Physical Activity Improves the Metabolic Risk Profiles in Men and Women

The Tromsø Study

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**Background:** Because physical activity may affect risk of certain chronic diseases, we wanted to examine the effects of leisure time physical activity on the metabolic profiles.

**Methods:** In a population-based cohort study, 5220 men and 5869 women, aged 20 to 49 years at entry, took part in 2 surveys (1979-1980 and 1986-1987) with repeated assessments of self-reported leisure time activity. Measurements of body mass index (measured as the weight in kilograms divided by the square of the height in meters [BMI]) and levels of serum triglyceride, total cholesterol (total C), and high-density lipoprotein cholesterol (HDL-C) were studied in relation to 4 levels of physical activity.

**Results:** There was a dose-response relationship between serum lipid levels and BMI, and levels of physical activity in both sexes after adjustments for potential confounders. Differences in BMI and serum lipid levels between sedentary men and women improved the metabolic risk profiles, whereas a decrease worsened them in both sexes.

**Conclusions:** Sustained high levels and change from sedentary to higher levels of physical activity relative to sedentary men and women improved the metabolic risk profiles in both sexes. The differences observed are sufficiently large to have a beneficial effect in the prevention of certain chronic diseases.

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PHYSICAL ACTIVITY strengthens the musculoskeletal system, improves cardiovascular capacity and pulmonary function, influences the cumulative exposure to certain hormones, enhances the immune system, and increases insulin sensitivity. It is the largest source of variability in energy requirements, influencing body weight. The benefits of physical activity and fitness are associated with decreased overall mortality and reduced incidence of cardiovascular diseases, type 2 diabetes mellitus, and certain types of cancer.

Serum lipid levels are important biological risk markers for chronic diseases, particularly cardiovascular diseases that can be modified by physical activity. In addition, obesity is associated with an increased risk of cardiovascular diseases, diabetes, and colon and breast cancer. Weight gain in adult life may be a marker of a new metabolic steady state, which may have serious health consequences. Few population-based prospective studies have evaluated the importance of both sustained and change in level of physical activity over time on weight gain and lipid levels, taking age into account. Most studies are of men, but less is known about women.

The aim of our study was to elucidate the impact of physical activity on the metabolic risk profile in a population-based study of 5220 men and 5869 women with 2 self-reported assessments of leisure time activity within a 7-year interval. Biological markers of a metabolic risk profile were defined by body mass index (BMI), measured as the weight in kilograms divided by the square of the height in meters, triglyceride levels, total cholesterol (total C) concentrations, high-density lipoprotein cholesterol (HDL-C) levels, and the ratio of total C/HDL-C. Data on smoking habits, menopausal status, diet, alcohol consumption, and use of hormonal contraceptives allowed for adjustments of potentially confounding factors during follow-up. Heart rate and physical fitness (women) made a validation of self-reported physical activity possible.
SUBJECTS, MATERIALS, AND METHODS

STUDY SUBJECTS

The study subjects were men and women who participated in 2 population surveys carried out within a 7-year interval in the municipality of Tromsø, northern Norway. In the 1979-1980 survey, all men (aged 20-54 years) and women (aged 20-49 years) were invited and 16,621 subjects attended, 78% of the invited population. The total number of individuals examined at the 1986-1987 survey was 21,826 subjects, 81.3% of the invited population. Eligible for the present study were those 11,508 subjects (5,423 men and 6,085 women) who were aged 20 to 49 years at baseline (1979-1980) and attended both surveys (88.3% of those invited to both surveys). We excluded subjects who at baseline reported previous myocardial infarction, stroke, angina pectoris, diabetes, and use of antihypertensive medications (192 men and 207 women), and those with missing information about leisure time activity at either survey (11 men and 9 women). Hence, the present cohort consisted of 5,220 men and 5,869 women, aged 20 to 49 years in 1979-1980.

SCREENING PROCEDURES

The methods and questionnaires used in the 2 surveys were almost identical. The screening comprised a main questionnaire about disease, symptoms, and smoking. Trained nurses checked the questionnaire for inconsistencies and measured subjects’ height and weight. In the 1979-1980 survey, blood pressure was measured by personnel trained according to tape recordings of insufficient information about nutritional habits.

