PAPERS AND ORIGINALS

Long-term effects of physical training programme on risk factors for coronary heart disease in otherwise sedentary men

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Summary and conclusions

Three hundred and seventy sedentary men aged 20-65 years enrolled in a physical training programme after a medical and fitness examination that included measurements of "classical" risk factors for coronary heart disease. Five years later re-examination showed (a) that on average the subjects had not changed significantly in weight, blood pressure, serum lipid concentrations, smoking habits, and physical working capacity; (b) that men who had remained active and therefore had a higher degree of fitness did not differ in risk factors from men who had returned to sedentary habits; and (c) that men who had improved substantially in fitness did not differ in risk factors from men whose fitness had not changed or had declined. Five years after the initial programme one-third of the men were continuing with regular vigorous exercise.

These results do not support the view that classical risk factors for coronary heart disease improve with increased physical activity and fitness.

Introduction

Favourable associations have been reported between vigorous physical activity and coronary heart disease¹⁻³ and between physical fitness and risk factors for coronary heart disease.⁴⁻⁶ Such associations, however, are probably influenced by selective factors that predispose certain people to be more active and at the same time protect against coronary heart disease.⁶ Consequently the protective effect of physical activity per se is not clear, and it remains to be shown whether sedentary people taking up regular exercise benefit their cardiovascular health compared with similar people who remain sedentary. We have therefore evaluated the effects of a physical fitness intervention programme on such risk factors as serum lipid concentrations, blood pressure, obesity, smoking, and physical activity in a group of men five years after initial intervention.

Subjects and methods

Out of 673 men aged 20-65 years who enrolled for a physical training course after a medical and fitness examination, 370 were re-examined four to six years later. Details of all people enrolling for the course are given elsewhere.⁷ The men were predominantly of British ancestry (93%) and in "professional" or "administrative" occupations (70%); only 5% were "blue-collar" workers. Thirty per cent were cigarette smokers (national mean about 40%) and 70% drinkers (close to the national mean). Average total daily energy intake was 10.29 MJ (2460 kcal)—that is, close to the recommendation for Australian sedentary men—9% being taken as alcohol, 45% as fat, and 30% as highly refined carbohydrates; cholesterol intake averaged 1.28 mmol (494 mg) daily. Half the men weighed 10% or more above the ideal; 21% had a diastolic blood pressure of 95 mm Hg or more; 36% had serum cholesterol concentrations above 6.5 mmol/l (250 mg/100 ml); and 29% had serum triglyceride concentrations above 2.0 mmol/l (177 mg/100 ml).

The medical and fitness examinations included clinical assessment, cardiovascular and anthropometric measurements, determination of serum triglyceride and cholesterol concentrations, and a test of physical working capacity (PWC). The initial examination was to

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assess the safety of vigorous exercise and establish baseline data. Of the 370 men re-examined four to six years later, 14 (4%) were at high risk for coronary heart disease and attended the course under medical supervision. Blood pressure was taken lying after at least five minutes' rest, diastolic pressure being recorded at the muffling of sounds. Height and weight were measured in shorts only. Quetelet's index⁸ (weight over height-squared) was used to assess changes in obesity. Serum triglyceride and cholesterol concentrations were determined after a 14-hour fast using Technicon methods N-24a and N-78a at the first examination^{9,10} and enzymatic methods at the second^{11,12}; the two techniques give closely comparable results. Physical fitness—defined as PWC_{150} (amount of work required to produce a heart rate of 150 beats/min on a bicycle ergometer)—was measured as described.¹³ At the second examination subjects completed a questionnaire on physical activity, including occupational and leisure. The intention was to identify men engaging for at least two hours a week in moderate to heavy exercise—for example, squash, running, field games, fitness training, and heavy manual activity. Such men were classified as "active" and the remainder as "inactive." A smoking questionnaire was completed at both examinations.¹⁴

The fitness programme comprised 12 weeks of twice-weekly, one-hour sessions of callisthenics, interval running, and volley-ball. In a controlled study of 56 men this model of training increased PWC_{150} by 18%.¹³ The subjects were taught how to exercise safely and effectively, and the value of dieting and giving up smoking was emphasised. After three months 49% of all participants requested reassessment (PWC_{150} , weight, resting and post-exercise electrocardiograms) and about 40% enrolled for a further course.

Four to six years after the initial course all 673 men were posted a request to attend for re-examination. Of these, 559 were presumed able to comply (the others being too ill, untraceable, absent, or dead), of whom 133 failed to respond, 53 missed their appointment, and three refused. The remaining 370 (66%) were therefore re-examined.

Statistical—Mean values and standard deviations were computed and Student's *t* test used to assess the significance of differences between means. The composition of subgroups was computed by cross-tabulation analysis, and linear and quadratic regressions conducted to estimate the variance contributed to risk factors by change in physical fitness while controlling for the effects of initial fitness and other variables.

