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>480 27 974</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>381 28 072</td>
<td>0.83 (0.72–0.95)</td>
<td>0.85 (0.74–0.98)</td>
<td>0.83 (0.72–0.95)</td>
<td>0.84 (0.71–0.99)</td>
</tr>
<tr>
<td>High</td>
<td>42 5024</td>
<td>0.63 (0.46–0.87)</td>
<td>0.70 (0.51–0.96)</td>
<td>0.67 (0.49–0.93)</td>
<td>0.69 (0.49–0.99)</td>
</tr>
<tr>
<td>P for trend</td>
<td>...</td>
<td>0.002</td>
<td>0.016</td>
<td>0.005</td>
<td>0.038</td>
</tr>
</tbody>
</table>

*Model 1 was adjusted for age, sex and study year; model 2, additionally adjusted for BMI, systolic blood pressure, cholesterol, and smoking; model 3, also adjusted for other 2 physical activities; model 4, same exclusions as model 3 plus subjects who at baseline were diagnosed with CHD, stroke, and heart failure; who may have been physically inactive because of severe disease or disability at baseline; and who died during the first 2 years of follow-up.

The multivariate-adjusted (age, sex, study year, BMI, systolic blood pressure, cholesterol and smoking) hazard ratios (HRs) associated with light, moderate, and active work were 1.00, 0.80, and 0.59 (P<0.001) for total mortality and 1.00, 0.84, and 0.59 (P<0.001) for CVD mortality, respectively (Table 2). These inverse associations were still strong and statistically significant (P<0.001) after further adjustment for commuting and leisure-time physical activity and after exclusion of participants diagnosed with CHD, stroke, or heart failure; those who may have been physically inactive because of severe disease or disability at baseline; and those who died during the first 2 years of follow-up. When we excluded retired participants (n=867) from the analysis, the protective effect of occupational physical activity did not appreciably change (P<0.001; data not shown).
Daily walking or cycling to and from work was significantly and inversely associated with multivariate-adjusted risk for total ($P_{\text{trend}}<0.001$) and CVD ($P_{\text{trend}}=0.002$) mortality. However, these inverse relations were no longer significant after additional adjustment for both occupational and leisure-time physical activity and after exclusion of participants who were previously diagnosed with CHD, stroke, or heart failure; who may have been physically inactive because of severe...
disease or disability at baseline; and who died during the first 2 years of follow-up.

The multivariate-adjusted HRs associated with low, moderate, and high leisure-time physical activity were 1.00, 0.84, and 0.73 ($P_{\text{trend}}=0.001$) for total mortality and 1.00, 0.85, and 0.70 ($P_{\text{trend}}=0.016$) for CVD mortality, respectively. These inverse associations were also significant after further adjustment for occupational and commuting physical activity and after excluding participants who were previously diagnosed with CHD, stroke or heart failure; who may have been
physically inactive because of severe disease or disability at baseline; and who died during the first 2 years of follow-up ($P_{\text{trend}}<0.05$).

In multivariate analyses, we estimated independent and joint effects of any 2 or all 3 types of physical activity on the risk of total (Figure 1 and Figure 3A) and CVD (Figure 2 and Figure 3B) mortality. We dichotomized all 3 types of physical activity at light versus moderate to high levels for occupational and leisure-time physical activity and at a threshold of 1 minute for commuting physical activity. When we assessed the joint effects of any 2 types of physical activity on mortality, patients with any 1 type of moderate or high physical activity or any 2 types of moderate or high physical activity combined had significantly decreased total (Figure 1) and CVD (Figure 2) mortality. Compared with patients who reported low levels of occupational, commuting, and leisure-time physical activity, patients who reported 2 or 3 types of moderate to high physical activity had a 45% to 48% decreased risk for total mortality and a 44% to 48% decreased risk for CVD mortality; patients who reported only 1 type of moderate to high physical activity had a 31% to 51% decreased risk for total mortality and a 31% to 50% decreased risk for CVD mortality (Figure 3). These inverse associations did not appreciably change after additional exclusion of participants who were previously diagnosed with CHD, stroke or heart failure; who may have been physically inactive because of severe disease or disability at baseline; and who died during the first 2 years of follow-up, (data not shown).