RESULTS

At baseline the mean age was 34.4 years in men and 33.7 years in women. Leisure time activity was reported as sedentary by 19.4% and 21.9%, moderate by 44.9% and 64.9%, hard by 29.3% and 12.2%, and very hard by 6.3% and 1.0% of the men and women, respectively (Table 1).

Physically active men compared with sedentary men at baseline tended to be slightly leaner, have an increased daily intake of fruit/vegetables and low-fat milk, have lower diastolic blood pressure, smoke less, consume fewer cups of coffee, and have a lower daily alcohol and saturated table fat intake (Table 1). Leisure time active women tended to be taller, have lower systolic blood pressure, have a higher daily intake of low-fat milk, consume fewer cups of coffee, and smoke less than sedentary women.

After 7 years, more individuals reported decreased (men, 30.6%; women, 21.8%) than increased physical activity (men, 18.0%; women, 16.8%). There was a decline in activity with increasing age. In addition, by comparing activity groups at follow-up with those who were 7 years older at baseline, there was a decline by 3% to 5% in subjects who reported hard and very hard activity (results not presented).

There was an overall increase in BMI, triglyceride levels, total C concentrations, total C/HDL-C ratio, and a decrease in HDL-C levels in both sexes after 7 years (Table 2). After adjustment for age, we observed a significant inverse dose-response pattern from most reduced to most increased changes in activity level in both sexes for total C concentrations, total C/HDL-C ratio, and BMI. Comparing the 2 extremes in the change of physical activity level (≤2 levels decrease vs ≥2 levels increase), there was also a significant difference in triglyceride levels (P < .02) and HDL-C (P < .02) for men. Change in smoking habits, dietary fat intake, coffee drinking, and menopausal status were significant predictors of changes in the risk profiles, but adjustments did not affect these results. Furthermore, adjustments for baseline leisure activity, work activity, present use of or change in eating fruits/vegetables, use of hormonal contraceptives, and alcohol consumption did not significantly influence this association and were omitted from the final model.

The influence of sustained activity on metabolic risk factors was analyzed in those who maintained their baseline activity after 7 years of follow-up. After adjustments the differences in serum lipid levels and BMI between the sedentary and exercising groups were consistently more pronounced after 7 years than at baseline (Table 3). This difference was especially marked among those who sustained activity compared with all participants and observed for both sexes. Men reporting sustained very hard exercise had reduced levels, compared with sustained sedentary men, of total C by 9.0%, triglyceride levels by 27.6%, and total C/HDL-C ratio by 19.0%. There was also an increase in HDL-C levels of 13.2% plus a 7.0% lower BMI. Women who reported hard or very hard exercising had a reduced concentration, compared with sedentary women, produced by the London School of Hygiene and Tropical Medicine, London, England. Resting heart rate, measured only in 1986-1987, was derived from the median pulse-to-pulse interval during the time of the blood pressure measurement (Dinamap, Criticon, Tampa, Fla). Three recordings of heart rate were made at 2-minute intervals, and the lowest measurement recorded was used.

A nonfasting blood sample was taken at the screening and analyzed at the Department of Clinical Chemistry, University Hospital of Tromsø, Tromsø. In 1979-1980, total C concentrations were measured directly with the enzymatic oxidase method, using a commercially available kit (Boehringer-Mannheim, Mannheim, Germany). Triglyceride levels were enzymatically determined as glycerol (Boehringer 15725, Boehringer-Mannheim). In 1986-1987, total C concentrations and triglyceride levels were analyzed using colorimetric methods with commercially available kits (CHOD-PAP for cholesterol, GPO-PAP for triglyceride levels, Boehringer-Mannheim). High-density lipoprotein cholesterol levels were measured after precipitation of low-density lipoproteins with heparin and manganese chloride. The laboratory was standardized against the World Health Organization Lipid Reference Laboratory in Prague, Czechoslovakia.

A second questionnaire, given to the participants at both surveys, was a combined food frequency and a questionnaire about chronic diseases. The nutritional part covered type and quantity of table fat, milk, coffee drinking, vegetables, fruit, and alcohol habits. It was returned by 88% of 16,621 participants at the 1979-1980 survey and 92% of 21,826 participants at the 1986-1987 survey. Energy or fat intake for each individual could not be calculated because of insufficient information about nutritional habits.
ASSESSMENT OF PHYSICAL ACTIVITY AND PHYSICAL FITNESS

The questionnaire covering physical activity was checked at the screening for inconsistencies. Leisure time activity was graded from 1 to 4 as follows: 1, sedentary—reading, watching television, or other sedentary activities; 2, moderate—walking, bicycling, or physical activities for at least 4 hours per week; 3, hard—exercises to keep fit for at least 4 hours per week; 4, very hard—regular hard training or exercise for competition several times per week.

