Adopting an Active Lifestyle During Adulthood and Health-Related Quality of Life: The Doetinchem Cohort Study

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It is often suggested that lifestyle during childhood, adolescence, and middle age will affect health in old age. A lifelong healthy lifestyle is assumed to be the most favorable for health in an aging population. Whether adopting a healthy lifestyle during middle age is too late or still effective is unknown. The prospect of better health and health-related quality of life may help motivate adults to change unhealthy lifestyles, and may therefore be important for public health.

Physical inactivity is associated with future health problems such as obesity, diabetes, cardiovascular diseases, stroke, certain types of cancer, and also with reduced levels of health-related quality of life. Most evidence regarding physical activity and future health is based on measuring physical activity at one point in time only. However, physical activity is likely to change over the course of life. Only a minority of the general population remains physically active for longer periods of time during the life course.

In the United States, only 11% of the population remained active during an 8-year period in midlife whereas a majority (59%) remained inactive during this period. Physical activity levels were higher in Dutch adults: almost one third of adults were physically active during 10 years, whereas 24% were inactive and 18% became physically active. Health effects of becoming active versus remaining inactive over longer periods of time are largely unknown. Two studies in women and university graduates have suggested that improvements in health-related quality of life are likely to occur in those who increased their physical activity levels. It is not clear whether this is also the case for levels of physical activity that go beyond the physical activity recommendations.

The objective of this study was to examine the relation between long-term physical activity levels and health-related quality of life. We focused on the impact of becoming physically active. We compared adults who were inactive at baseline and became active during 10 years of follow-up with adults who remained physically inactive, remained active, became inactive, and reported varying levels of activity. We hypothesized that adults who became physically active would report a better health-related quality of life after 10 years than adults who remained or became inactive, and a poorer health-related quality of life than adults who had been active and remained active during this period.

Methods
The Doetinchem Cohort Study is a prospective population-based study on lifestyle, biological risk factors, and health during adulthood. The first examination round (1987–1991) was carried out among 12,405 men and women (initial response 62%) aged 20 to 59 years in Doetinchem, a town in the Eastern part of the Netherlands. Of those 12,405 participants, a random sample of 7769 participants was invited once every 5 years to participate in the second, third, fourth, and fifth (ongoing) rounds. Response rates of the second to fifth round were 79%, 75%, 78%, and 79%, respectively (Figure A available as a supplement to the online version of this article at http://www.ajph.org). The study is described in more detail elsewhere. The health-related quality of life was measured from the year 1995 onward. Therefore, for the present analyses, we considered the period 1995 to 1999 as t0 (baseline), 2000 to 2004 as t1, and 2005 to 2009 as t2. An ethical review board approved the protocol of the Doetinchem Cohort Study. All participants gave written informed consent.

Measurement of Physical Activity
Physical activity was measured with a self-administered questionnaire designed for adults...
international European Prospective Investigation Into Cancer and Nutrition study and extended with a question on sports and other strenuous leisure-time physical activities.\textsuperscript{16} Time spent on leisure-time activities (bicycling, gardening) was assessed for summer and winter separately. Respondents were asked about time spent on sports and other strenuous physical activities during a regular week in the previous year. These included open-ended questions on type, frequency, and duration for a maximum of 3 different activities. In accordance with the Dutch guideline for physical activity,\textsuperscript{17} leisure-time physical activities of at least 4.0 metabolic equivalents were considered.

To determine whether individuals reached the recommended levels, we calculated the total amount of time (hours per week) spent on moderate-to-vigorous leisure-time physical activities and heavy work. To ensure a conservative estimate for cycling and gardening, we used the smallest number of hours per week reported for either summer or winter. We included total time spent in jobs that require heavy physical work, such as the physical activity required in construction work, farming, or cleaning. The Dutch physical activity guideline recommends adults to be physically active at a moderate or higher intensity for a minimum of half an hour a day on at least 5 days a week (i.e., at least 2.5 hours per week).\textsuperscript{17,18} We set the cut-off point for reaching the recommended levels at 3.5 hours a week spent on at least moderately intense physical activities. There are 2 reasons for this cut-off point: to account for the observation that the amount of activity is usually overreported\textsuperscript{19} and the fact that we have only data averaged during a week whereas the recommended levels pertain to at least 5 days a week.

