A 15-year physical activity pattern is positively related to aerobic fitness in young males and females (13–27 years)

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Abstract The purpose of this paper is to test the hypothesis that daily physical activity over a period of 15 years has been beneficial to aerobic fitness in young male and female participants (13–27 years) in the Amsterdam Growth and Health Longitudinal Study. Only subjects with the maximal data of six sets of measurements were included (83 male and 98 female participants). Daily physical activity was assessed using a standardized interview on activity and expressed as a weighted activity score. Aerobic fitness was assessed using a maximal running test on a treadmill and measuring the maximal oxygen uptake ($V'_{O2}$max) and the maximal slope of the track ($S_{max}$). To assess the longitudinal relationship between daily physical activity and aerobic fitness a real longitudinal analysis was carried out with generalized estimating equations, adjusting for differences in initial aerobic fitness at age 13, and for other lifestyle (dietary intake, smoking and alcohol consumption) and biological parameters (biological age, body fat, blood pressure and concentration of serum cholesterol). A significant relationship ($P<0.01$) was observed between daily physical activity and both $V'_{O2}$max and $S_{max}$. It can be concluded that the development of aerobic fitness between the age of 13 and 27 years is independently and positively related to daily physical activity in this group of male and female participants in the study. The functional implications, however, are small: a relatively high increase in the weighted physical activity score of 30% over a period of 15 years results in a 2%–5% increase in aerobic fitness.

Keywords Maximal oxygen uptake · Daily physical activity · Longitudinal study · Young men and women

Introduction

Hypoactivity is believed to be a direct and indirect cause of many paediatric diseases (Bar-Or 1984) but also of adult chronic diseases such as cardiovascular diseases (CVD), diabetes mellitus, osteoporosis and several types of cancer (US Department of Health and Human Services 1996). The high prevalence of hypoactivity is striking. Caspersen (1989), for example, estimated that 59% of the United States population fails to perform regular leisure-time physical activity. This prevalence is much higher than for the three traditional CVD risk factors. For hypercholesterolaemia the prevalence is 19%, for cigarette smoking 18%, and for high blood pressure only 10%. The increase in relative risk (RR) for each of the four CVD risk factors is of similar magnitude. The RR varies from 1.9 (physical inactivity) to 2.5 (cigarette smoking). Mostly due to the high prevalence, the population attributable risk for physical activity on all-cause mortality and CVD mortality is the highest (Powell et al. 1987). In the Netherlands (Ruwlaard and Kramers, 1997) physical inactivity is also an important lifestyle factor in the contribution to CVD mortality. Therefore, physical activity appears to be of more important concern as to its influence on the population than the other above-mentioned risk factors (Caspersen 1989).

Next to the association between physical activity and CVD an even stronger association has been demonstrated between aerobic fitness and CVD, with the relative risk for CVD mortality of the least fit generally being fivefold or more higher than for the most fit (Bijnen et al. 1994; Blair et al. 1989, 1996; Lee and Paffenbarger 1996; Paffenbarger et al. 1986). The study of Lakka et al. (1994) concluded that physical fitness only protected against CVD in physically active individuals. The majority of the studies show that the
greatest differences in CVD rates are found between the least active or fit and the moderately active or fit individuals, with little additional benefit seen with additional activity or fitness, suggesting a threshold effect. This is also in agreement with the data from the Multiple Risk Factor Intervention Trial, as described by Leon et al. (1997). However, a meta-analysis by Berlin and Colditz (1990) demonstrated a greater dose-response relationship between the intensity of the physical activity and CVD risks: a lower relative risk for CVD risk indicators and lower CVD mortality rate was related to a higher intensity of physical activity in the studies included.