A random subsample of those attending the 1986-1987 survey was invited to a graded submaximal or maximal bicycle exercise test. Among those, 297 men and 312 women attended (attendance rates, 94% in men and 89% in women) as described in detail elsewhere. The initial workload was set at 25 W, with a 25-W increment every minute, up to a maximum of 250 W after 10 minutes. Physical fitness was defined as the maximum workload performed. Because of our inclusion criteria, only 156 men and 220 women could be tested. About 75% of the men reached the maximum workload, and therefore only the measurements of women were used.

Physical fitness, assessed in 220 women, increased with increasing level of leisure time activity (age-adjusted means ± SEM: sedentary, 144.1 ± 4.59 W; moderate, 158.7 ± 2.80 W; and hard/very hard, 186.1 ± 8.25 W) (*P for trend < .001) (results not presented).

STATISTICAL ANALYSIS

The primary aim was to analyze differences, changes, and dose-response patterns in metabolic risk factors (serum lipid levels and BMI) between sedentary leisure time and active attendees over 7 years of follow-up. Baseline characteristics were age adjusted and compared across levels of leisure time activity using analysis of covariance. In the analysis of changes in BMI, total C concentrations, levels of HDL-C and triglycerides, and total C/HDL-C ratio, comparison activity groups combining both surveys were defined as 2 levels or less or those who reduced at least 2 levels of activity: −1 level or those who reduced 1 level of activity; unchanged or those who reported the same activity level after 7 years of follow-up; +1 level or those who increased 1 level of activity; and 2 or more levels or those who increased at least 2 levels of activity.

We adjusted for age at entry, use or change in smoking habits, coffee drinking, type of table fat used, and menopausal status when analyzing the effect of sustained or change in physical activity in metabolic profiles. Time since last meal was included as a covariate in the analyses of triglyceride levels. Analyses of covariance were used for adjustments and in comparing the different groups. Because few women reported very hard exercise (level 4), levels 3 and 4 were merged in some analyses.

Excluding 204 men and 211 women who reported chronic diseases during follow-up did not change the results because neither group related to the influence from change in activity or sustained activity. These persons were therefore included in the final analyses.

We examined models stratified by age at entry (20-29 years, 30-39 years, and 40-49 years) and BMI (tertiles) to analyze whether there was any effect of modification by age and BMI of leisure time activity. As a result of missing data, the number of subjects included in the separate analyses varied slightly. Tests for linear trends were performed by linear regression. All significance tests were 2-tailed and the significance level was chosen at 5%. The SAS (SAS Institute Inc, Cary, NC) statistical package version 6.11 was used.

### Table 1. Baseline Characteristics According to Level of Leisure Time Physical Activity at Survey 1979-1980*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean†</th>
<th>P for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 1015)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>34.4</td>
<td>35.2</td>
</tr>
<tr>
<td>Moderate</td>
<td>24.5</td>
<td>24.2</td>
</tr>
<tr>
<td>Hard</td>
<td>176.6</td>
<td>177.1</td>
</tr>
<tr>
<td>Very Hard</td>
<td>129.4</td>
<td>129.6</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>81.7</td>
<td>81.8</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 3811)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>32.9</td>
<td>33.9</td>
</tr>
<tr>
<td>Moderate</td>
<td>22.6</td>
<td>22.7</td>
</tr>
<tr>
<td>Hard</td>
<td>163.5</td>
<td>163.6</td>
</tr>
<tr>
<td>Very Hard</td>
<td>121.3</td>
<td>121.2</td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 1284)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71.3</td>
<td>72.2</td>
</tr>
<tr>
<td>Moderate</td>
<td>12.1</td>
<td>13.7</td>
</tr>
<tr>
<td>Hard</td>
<td>31.8</td>
<td>40.6</td>
</tr>
<tr>
<td>Very Hard</td>
<td>68.1</td>
<td>61.0</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 175)</td>
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<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>17.8</td>
<td>13.7</td>
</tr>
<tr>
<td>Moderate</td>
<td>59.8</td>
<td>48.6</td>
</tr>
<tr>
<td>Hard</td>
<td>4.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Very Hard</td>
<td>8.4</td>
<td>7.3</td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 59)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>95.2</td>
<td>95.6</td>
</tr>
</tbody>
</table>

*a Baseline characteristics were adjusted for age. BMI indicates body mass index.