We defined 5 different (longitudinal) time patterns of physical activity using data from the 3 consecutive measurements.\textsuperscript{11} We classified adults who were inactive at t0 but who became physically active at the second or third measurement as becoming active. We classified adults who were inactive at all 3 measurements as persistently inactive, and adults who were physically active at all 3 measurements as persistently active. We classified adults who were active at t0 and had become inactive at the second or third measurement as becoming inactive. We classified the remaining individuals as adults with varying activity levels, namely those with the following patterns: active—inactive—active or inactive—active—inactive.

**Measurement of Quality of Life**

We measured health-related quality of life with the Dutch version of the RAND36, which is similar to the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36).\textsuperscript{20,21} The 8 dimensions of the SF-36 are physical functioning, role limitations because of physical health problems, bodily pain, general health perceptions, vitality, social functioning, role limitations because of emotional problems, and mental health. The validity and reliability of the SF-36 have been established.\textsuperscript{21} For each dimension, scores are coded, summed, and transformed to a 0-to-100 scale. Higher scores indicate higher levels of functioning or well-being.

During the 10-year follow-up, we defined educational level as the highest education obtained. We distinguished 3 categories: low (intermediate secondary education or less), moderate (intermediate vocational or higher secondary education), and high (higher vocational education or university). We defined work status at t2 as having a paying job (including salaried employment and being self-employed) or not (including being a housewife, retired, unable to work, and other). We defined household composition at t2 as living alone or not living alone (living with a partner, with children, with parents, or with other adults). We categorized smoking behavior at t2 as current smoker or nonsmoker; the latter included exsmokers. We calculated body mass index (BMI, defined as weight in kilograms divided by the square of height in meters) at t2 from measured height and body weight. We categorized BMI as normal (< 25 kg/m\textsuperscript{2}), overweight (25–< 30 kg/m\textsuperscript{2}), and obesity (30 kg/m\textsuperscript{2}). Six chronic diseases were (self)-reported at all measurements, i.e., diabetes mellitus, myocardial infarction, stroke, cancer, asthma, and persistent chronic low back pain. We constructed dummy variables for chronic disease status at baseline and during follow-up on the basis of having any of these 6 chronic diseases.

**Statistical Analyses**

A total of 3848 respondents participated in all 3 examination rounds. We excluded women who were pregnant at 1 of the 3 measurements (n = 41) and respondents with missing values on any of the variables used in the analyses (n = 186), leaving 3621 respondents for the analyses (Figure A, available as a supplement to the online version of this article at http://www.ajph.org). We found that 1286 adults were consistently active, 727 adults were persistently inactive, 618 adults were inactive at baseline but became active during the 10-year follow-up period, 535 adults became inactive, and 455 adults had varying physical activity levels.

We summarized characteristics of the study population as means and we determined standard deviations and mean adjusted health-related quality-of-life scores for each physical activity pattern. We performed multivariable linear regression analyses to determine differences in health-related quality of life between adults who became active versus the 4 other physical activity patterns. We observed skewed distributions of residuals for 5 subscales: physical functioning, bodily pain, social functioning scales, and for role limitations because physical and mental health problems. We applied linear regressions using generalized estimated equations with estimation of robust standard errors for these 5 subscales. We adjusted each regression analysis for gender, age, education, living alone status, work status, BMI, smoking, and baseline and chronic disease status during follow-up.

Mean health-related quality of life at baseline differed according to physical activity patterns; therefore we adjusted all analyses for baseline SF-36 scale score. We calculated differences between the adjusted means (and 95% confidence intervals) in health-related quality of life of adults who became active versus adults in the 4 other physical activity patterns by the least squares means option. We expressed differences as the number of standard deviations from the population mean. We tested interaction effects between physical activity patterns and gender and age in the crude regression models (P<.1). Interaction effects occurred only in a few comparisons; therefore, we additionally described results of stratified analyses for these domains only.
We used SAS software version 9.2 (SAS Institute, Cary, NC).

RESULTS

About 48% of the study population were male and the mean age at baseline was 47 years for all 5 physical activity patterns (Table 1). Adults who remained active over the 10-year period spent on average 12 or 13 hours per week on at least moderately intense physical activities, whereas those who remained inactive spent 1 hour only per week on such activities (Figure 1). Adults who became active reported on average 2 hours a week of moderate and vigorous intensity at baseline, and 6 and 9 hours, respectively, per week at the second and third examination. Those who became inactive reported, on average, 10, 6, and 2 hours, respectively, of these activities per week. The mean number of hours of moderate-to-vigorous physical activities among adults with varying levels of activity was quite constant at 5 and 6 hours a week over the 3 rounds. Persistently active adults reported the highest health-related quality of life scores for most domains, except for general health and role limitations because of physical health problems. Adults who became active reported the best general health, and those with varying levels of activity reported the fewest role limitations because of physical health problems (Table 2).

