Abstract

Background: Three important results came from the Amsterdam Growth and Health Longitudinal Study (AGAHLS). This study followed three birth cohorts (1962, 1963 and 1964) of boys and girls in the Amsterdam region in the Netherlands. The follow-up period was 25 years, with 10 measurements from age 12 to 42 years. The main purpose of the AGAHLS was to detect changes in health and lifestyle over time during the teenage and young adult period.

Methods: In total, 617 subjects were recruited from two secondary schools in Amsterdam and Purmerend. We measured aerobic fitness (VO₂ peak), bone mineral density (BMD), obesity from body mass index (BMI) and body fatness from the sum of four skinfolds (S4S). Daily physical activity (DPA) was measured from heart rate, pedometers and an interview. Daily food intake (DFI) was measured by a cross-check dietary history interview.

Results: Longitudinal data analyses revealed that: (1) aerobic fitness, as measured by direct measurement of maximal oxygen uptake (VO₂ peak), increased more significantly in the physically active percentile (P > 75) of males and females than in the physically inactive percentile (P < 25), (2) BMD, as measured with dual X-ray absorptiometry (DEXA) in the wrist, hip and lumbar region, showed that physical activity in youth with a high mechanical load on the bones (mostly weight bearing) increased bone formation in the hip and lumbar region of males and females in adulthood, (3) the longitudinal relationship between DPA and DFI with the development of overweight and obesity (measured from BMI and S4S) showed that more DPA resulted in significantly lower fat mass, but no relationship could be demonstrated with DFI.

Conclusion: The main conclusion from this 25-year longitudinal research is that the promotion of physical activity (including physical education and sport) in adolescence can potentially be a strong tool to prevent chronic diseases and reduce healthcare costs later in life.

Keywords: longitudinal study, physical activity, food intake, aerobic fitness, bone health, body fatness

The assumptions and results about working mechanisms in the complex relationships between health and physical activity are derived from the Amsterdam Growth and Health Longitudinal Study (AGAHLS). This study reached a longitudinal follow up of 25 to 30 years in a group of 617 males and females, measuring health and lifestyle over the period from 12 to 42 years of age.

In Table 1, an overview is given of the measurements that were carried out on the 10 time points during the study period.

The participants were recruited from two schools. Pupils from one school in Amsterdam participated in a four-year annual repeat study (longitudinal design). In the other school, in Purmerend, the Netherlands, the pupils were measured only once during the first four years (cross-sectional design). Later these participants (n = 202) were also measured longitudinally.

Table 2 is a flow chart of the attending participants from the two schools over time.

The main outcomes, with a description of methods, statistical analyses (generalised estimation equations) and results over the adolescent (12 to 18 years), young adult (18 to 27 years) and adult periods (27 to 37 years) are published elsewhere.

The main purpose of the AGAHLS was to detect changes in health and lifestyle over time during the teenage and young adult periods. In this article, we determined the longitudinal relationship between daily physical activity (DPA), measured by heart rate integrators [converted to metabolic (MET) scores], pedometers and a cross-check activity interview, and daily food intake (DFI), measured by a cross-check dietary history interview on one hand, and aerobic fitness (VO₂ peak), bone mineral density (BMD) and body fatness on the other hand.

Methods

Only the relevant measurements are described here, such as VO₂ peak, BMD, body fatness and obesity. Other measures such as anthropometrics (height, weight, skinfolds, bone diameters, circumferences, peak height velocity and skeletal age),
cardiovascular measurements (blood pressure, cholesterol levels, arterial stiffness) and lung function measurements (FEV1), motor performance fitness tests (muscle strength, speed, co-ordination, endurance) and psychosocial tests (personality traits, sociometric status) have been described previously in detail.3-5

Aerobic fitness was measured with a maximal running test on a treadmill with continuous measurement of oxygen uptake (VO2 max).4 There after a six-minute sub-maximal running test at a speed of 8 km/h and increasing slope of 0, 2.5 and 5% was recorded. After a short rest, running was continued at the same constant speed of 8 km/h while the slope was increased every two minutes by 2.5 or 5%, depending on the heart rate. This maximal test was continued until complete exhaustion had been reached.7

The bone mineral content was measured in the hip, lumbar spine and wrist with dual X-ray absorptiometry. The BMD was measured on each side.8,9

Obesity was estimated with body mass index (BMI) from body mass and body height squared. Fatness was calculated from the sum of four skinfolds (S4S) from the biceps, triceps, sub-scapular and iliocristal skinfolds.10

All the participants (and their parents) in the study received and signed the informed consent prior to and during this longitudinal research.