†Number of participants for activity categories in parentheses. For some subjects, information concerning certain variables was missing.

of total C by 3.4%, triglycerides by 12.7%, and total C/HDL-C ratio by 7.5%; they also had an increase in HDL-C levels of 4.0% plus a 2.1% lower BMI. All tests for linear trend with increasing activity showed a significant dose-response effect (*P < .001) for both sexes, except for HDL-C levels in women.
The effect of sustained activity on metabolic profiles in different age groups of men is demonstrated in Figure 1. First, when comparing the sedentary and very hard exercise group the differences in BMI, total C concentrations, triglyceride and HDL-C levels, and total C/HDL-C ratios were more pronounced in the oldest than in the youngest age groups; these differences increased after 7 years. Second, the average levels of the metabolic profiles were consistently less

### Table 2. Changes in Serum Lipid Levels and BMI After 7 Years of Follow-up*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baseline, Mean ± SD</th>
<th>1986-1987, Mean ± SD</th>
<th>Change in Level of Leisure Time Activity</th>
<th>P for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n = 261</td>
<td>n = 1337</td>
<td>n = 823</td>
</tr>
<tr>
<td>Cholesterol, mmol/L (mg/dL)</td>
<td>(229 ± 49)</td>
<td>(234 ± 48)</td>
<td>0.01</td>
<td>.90</td>
</tr>
<tr>
<td>Triglycerides, mmol/L (mg/dL)</td>
<td>(144 ± 85)</td>
<td>(146 ± 95)</td>
<td>0.01</td>
<td>.90</td>
</tr>
<tr>
<td>HDL-C, mmol/L (mg/dL)</td>
<td>(56 ± 17)</td>
<td>(56 ± 17)</td>
<td>0.01</td>
<td>.90</td>
</tr>
<tr>
<td>Total cholesterol/HDL-C ratio</td>
<td>4.36 ± 1.46</td>
<td>4.71 ± 1.63</td>
<td>0.28</td>
<td>.01</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.2 ± 2.8</td>
<td>24.9 ± 2.9</td>
<td>0.01</td>
<td>.90</td>
</tr>
</tbody>
</table>

*The changes in serum lipid levels and body mass index (BMI) have been adjusted for age at baseline and changes in smoking habits, intake of table fat, coffee drinking, and menopausal status in women. HDL-C indicates high-density lipoprotein cholesterol. For some subjects, information concerning certain variables was missing.

### Table 3. Serum Lipid Levels and BMI at Baseline Among All Participants and After 7 Years of Follow-up Across Levels of Leisure Time Physical Activity†

<table>
<thead>
<tr>
<th>Parameters</th>
<th>All Participants Survey 1979-1980</th>
<th>Sustained Activity Survey 1986-1987‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sedentary (n = 1015)</td>
<td>Moderate (n = 2344)</td>
</tr>
<tr>
<td>Cholesterol, mmol/L (mg/dL)</td>
<td>6.09 (235)</td>
<td>5.93 (229)</td>
</tr>
<tr>
<td>Triglycerides, mmol/L (mg/dL)</td>
<td>1.73 (153)</td>
<td>1.62 (143)</td>
</tr>
<tr>
<td>HDL-C, mmol/L (mg/dL)</td>
<td>1.43 (55)</td>
<td>1.45 (56)</td>
</tr>
<tr>
<td>Total cholesterol/HDL-C ratio</td>
<td>4.58 (245)</td>
<td>4.38 (224)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.5 (1284)</td>
<td>24.2 (3811)</td>
</tr>
</tbody>
</table>

*BMI indicates body mass index; HDL-C, high-density lipoprotein cholesterol. Adjustments were done for age at baseline and current smoking habits, coffee drinking, intake of table fat, coffee drinking, and menopausal status in women. HDL-C indicates high-density lipoprotein cholesterol. For some subjects, information concerning certain variables was missing.

