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THE AEROBIC FITNESS AND PHYSICAL ACTIVITY PARADOX: ARE WE FIT BECAUSE WE ARE ACTIVE, OR ARE WE ACTIVE BECAUSE WE ARE FIT?

INTRODUCTION

The purpose of this paper is to test the hypothesis that physical activity (PA), measured over a period of 23 years is beneficial to aerobic fitness (VO_2max) in boys and girls (13-36 years) from the Amsterdam Growth and Health Longitudinal Study (AGAHLS).

Multiple randomized controlled trials have demonstrated that in males and in females, in children and adults the physical fitness can be improved by effective physical activity programs [1]. All these training studies however, are relatively short in duration (from 6 weeks to 12 months) and most of the time in populations of healthy volunteers. These results can therefore be confounded by self-selection. Moreover the short-term effects of these training programs are not indicative for lifetime changes of physical activity patterns on physical fitness. Lifetime intervention studies, even if these are performed over several years, are not feasible and also not ethical in human populations.

Positive relationships between physical activity and physical fitness in children as well as in adults are often demonstrated by significant correlations in cross sectional studies [2]. However in these studies the correlations do not indicate the direction of the relationship: a high correlation between activity and fitness can be explained in both ways: the population under study is more physically fit because they are more active or the other way around: the population is more active because they are more fit.

One way to come out of this dilemma is to do a prospective observatory study in a population and to compare fitness and in subpopulations of subjects who showed during the observation period respectively relatively low and high physical activity patterns.

METHODS

In the Amsterdam Growth and Health Longitudinal Study (AGAHLS) ca 300 boys and 300 girls at age 13 years, were followed over a period of almost 25 years till age 36 years [7, 8].

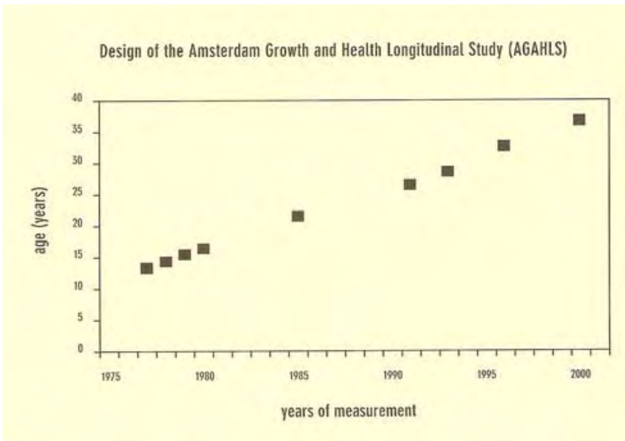

Figure 1. General design of the AGAHLS, with time of measurement (horizontal axis) and mean calendar age (vertical axis) of the study cohort

Physical activity and aerobic fitness were measured repeatedly at least three times and maximally nine times (fig. 1).

Physical activity was measured by a cross-check interview [10] estimating weighted metabolic energy expenditure (MET score) of all daily physical activities (including school physical education, job, sport, active transportation, walking, cycling and stair climbing etc)

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during the three previous months, and aerobic fitness [6] by a maximal treadmill test (running at 8 km/hour with increasing slope) while measuring directly and continuously the maximal oxygen uptake from expired air (VO_2max).

To get an indication of a possible long-term effect of these patterns of activity on aerobic fitness different longitudinal analyses were 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 and blood pressure).

The statistical analysis used was generalized estimating equations (GEE) [11], in which the longitudinal relationship was analysed including all available physical activity and aerobic fitness data with adjustment for both time dependent (biologic and lifestyle variables) and time independent covariates (gender).

Because the aerobic fitness at the start of the study could have biased the effect on physical activity, in one GEE analysis was also adjusted for differences in initial aerobic fitness at age 13 years. In a second GEE analysis an autoregressive model was used, in which the longitudinal relation of present physical activity on the VO_2max value of the next measurement was calculated. For all analyses, a 5 % significance level was used.

RESULTS

Data on both aerobic fitness and physical activity were gathered nine times and revealed paradoxical results: VO_2max was significant and positively related in both sexes with physical activity, but a change in VO_2max appeared not to be related with a change in physical activity over the different age periods.

In figure 2 the boys and girls were divided during their adolescent period (12-17 years of age) in active and inactive groups from longitudinal measurement of their daily physical activity by heart rate monitoring, pedometer scores and questionnaires.

The results show that the active adolescents have always a higher aerobic fitness (VO_2max/bodymass) compared with the inactive adolescents; in males the differences are more pronounced at age 16/17 than at age 12/13 and highly significant, indicating that physical activity is increasing aerobic fitness during adolescent age.

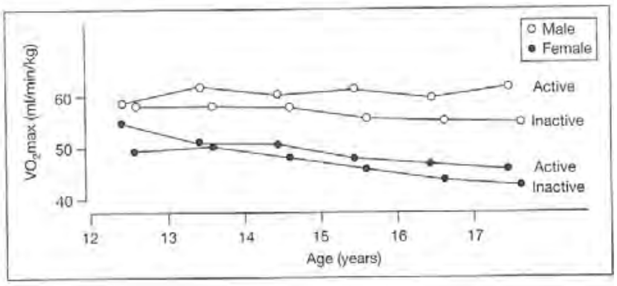

Figure 2. Longitudinal relationship between physical inactive teenagers and physical active teenagers and aerobic fitness, measured from 12 to 17 years of age in the AGAHLS study (from: Kemper, ed. [7])

The same results were observed in the follow-up of the AGAHLS study till the age of 27 years. In figure 3 the low and high active males and females were divided on the basis of tertiles of physical activity estimated from the six repeated physical activity crosscheck interviews.