Statistical analysis

The statistical methods used in this study are described in detail elsewhere.3-5 Briefly, four variables (VO2 peak, BMD, obesity from BMI, and body fatness from S4S), measured 10 times over a period of 25 years, were included in the analysis. The general estimated equation and random coefficient analysis were suitable for answer all the research questions and were much more flexible than MANOVA for repeated measurements. All analyses were carried out with the Statistical Package of Social Science, 10.1 for Windows (SPSS, Inc, Chicago, III, USA). The level of significant was set at p < 0.05.

Results and Discussion

Data on both aerobic fitness and daily physical activity were gathered nine times. A multilevel auto-regression analysis revealed paradoxical results (Table 3). From the results, it can be concluded that over the 25-year period of follow up, the...
development of aerobic fitness between 13 and 36 years of age was independently and positively related to daily physical activity in both genders (p < 0.001). This relationship was significant in the crude univariate model (corrected for gender and initial VO2 peak value) as well as in the two models adjusted for lifestyle and biological parameters (Table 3).

However, the functional implications of the statistically highly significant relationships seem to be small: a 10% difference in MET-score was positively related to a 0.3% difference in VO2 peak.

By contrast, the results of the auto-regression model, which was controlled for present VO2 peak, revealed no significant relationship between physical activity and aerobic fitness in both genders over the period of follow up (13- to 36-year age period). A difference in physical activity of 10% appeared to be positively related to a non-significant difference in VO2 peak of only 0.04% (95% CI: –0.06 to 0.13).

The BMD of hip, lumbar spine and wrist was measured three times by dual X-ray absorptiometry (DEXA) between 27 and 36 years of age. Lumbar and hip BMD was significantly and positively related to physical activity but not to dietary calcium intake during the teenage period.

Type of daily physical activity is also important for bone mass. From animal experiments, it is known that dynamic mechanical loading of short duration seems more effective than metabolic loading. In the lumbar spine and femoral neck during youth, the explained variance was 15 and 11% with mechanical physical activity (MECHPA) and only 4 and 2% with metabolic physical activity (METPA). No difference could be observed on the distal radius. This last result validates the importance of mechanical loading, because in general, the daily load on the upper extremities is far less than on the lower extremities in humans.

Fig. 1 shows the standardised regression coefficients (corrected for gender, body height and weight, fat mass, biological age and calcium intake) of the lumbar BMD at age 32 years with the physical activity pattern during three periods: adolescence (13–16 years), young adulthood (21–27 years) and the total period (13–27 years). The highest coefficients (beta) were with MECHPA over the period of 15 years (beta = 0.33; p < 0.01). During young adulthood (the seven-year period of age 21–28 years), MECHPA was also significantly related to lumbar BMD at age 32 years (beta = 0.20; p = 0.01). Only METPA results during adolescence and during the total period were significantly (p < 0.01) related to lumbar BMD at age 32 years, with beta values of 0.18 and 0.21 respectively.

We investigated the longitudinal relationship between daily physical activity and daily food intake on one hand, with the development of overweight and obesity over the 23-year follow-up period on the other hand. Fig. 2 shows that the percentage of males and females with a BMI above 25 kg/m2 increased exponentially with age: at 36 years, 43% of the males and 25% of the females were overweight or obese, while less than 5% were overweight in adolescence.

The longitudinal relationship of the actual values of daily physical activity with BMI resulted in significant (p = 0.02) negative regression coefficients in males but not in females. As expected, more daily physical activity resulted in less fat mass with daily food intake; however, the regression coefficients with S4S were significant in both males and females, and with BMI only in females, but these were not in the expected direction (lower daily food intake resulted in more fat mass) (Table 4).

More daily physical activity resulted in significantly lower fat mass and less overweight and obesity. Surprisingly, higher S4S and BMI were related to lower daily food intake. This unexpected result that a lower energy intake over 23 years was related to higher fat mass can be explained in two ways: (1) under-reporting of daily food intake by the more overweight subjects, and (2) repeated measurements could introduce negative testing effects.

Therefore, the origin of overweight and obesity in this longitudinal study cannot merely be explained by an increase in energy intake, but rather by a decrease in energy expenditure.11
Later analyses revealed that arterial stiffness and longer sitting time (TV viewing and PC use) in adulthood appeared to be related to lower aerobic fitness and higher fat mass.

Conclusion

The main message from this longitudinal research is that prevention of health-related problems in later life by the promotion of more physical activity (including sport and physical education) in normal daily life during adolescence could potentially be a strong tool to reduce healthcare costs by the prevention of cardiovascular and pulmonary diseases, osteoporosis and obesity.

We acknowledge the members of the AGAHLS research team that collected the data over the 25 years and published the scientific articles. We are most indebted to all the subjects, boys and girls, men and women who gave their time and effort to share with us their physical and mental state of health and gave insight on their daily lifestyle over the years. They were invaluable in contributing to the success of the AGAHLS longitudinal research.

References