We observed significant differences in health-related quality of life between adults who became active and adults who remained inactive, and between adults who became active and adults who became inactive (Figure 2). Adults who became active during the 10-year follow-up reported better physical functioning, general health, and vitality compared with persistently inactive adults, scoring 1.7 (95% confidence interval [CI] = 0.2, 3.2) points higher for physical functioning, 2.9 (95% CI = 1.4, 4.4) points higher for general health, and 1.7 (95% CI = 0.2, 3.2) points higher for vitality. The scores for bodily pain, social functioning, mental health, and physical and emotional role limitations did not differ. We observed interaction effects with gender for general health, physical functioning, physical role limitations, and mental health. However, in gender-stratified analyses, only the difference in general health was significant in women (women 3.7; 95% CI = 1.6, 5.8; men

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**TABLE 1—Characteristics of the Study Population, Men and Women Aged 26–70 Years: the Doetinchem Cohort Study, 1995–2009**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Becoming Active (n = 618), % or Mean ± SD</th>
<th>Persistently Active (n = 1286), % or Mean ± SD</th>
<th>Persistently Inactive (n = 727), % or Mean ± SD</th>
<th>Becoming Inactive (n = 535), % or Mean ± SD</th>
<th>Varying Activity Levels (n = 455), % or Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender: male</td>
<td>48.9</td>
<td>48.4</td>
<td>49.0</td>
<td>45.6</td>
<td>48.6</td>
</tr>
<tr>
<td>Age at t0, y</td>
<td>47.3 ± 9.7</td>
<td>47.3 ± 10.1</td>
<td>47.9 ± 10.2</td>
<td>47.4 ± 10.5</td>
<td>47.0 ± 10.2</td>
</tr>
<tr>
<td>Highest level of education&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>26.8</td>
<td>28.5</td>
<td>29.8</td>
<td>22.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Moderate</td>
<td>31.4</td>
<td>35.3</td>
<td>29.2</td>
<td>36.3</td>
<td>29.9</td>
</tr>
<tr>
<td>Low</td>
<td>41.8</td>
<td>36.2</td>
<td>41.0</td>
<td>41.3</td>
<td>44.8</td>
</tr>
<tr>
<td>Living alone at t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>11.5</td>
<td>11.5</td>
<td>14.6</td>
<td>14.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Paid job at t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>53.7</td>
<td>57.3</td>
<td>52.3</td>
<td>53.3</td>
<td>53.4</td>
</tr>
<tr>
<td>Smoking at t&lt;sub&gt;2&lt;/sub&gt;</td>
<td>18.6</td>
<td>14.9</td>
<td>23.7</td>
<td>20.0</td>
<td>19.6</td>
</tr>
<tr>
<td>BMI at t&lt;sub&gt;3&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal (&lt; 25 kg/m²)</td>
<td>38.9</td>
<td>39.3</td>
<td>39.5</td>
<td>32.3</td>
<td>38.0</td>
</tr>
<tr>
<td>Overweight (25&lt; 30 kg/m²)</td>
<td>45.6</td>
<td>47.4</td>
<td>39.8</td>
<td>49.2</td>
<td>44.0</td>
</tr>
<tr>
<td>Obese (≥ 30 kg/m²)</td>
<td>15.5</td>
<td>13.3</td>
<td>20.8</td>
<td>18.5</td>
<td>18.0</td>
</tr>
<tr>
<td>Chronic disease status&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;0&lt;/sub&gt;</td>
<td>18.9</td>
<td>19.4</td>
<td>24.5</td>
<td>24.5</td>
<td>24.8</td>
</tr>
<tr>
<td>Follow-up</td>
<td>36.0</td>
<td>38.5</td>
<td>41.7</td>
<td>39.8</td>
<td>36.3</td>
</tr>
<tr>
<td>Health-related quality of life at t&lt;sub&gt;0&lt;/sub&gt;</td>
<td></td>
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</tr>
<tr>
<td>Physical functioning</td>
<td>91.3 ± 13.2</td>
<td>89.4 ± 15.6</td>
<td>86.3 ± 18.4</td>
<td>88.9 ± 15.1</td>
<td>88.7 ± 15.8</td>
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<tr>
<td>Physical role limitations</td>
<td>85.1 ± 30.0</td>
<td>83.3 ± 30.7</td>
<td>81.4 ± 32.6</td>
<td>83.2 ± 30.7</td>
<td>83.7 ± 31.0</td>
</tr>
<tr>
<td>Bodily pain</td>
<td>81.9 ± 20.9</td>
<td>81.0 ± 21.2</td>
<td>79.1 ± 22.2</td>
<td>79.9 ± 21.3</td>
<td>79.6 ± 22.0</td>
</tr>
<tr>
<td>General health</td>
<td>75.3 ± 16.0</td>
<td>73.5 ± 16.8</td>
<td>71.5 ± 17.9</td>
<td>74.1 ± 16.7</td>
<td>74.3 ± 16.0</td>
</tr>
<tr>
<td>Vitality</td>
<td>69.6 ± 16.1</td>
<td>67.0 ± 17.0</td>
<td>65.1 ± 17.6</td>
<td>67.0 ± 17.1</td>
<td>67.2 ± 15.4</td>
</tr>
<tr>
<td>Social functioning</td>
<td>87.7 ± 18.7</td>
<td>86.1 ± 20.8</td>
<td>86.1 ± 20.2</td>
<td>86.3 ± 19.4</td>
<td>86.6 ± 19.0</td>
</tr>
<tr>
<td>Emotional role limitations</td>
<td>89.4 ± 26.7</td>
<td>86.2 ± 30.2</td>
<td>86.6 ± 29.2</td>
<td>85.9 ± 29.6</td>
<td>88.2 ± 28.1</td>
</tr>
<tr>
<td>Mental health</td>
<td>78.3 ± 13.9</td>
<td>76.6 ± 14.8</td>
<td>76.2 ± 15.1</td>
<td>75.6 ± 15.3</td>
<td>76.6 ± 14.4</td>
</tr>
</tbody>
</table>