Regression analysis demonstrated a significant higher aerobic fitness in both males and females in the highest tertile for physical activity compared with the lowest tertile for physical activity. At the age of 13 years in both sexes no difference in VO_2max can be seen, but after that age the differences between activity groups are clear.

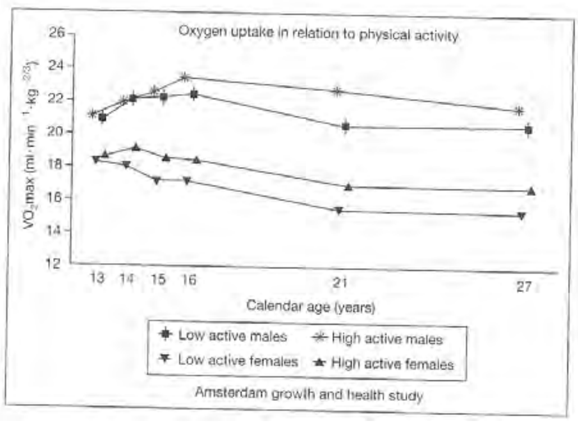

Figure 3. Longitudinal regression analysis of aerobic fitness and DPA over six measurements over the age period from 13 to 27 years (from: Kemper, ed. [8])

From the results it can be concluded that over the 25 years period of follow-up the development of aerobic fitness between 13 and 36 years of age is independently and positively related to daily physical activity in both sexes ($p<0.01$). This relationship (table 1) was significant in the crude model as well as in the models adjusted for lifestyle and adjusted for biological parameters.

Table 1. Standardized regression coefficients and p-values obtained by GEE regarding the longitudinal relationship between physical activity and aerobic fitness

	VO_2-max	
	ß	p-value
analysis		
crude	0.09	<0.01
adjusted1	0.08	<0.01
adjusted2	0.07	<0.01

crude "univariate" analysis (correcting for gender time and initial value of VO_2max

adjusted1 multiple analysis like crude also correcting for lifestyle parameters (eating, drinking and smoking)

adjusted2 multiple analysis like crude also correcting for biological parameters (blood pressure, fatness and hypercholesterolaemia)

However, the functional implications of the highly statistical significant relationships seem to be small: a 10% difference in MET-score was positively related to a 0.3% difference in VO_2max.

In contrast, the results of the autoregressive model in which physical activity was controlled for present VO_2max, reveal no significant relations between physical activity and aerobic fitness over the period of follow-up in both sexes over the 13-36 years age period: A difference in physical activity of 10% appeared to be positively related to a non-significant difference in VO_2max of only 0.04% (95% Confidence Interval: –0.06 to 0.13).

CONCLUSION

The longitudinal data from AGAHLS do not fully support the hypothesis that physical activity effects aerobic fitness. It seems there is a paradox: If a correlational approach is followed between aerobic fitness and physical activity, the results show highly significant and positive correlation coefficients between aerobic fitness and physical activity in this aging population. However, the direction of these relationships remain unclear because a longitudinal auto-regression analysis, taking into consideration the effects of present physical activity on future aerobic fitness resulted in non significant relationship.

This may indicate that that genetic factors are more important than environmental factors in the question about the importance of physical activity for aerobic fitness, or that the effect is so short lived that it is not detectable with time intervals of between one and five years [4].

Acknowledgement

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REFERENCES

[1] Bar-Or O., Pediatric Sports Medicine, from physiologic principles to clinical applications, Springer Verlag, New York, 1984, pp. 66-73.

[2] Berlin J.A., Colditz G.A., A meta-analysis of physical activity in the prevention of coronary heart disease, *Am J Epidemiol*, 1990, 132: 612-628.

[3] Bouchard C., Malina R.M., Perusse L., eds., Genetics of fitness and physical performance, Human Kinetics, Champaign, IL, 1997.

[4] Joyner M.J., ACE genetics and VO_2max, *Exercise and Sport Sciences Reviews*, 2001, vol. 29, 2: 47-48.

[5] Kemper H.C.G., Hof M.A. van 't: Design of a multiple longitudinal interdisciplinary study of growth and health in teenagers, *Eur J Pediatr*, 1978, 129: 147-155.

[6] Kemper H.C.G., Binkhorst R.A., Verschuur R., Visser A.C.A., Reliability of the Ergoanalyzer, *J Cardiovasc Techn*, 1976, 4: 27-30.

[7] Kemper H.C.G., ed., Growth, health and fitness of teenagers, longitudinal research in international perspective, Medicine and Sport Science (Hebbelinck M, ed.) Basel, Karger, 1985, vol. 20.

[8] Kemper H.C.G., ed., The Amsterdam Growth Study, a longitudinal analysis of health, fitness, and lifestyle. HK Sport Science Monograph Series, Human Kinetics Champaign, 1995, vol. 6.

[9] Kemper H.C.G., ed., Amsterdam Growth and Health Longitudinal Study, a 23-year follow-up from teenager to adult about lifestyle and health. Medicine and Sport Science (Borms J, Hebbelinck, Hills AP., eds.) 2004, vol. 47.

[10] Montoye H.J., Kemper H.C.G., Saris W.H.M., Washburn R.A., Measuring physical activity and energy expenditure. Human Kinetics, Champaign IL, 1996, appendix-P: 183-184.

[11] Zeger S.L., Liang K-Y., Longitudinal data analysis for discrete and continuous outcomes, *Biometrics*, 1986, 42: 121-130.