Discussion
Physically active work, leisure-time physical activity, and daily commuting to and from work reduced the risk for total and CVD mortality among patients with type 2 diabetes. Simultaneous engagement in several types of physical activity showed a slightly stronger protective effect than doing only 1 type of activity. These associations were independent of age, BMI, systolic blood pressure, cholesterol, and smoking.

This is the first study to show that moderate or vigorous occupational activity was independently and significantly associated with a lower risk of total and CVD mortality among patients with type 2 diabetes. If this finding represents a causal relation, this approach is highly relevant to the improvement of health and longevity among working-aged patients because the increase in computerization and mechanization has resulted in ever-increasing numbers of people being sedentary for most of their working time. Inaccurate assessment of occupational activity in epidemiological studies most probably causes an underestimation of overall physical activity, particularly in women and persons from lower socioeconomic groups.19
We also found that daily walking or cycling to and from work may reduce total and CVD mortality in patients with type 2 diabetes. This is an important finding because daily walking or cycling to work is a major source of total physical activity in some populations; it can be implemented virtually everywhere and is inexpensive. In urban China, >90% of people walk or cycle to and from work daily. In our study, >40% of patients with diabetes reported walking or cycling to work daily. Several studies have shown that regular walking or cycling to work is related to lower levels of CVD risk factors and reduces risk of type 2 diabetes and total mortality among general populations. Our study now expands this association to patients with diabetes. In many Western studies, commuting physical activity was indirectly measured by asking for the frequency and duration of walking or cycling. Our results emphasize the importance of commuting as a single physical activity component separate from overall physical activity for the prevention of chronic diseases.

The Aerobics Center Longitudinal Study, Nurses’ Health Study, Whitehall Study, National Health Interview Survey, and Health Professionals’ Follow-up Study have indicated that regular leisure-time physical activity is associated with reduced CVD and total mortality among patients with diabetes. Walking had an inverse association with the risk of CVD and total mortality similar to that for vigorous leisure-time physical activity. In the Aerobics Center Longitudinal Study, the low fitness group had a high relative risk for total mortality compared with the fit group. Our study supports these findings and expands the types of regular physical activity, including occupational activity and activity from daily walking or cycling to and from work. Simultaneously doing 1, 2, or 3 types of moderate or high occupational, commuting, and leisure-time physical activity reduced total and CVD mortality.

Regular physical activity may reduce CVD and total mortality among patients with diabetes through several mechanisms. In the general population, regular physical activity or exercise training can improve insulin sensitivity and other components of the metabolic syndrome such as increased blood pressure, increased HDL cholesterol, decreased triglycerides, weight loss, and weight maintenance and can reduce the risk of developing metabolic syndrome. Among patients with diabetes, regular physical activity is also associated with improved insulin sensitivity, glycemic control, and CVD risk factors.

Our study has several strengths and limitations. First, the number of participants is large and from a homogeneous population, and participants represent the diabetic population in general. The mean follow-up, 18.4 years, was long enough that a large number of CVD events were ascertained without loss of follow-up. Second, in addition to leisure-time physical activity, occupational and commuting physical activities were included in the analysis. Third, we excluded patients with type 1 diabetes from the analysis. Finally, we also carried out additional analyses that excluded subjects who may have been physically inactive because of prevalent CHD, stroke, or heart failure and who died during the first 2 years of follow-up to avoid the potential bias from excess early mortality resulting from severe disease in patients with low levels of physical activity at baseline. However, we did not have data on the severity of diabetes, glucose control, drug treatment for diabetes and other chronic diseases, and the presence of neuropathy and peripheral arterial disease, which remains sources of selection bias in our analyses. Another limitation of our study was the self-reported physical activity; however, the same questions were used throughout all surveys. Using a questionnaire to assess habitual physical activity is crude and imprecise. Although no assessment of repeatability or validity of our questionnaire has been carried out, a similar questionnaire has been used in the Seven Countries Study and in a large number of cross-sectional or prospective studies in Finland and other Nordic countries.

In conclusion, our study confirmed that moderate or higher levels of physical activity can reduce total and CVD mortality among patients with type 2 diabetes. Moreover, we have provided evidence that not only leisure time physical activity but also occupational activity and daily walking or cycling to and from work are important components of a healthy lifestyle among diabetic patients.

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References


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