†Sustained activity level: men and women who reported the same level of leisure time activity in 1979-1980 or 1986-1987, respectively. For some subjects, information concerning certain variables was missing.

‡Hard and very hard leisure time activity are combined in women.

The effect of sustained activity on metabolic profiles in different age groups of men is demonstrated in Figure 1. First, when comparing the sedentary and very hard exercise group the differences in BMI, total C concentrations, triglyceride and HDL-C levels, and total C/HDL-C ratios were more pronounced in the oldest than in the youngest age groups; these differences increased after 7 years. Second, the average levels of the metabolic profiles were consistently less fa-
vorable after 7 years in the sedentary and moderately active individuals of all ages. It was possible to reduce the BMI and total C and triglyceride levels below the baseline level by hard and very hard exercising after 7 years, but this occurred mainly in the oldest segment. Similar effects were seen for women (Figure 2).

The possibility of an effect modification of weight was elucidated by stratified analyses of BMI. Leisure time activity had the same association with serum lipid levels in all tertiles of BMI in both sexes (Figure 3). Within each tertile of BMI, total C and triglyceride levels, and the total C/HDL-C ratio were reduced and HDL-C levels were increased with increasing leisure time activity.

In men who never smoked who sustained their baseline activity during follow-up, we observed after adjustments with increasing leisure activity the following values of total C, respectively: 6.05 mmol/L (234 mg/dL), 5.95 mmol/L (230 mg/dL), 5.84 mmol/L (226 mg/dL), and 5.52 mmol/L (213 mg/dL); HDL-C: 1.37 mmol/L (53 mg/dL), 1.38 mmol/L (53 mg/dL), 1.40 mmol/L (54 mg/dL), and 1.50 mmol/L.
increasing leisure activity except for HDL-C levels; total C:

Figure 3. Age-adjusted mean values of serum lipid levels across levels of leisure time physical activity stratified by tertiles of body mass index (BMI) surveys. Triglyceride levels were adjusted for time since last meal. HDL-C indicates high-density lipoprotein cholesterol.

Total Cholesterol/
HDL Cholesterol Ratio

Table 4. Mean Values of Heart Rate by Level and Changes in Leisure Time Physical Activity for Combined Surveys

<table>
<thead>
<tr>
<th>Year of Survey</th>
<th>Heart Rate, Beats/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979-1980</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>1986-1987</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Sedentary</td>
<td>71.5 68.4 63.3 NA</td>
</tr>
<tr>
<td>Moderate</td>
<td>71.6 66.2 56.8 NA</td>
</tr>
<tr>
<td>Hard</td>
<td>69.1 62.6 NA</td>
</tr>
<tr>
<td>Very Hard</td>
<td>NA</td>
</tr>
</tbody>
</table>

4 The heart rate was adjusted for age at baseline for 1979-1980. All P values were <.001. NA indicates that data was not applicable.

(58 mg/dL); and BMI: 25.6, 25.2, 24.6, and 24.1 kg/m². Similar results were observed for women who never smoked with increasing leisure activity except for HDL-C levels; total C:

5.93 mmol/L (229 mg/dL), 5.93 mmol/L (229 mg/dL), and 5.68 mmol/L (220 mg/dL); HDL-C: 1.75 mmol (68 mg/dL), 1.74 mmol/L (67 mg/dL), and 1.75 mmol/L (68 mg/dL); and BMI: 24.7, 23.9, and 23.3 kg/m².

A significantly lower heart rate with increasing physical activity level was demonstrated (Table 4) for both sexes in all groups (P for trend <.0001). Comparing those who increased or decreased their activity level with those who sustained their baseline activity between the 2 surveys, a lower heart rate among those who increased and a higher heart rate among those who decreased their activity level was found. The lowest heart rate was observed among those who reported the highest level of leisure activity in both surveys in both sexes.

In addition to an age-dependent decline in level of leisure activity, we also observed a general decrease in level of leisure activity in the cohort that was independent of age. The large sample size and repeated assessment of physical activity made it possible to test for the influence of both sustained physical activity and change in physical activity on weight and serum lipid levels in an adult population. Sustained physical activity reduced the age-related weight gain and improved lipid profiles across all BMI strata. Maintenance of a high level of physical activity after 7 years strengthened the associations observed at baseline. We were also able to demonstrate that an increase in leisure activity over the 7 years improved the metabolic profiles, whereas a decrease worsened the profiles in both sexes.