Note. BMI = body mass index.
<sup>a</sup>Education categories defined as high (higher vocational education or university), moderate (intermediate vocational or higher secondary education), and low (intermediate secondary education or less).
<sup>b</sup>Self-reported diabetes mellitus, myocardial infarction, stroke, cancer, asthma, and persistent chronic low-back pain.
Although we observed no differences in physical role limitations, women who became active scored 5.9 (95% CI = 1.0, 10.8) points higher for physical role limitations than women who remained inactive.

Adults who became active reported better physical functioning (2.4; 95% CI = 0.6, 1.7 points higher), general health (2.9; 95% CI = 1.3, 4.5 points higher), vitality (2.6; 95% CI = 1.0, 4.2 points higher), social functioning (2.4; 95% CI = 0.3, 4.4 points higher), and less bodily pain (2.9; 95% CI = 0.7, 5.0 points higher) compared with adults who became inactive. The scores for mental health and physical role limitations did not differ between adults who became active and those who became inactive. We observed fewer role limitations among adults younger than 55 years who became active compared with those who became inactive (4.8; 95% CI = 1.4, 8.3 points higher). Interaction analyses also showed that we only observed better physical functioning and less bodily pain among adults who became active among those aged 55 years or older (8.5; 95% CI = 4.4, 12.6 and 7.8; 95% CI = 3.3, 12.2 points higher, respectively). We observed interaction with gender for vitality, which remained statistically significant in men only (men 4.0; 95% CI = 1.6, 6.3; women 1.2; 95% CI = –1.0, 3.5).

Although adults who became active reported somewhat lower health-related quality of life than those who were persistently active, we observed no significant differences between adults who became active and those persistently active or those with varying levels of activity.

**DISCUSSION**

Ten-year data on physical activity showed that adults who became active reported a health-related quality of life that was nearly as good as that of adults who were active over

**FIGURE 1**—Total time spent on moderate to vigorous physical activity per measurement and physical activity pattern among men and women aged 26–70 years: the Doetinchem Cohort Study, 1995–2009.
the whole study period. Moreover, adults who became physically active reported better physical functioning, general health, and vitality compared with those who remained inactive and also compared with those who were active at baseline but became inactive over the 10-year period. Adults who became physically active also reported less bodily pain and better social functioning than those who became inactive. Moreover, fewer physical role limitations were reported by women who became active compared with persistently inactive women, and fewer emotional role limitations were reported by adults younger than 55 years who became active compared with those who became inactive. Therefore, it seems worthwhile to become physically active during adulthood at levels recommended by current guidelines.