It is often suggested that a sufficient amount and intensity of regular physical activity during youth could decelerate the development of low levels of fitness, the advent of disease and approach of mortality (Leon et al. 1997). However, a prospective study comparing physically active children with less active children over a long period in a randomized controlled trial is difficult to implement. In the present study a group of 181 male and female participants between the ages 13 and 27 years were monitored over a period of 15 years with respect to their patterns of physical activity and concurrent aerobic fitness. To get an indication of a possible long-term effect of these patterns of physical activity on aerobic fitness a longitudinal analysis was carried out, correcting for possible confounders such as other lifestyle (dietary intake, alcohol and smoking behaviour) and biological variables (biological age, percentage body fat, serum cholesterol concentration, and blood pressure). Since the aerobic fitness of the subjects at the start of the study could have biased the effect of physical activity, the analyses were also adjusted for differences in initial aerobic fitness at age 13 years.

Methods

Subjects

The Amsterdam Growth and Health Longitudinal Study (AGA-HLS) used a multiple longitudinal design (see Fig. 1; Kemper and van’t Hof 1978). In this design repeated measurements have been made in three birth cohorts (1962, 1963 and 1964) of male and female pupils from a secondary school in Amsterdam (Kemper 1985). Between 1976 and 1992 the sets of measurements were repeated six times. (13–16 years). There were four annual measurements during the school period (at mean ages of 13, 14, 15 and 16 years, respectively), a fifth in 1985 (at a mean age of 21 years) and a sixth measurement in 1991 (mean age 27 years) (Kemper 1995).

Procedure

In view of the many confounding effects that are inevitably connected to longitudinal measurements, cohort effects, time of measurement effects and testing effects were estimated separately for all the measured variables (Kemper 1994, 1997).

The two parameters of interest in this paper (aerobic fitness and physical activity) in both the male and female participants did not show statistically significant effects ($P > 0.05$) between cohorts, time of measurements and repeated testing (Kemper 1991).

![Design of the Amsterdam Growth and Health Longitudinal Study (AGA-HLS)](image)

Fig. 1 Design of the Amsterdam Growth and Health Longitudinal Study with six repeated measurements in male and female participants between 13 and 27 years of age. The data are plotted at the mean ages of three birth cohorts

Also the dropouts (24% after the first four and 9% after the fifth sets of measurements) were no different from those that remained in the study. For example their mean body mass index, as an indication of aerobic fitness and physical activity level was not significantly higher in comparison with the group remaining in this longitudinal study (Kemper and van’t Hof 1978).

Physical activity

Daily physical activity was assessed six times over the 15-year period between the ages 13 and 27 years. The method used was a standardized activity interview based on a questionnaire (Montoye et al. 1996). The interview was the same over all the years and took place at the same time of year (between February and June). It reviewed activities over the previous 3 months.

The physical activities considered in the review covered the following areas: organized sports activities, unorganized sports activities, active transportation to and from school, work, etc. and work and home activities (van Mechelen and Kemper 1995). The only activities which were taken into account were those which had a duration of at least 5 min and an intensity of more than four times basal metabolic rate (MET). Activity below 4 MET is reported to contribute very little to aerobic fitness (American College of Sports Medicine 1990). The physical activities were classified as light (4–7 MET), medium–heavy (7–10 MET), and heavy (more than 10 MET) based on values found in the literature (Verschuuren 1987). For purpose of scoring, the MET assigned to these categories were 5.5, 8.5 and 11.5, respectively. The interview assessed the average weekly time spent in activities in each of the three categories and expressed the result as MET per week, derived by multiplying the average time spent per week (minutes) in each category by the respective MET value for that category. The scores of the three levels were then added to arrive at a score for total MET × minutes per week; i.e. weighted activity score = $(5.5 \times \text{min-week}^{-1}) + (8.5 \times \text{min-week}^{-1}) + (11.5 \times \text{min-week}^{-1})$ in MET per week. This weighted activity score was used as a combined estimate of the duration and intensity of the daily physical activity of the subjects for the year of measurement (Montoye et al. 1996).

Aerobic fitness

Aerobic fitness was measured using a running test on a treadmill (Quinton, model 18–54). A standard protocol was used with a submaximal test preceding the maximal test. The submaximal test consisted of three 2-min runs at a constant speed of 8 km·h$^{-1}$, with slopes of 0%, 2.5% and 5% (in that order). During practice for this