Self-reports of physical activity provide a possibility for underestimating or overestimating activity levels. A lower heart rate and higher level of physical fitness (women) with increasing physical activity in our study, as well as the earlier validation of the physical activity assessment used, support real differences in the level of physical activity among groups in our study. Additionally, exclusion of subjects with chronic diseases at baseline improves the quality of the physical activity data. Furthermore, adjusting for work activity did not influence the results.

An individual’s propensity to be physically active may be inherited. Lower total C and higher HDL-C concentrations at baseline may be markers for men and women who are genetically endowed with muscles that make physical activity easier. However, changes in the level of physical activity influenced both body weight and lipid profiles that indicate true metabolic effects of physical activity, not merely a genetic predisposition.

The improvement of metabolic profiles is not a residual effect of smoking since we observed the same impact of physical activity on the estimates in nonsmokers as in the total cohort. However, physically active subjects may have underestimated or overestimated the amount of certain foods consumed to a greater extent than inactive subjects. Additionally, the crude cutoffs used for foods generally consumed may cover residual effect of diet. However, exercise in overweight men and women improved the serum lipid levels and is additional to the effect of nutrition. Even if the consumption of fruits/vegetables and alcohol was low at baseline, change in this consumption of fruits/vegetables and alcohol during follow-up did not influence our results when included in multivariate analysis.

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models. This strengthens the generalizability of the results to populations with higher or lower intake of these items.

**WEIGHT**

Physical activity is important for long-term weight control. The inverse association between physical activity and BMI at baseline corroborates previous cross-sectional observations. We observed that sustained sedentary men weighed, on average, 1.8 kg/m² more than exercising men at the follow-up survey, which is consistent with a recent prospective study among American men. The difference was most marked in the oldest age group, with 2.5 kg/m² for low vs high physical activity; this finding suggests that inactivity results in more weight gain in older than in younger individuals. This age effect could be explained by an age-dependent metabolic change in energy use, reduction in resting metabolic rate, changes in nutrition, or a reduction in physical activity within, but not between, each level of activity. In addition, the weight gain observed in those who sustained very hard exercise may also reflect an increase in muscle mass.

People of higher weight may find it more difficult to exercise and therefore gain weight. Women who decreased their physical activity over the follow-up period weighed, on average, 1.2 kg/m² more after 7 years, whereas those women who increased their activity level had only a 0.4 kg/m² weight gain. Comparable results were observed for men; this finding suggests the possibility of changing physical activity patterns during adult life, influencing adult weight gain. Moreover, this finding demonstrates a strong relationship between physical activity and weight gain and suggests that physical activity is a main determinant of body weight throughout adulthood.

**SERUM LIPID LEVELS**

Cross-sectional and interventional studies have found lower concentrations of total C and triglyceride levels and higher concentrations of HDL-C in physically active compared with inactive individuals. We found more pronounced differences in total C concentrations, levels of triglycerides and HDL-C, and total C/HDL-C ratios between sedentary and exercising men and women at follow-up. These findings indicate an important effect of sustained physical activity on lipid profiles in the general population. This effect was most pronounced among the oldest members of the cohort.

A certain intensity and duration of physical activity are necessary to achieve the desired effects on lipid metabolism. Exercise for at least 4 hours per week may include both the intensity and timespan needed to improve certain metabolic profiles. We found an inverse dose-response relationship between both sustained and increased physical activity levels and total C concentration during follow-up, indicating that even moderate physical activity influences the level of total C. This was not the case with HDL-C and triglycerides, but comparing the extremes in changes of activity (reduction vs increased), the concentrations of HDL-C and triglycerides were improved notably in men. This finding indicates that improvement in levels of triglycerides and HDL-C requires a high level of physical activity. This may also explain the weaker association of serum lipid levels and physical activity in population-based studies, because these studies may have had a smaller distribution of activity than intervention studies.

High BMI values were associated with higher levels of serum cholesterol and triglycerides. Differences in body weight are frequently cited as the reason for differences in total C concentrations and levels of triglyceride and HDL-C between physically active and inactive persons. However, we observed an effect of physical activity on lipid profiles across all BMI strata. This supports an influence of physical activity on lipid profiles independent of the metabolic effect of weight gain or loss.