As physical activity is not a stable feature over time, it is remarkable that we observed such strong and consistent health effects of physical activity on the basis of single measurements. We identified 2 other studies with longitudinal measurements of physical activity, both showing a better health-related quality of life for adults who became physically active. Wolin et al. observed that women who increased their level of physical activity over 10 years reported a better health-related quality of life on all domains after 10 years compared with those who maintained their level of physical activity, among 63,152 middle- and old-aged women. Their findings showed improvements after becoming active in particular in the mental domains of health-related quality of life. Improvements in mental domains were not confirmed in our study, except for social functioning.

Long-term physical activity patterns were also investigated in relation to physical functioning assessed by performance tests, confirming the positive effects on physical functioning both of remaining active and of becoming active. The finding that increased levels of physical activity are particularly associated with a better health-related quality of life in women is confirmed in other studies, but a clear explanation is lacking.

We found no studies that assessed the impact of maintaining recommended physical activity. However, the finding that increased levels of physical activity are particularly associated with a better health-related quality of life in women is confirmed in other studies, but a clear explanation is lacking.
activity levels over several years in relation to health-related quality of life. By categorizing active and inactive adults according to recommended levels, our findings can be easily translated to interventions that aim to promote physical activity in inactive adults. A disadvantage of this approach could be that small increases in the duration of activities—for instance, an increase of only 15 minutes per week—may result in being classified as active instead of inactive. However, Figure 1 shows that adults who became active at recommended levels had quite a large increase in the number of hours spent on moderate intensity, from on average 2 hours a week at baseline to 9 hours a week after 10 years.

Our hypothesis that adults who became physically active report a better health-related quality of life after 10 years compared with adults who remained and became inactive was confirmed for physical functioning, general health, and vitality. Literature supports the finding that higher physical activity levels are associated more consistently with better physical functioning and vitality than other domains, but support for an association between physical activity and mental health is also present. Why we did not observe associations with the mental domain is unclear and is contrary to earlier analyses that showed a 1-hour-per-week increase in physical activity over several years in relation to health-related quality of life by our study during extended follow-ups. Nonrespondents were more frequently overweight, lower educated, smokers, and inactive compared with complete cases. The prevalence of being persistently active may be slightly overestimated because of this; however, the associations between physical activity patterns and health-related quality of life are usually not affected by small violations of representativeness.

This is the first study examining the association between becoming active over a period of 10 years versus other long-term physical activity patterns and health-related quality of life. The findings suggest a health benefit of becoming physically active during adult age. Higher levels of health-related quality of life may be achieved by public health strategies supporting inactive adults to adopt and maintain a physically active lifestyle during adulthood.

Long-term prospective studies such as the Doetinchem Cohort Study provide a wealth of opportunities to study dynamics in lifestyles and their effects on health during the life course. Strengths of this study are the prospective data collection, good participation rates, and the use of an extensive and identical questionnaire to measure physical activity at 3 successive examinations. However, some limitations should be taken into account when one is interpreting the findings. Self-reported physical activity levels usually overestimate actual physical activity levels. With the use of the lowest number of hours for winter and summer, we minimized overestimation in our study. However, to be able to capture all elements of physical activity that might influence long-term health, more detailed measurements and a more objective assessment of physical activity are needed.

Measurements of physical activity and health-related quality of life after 10 years occurred concurrently. Therefore, a causal relationship between becoming physically active and a better quality of life cannot be established on the basis of our findings. For instance, the reason that adults became inactive could be the occurrence of health problems. We adjusted analyses for chronic disease status at baseline and follow-up, for the most prevalent chronic diseases. However, the lack of information on less-prevalent diseases could lead to some residual confounding by chronic disease status.

Like in other prospective studies, more healthy participants tended to remain in the study during extended follow-ups. Nonrespondents were more frequently overweight, lower educated, smokers, and inactive compared with complete cases. The prevalence of being persistently active may be slightly overestimated because of this; however, the associations between physical activity patterns and health-related quality of life are usually not affected by small violations of representativeness.

The study period was extended to 10 years, which increased the power to detect small differences in health-related quality of life.
References