Observations of an increase in aerobic metabolism, oxygen uptake, and fatty acid use for muscular energy supply during exercise may explain why physical activity is able to bring about a reduction in triglyceride levels and total C concentration and an increase in HDL-C levels. It also supports the assumption that exercise over a long period (common in leisure time activity) has more impact than exercise over a short period—static exercise (common in occupational activities)—on lipid profiles. It has been suggested that women have different physiological responses to physical activity than men in terms of BMI and lipid profiles. We observed almost identical effects on BMI across all physical activity levels, supporting common physiological responses of weight to physical activity in both sexes.

Our data also contradict the assumption that the generally higher HDL-C concentrations in women compared with men limit the potential for any further increase with exercise. In contrast to some, we and others have observed a smaller increase in HDL-C concentrations in exercising women relative to men. This may result from a smaller distribution in physical activity in women, with no relation to differences in biological effect between the sexes. The larger difference observed in heart rate according to level of activity in men than in women emphasizes the larger range of physical activity carried out by men. Hence, women have to perform a comparable amount of physical activity to achieve the same improvements as men in the concentrations of lipids.

**IMPLICATIONS FOR CHRONIC DISEASES**

Large but even modest weight gains during adulthood are associated with increased morbidity or mortality of chronic diseases. The improvement of lipid profiles by 9.0% to 27.6%, as achieved in men who sustained very hard exercise, may represent, from previous studies, a reduction in morbidity and mortality from coronary heart disease of 20% and 25%, respectively. The reduction in triglyceride levels may be important for risk of cardiovascular diseases and breast cancer.

The benefits of physical activity may be hypothesized to act through a common link. Weight gain during adulthood and physical inactivity give a diminished sensitivity to insulin, which is associated with increased risk for type 2 diabetes mellitus and cardiovascular diseases. Weight gain and inactivity have also been recently suggested to be important in carcinogenesis of the colon and breast.
In conclusion, we observed that sustained physical activity reduces age-related weight gain and improves lipid profiles in both sexes. A change from sedentary to higher levels of physical activity improves metabolic profiles, whereas a reduction in activity worsens the profiles. However, only sustained hard or very hard exercise is sufficient to compensate for the age-dependent worsening of metabolic profiles. These observations strengthen the importance of leisure time activity in the prevention of certain chronic diseases.

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of HF with advancing age, the incidence rates of HF were generally higher for men than for women. In the Framingham Study, hypertension, coronary heart disease, left ventricular hypertrophy, and diabetes were associated with an increased risk for HF. Excess body weight had a modest effect on the risk of HF, while cigarette smoking was associated with HF, particularly in women.

Given the aging of the American population, and likely similar patterns taking place in other countries experiencing declines in coronary heart disease mortality rates and aging of their populations, considerably more concerted efforts are needed to describe the current magnitude of HF and recent trends therein. Data are needed describing the short- and long-term mortality patterns associated with this condition, changes in functional status over time, and physicians’ prescribing patterns. The role of precipitating factors associated with exacerbation of HF might also be explored in these studies as has been recently applied in the study of triggering agents for acute myocardial infarction.19,20 Furthermore, few representative epidemiological data are available, particularly from a defined community-wide perspective, to assess the magnitude, natural history, and the approaches used in the diagnosis and management of patients with systolic compared with diastolic dysfunction.21 By developing population-based registries of HF in a number of communities throughout the United States, it would be possible to systematically monitor these outcomes and provide promising therapeutic interventions to at-risk groups with the hopes of forestalling this ongoing epidemic.

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Correction

Error in Figure Legend. In the article by Thune et al titled “Physical Activity Improves the Metabolic Risk Profiles in Men and Women: The Tromso Study,” which appeared in the August 1998 issue of the ARCHIVES (1998;158:1633-1640), the legend for Figure 3 should have read, “For men, darkened squares [not circles] indicate BMI <23.5 kg/m2; open circles, BMI 23.5-25.9 kg/m2; and darkened circles [not squares], >25.9 kg/m2. For women, darkened squares [not circles] indicate BMI <21.7 kg/m2; open circles, BMI 21.7-24.2 kg/m2; and darkened circles [not squares], >24.2 kg/m2 . . . .”