Results

WHOLE SAMPLE

Analysis of the sample as a whole (table I) and in 10-year age groups showed no significant difference in any measurement between the initial and final examinations. Nevertheless, several individual changes occurred. During the five years 104 (28%) of the men lost weight (>2 kg), 166 (45%) remained stable (± 2 kg), and 100 (27%) gained weight (>2 kg), 19 men (5%) gaining over 6 kg. The general trend for smoking was essentially unaltered (table II), though many

men had changed their smoking habits, particularly the light and moderate smokers (table III); abstainers, reformed, and heavy smokers showed the least change. Lipid states (table IV) also showed little overall change except for a slight reduction in type IV hyperlipoproteinaemia. Out of 98 men (64% of the 153 who had both

TABLE II—Percentages of men in five smoking categories

	Never smoked	Reformed smokers	Smokers			All
			Light (1-9/day)	Moderate (10-19/day)	Heavy (≥ 20 /day)	
Examination 1	34	37				29
Examination 2	34	36	6	8	15	30

TABLE III—Percentages of men changing smoking categories between examination 1 and examination 2

	Reformed	Decreased	Increased	Started	Stable
Never	5*			3	92
Reformed				17	83
Light (1-9/day)	23		27		50
Moderate (10-19/day)	25	19	15		41
Heavy (≥ 20 /day)	15	12			73

*Categories "never," "reformed," etc were given at entry: the 5% were therefore men who began smoking for the first time during the five-year study period and claimed to have stopped before the second examination.

TABLE IV—Percentages of men with normal and abnormal lipid values at examinations 1 and 2

	Normal	Type II or mixed or other	Type IV
Examination 1	64	5	31
Examination 2	68	7	25

lipids measured at tests 1 and 2) with normal lipid values at the initial examination, 87 (89%) had normal values five years later, the remaining 11 (11%) having type IV hyperlipoproteinaemia. Of the 47 men (31%) with type IV hyperlipoproteinaemia at the initial examination, however, 18 (38%) were normal five years later, 26 (56%) remaining unchanged and 3 (6%) being classified as type IIb hyperlipoproteinaemia (mixed).

TABLE I—Characteristics of subjects at examinations 1 and 2. Values are means $\pm$ SD

	Age (years)	Height (cm)	Weight (kg)	Wt/ht ² (kg/m ²)	Blood pressure (mm Hg)		Physical working capacity		Serum cholesterol* (mmol/l)	Serum triglycerides* (mmol/l)
					Systolic	Diastolic	kpm/min	kpm/min/kg BW		
All subjects (n=370):										
Examination 1	44.4 $\pm$ 7.8	175.6 $\pm$ 6.3	80.4 $\pm$ 11.4	26.0 $\pm$ 3.2	137 $\pm$ 19	84 $\pm$ 11	862 $\pm$ 176	10.8 $\pm$ 2.2	6.1 $\pm$ 1.1	1.8 $\pm$ 1.0
Examination 2	49.6 $\pm$ 7.8	175.4 $\pm$ 6.3	80.2 $\pm$ 11.6	26.1 $\pm$ 3.3	134 $\pm$ 20	83 $\pm$ 11	879 $\pm$ 196	11.1 $\pm$ 2.4	6.0 $\pm$ 1.1	1.7 $\pm$ 1.0
Active versus inactive subjects (n=339):										
Inactive (n=223):										
Examination 1	44.5 $\pm$ 7.8	175.6 $\pm$ 6.4	80.8 $\pm$ 11.2	26.2 $\pm$ 3.2	137 $\pm$ 20	84 $\pm$ 12	861 $\pm$ 157	10.7 $\pm$ 2.0	6.0 $\pm$ 1.1	1.9 $\pm$ 0.8
Examination 2	49.8 $\pm$ 8.0	175.4 $\pm$ 6.4	81.0 $\pm$ 11.6	26.4 $\pm$ 3.4	133 $\pm$ 20	83 $\pm$ 11	840 $\pm$ 175	10.5 $\pm$ 2.2	6.0 $\pm$ 1.2	1.7 $\pm$ 0.9
Active (n=116):										
Examination 1	44.1 $\pm$ 7.8	175.4 $\pm$ 5.9	79.5 $\pm$ 11.9	25.8 $\pm$ 3.3	137 $\pm$ 16	83 $\pm$ 9	865 $\pm$ 210	10.9 $\pm$ 2.5	6.2 $\pm$ 1.1	1.9 $\pm$ 1.4
Examination 2	49.2 $\pm$ 7.9	175.5 $\pm$ 6.0	78.6 $\pm$ 11.4	25.5 $\pm$ 3.3	135 $\pm$ 20	84 $\pm$ 11	956 $\pm$ 212	12.3 $\pm$ 2.4	6.0 $\pm$ 1.0	1.8 $\pm$ 1.1
Subjects classified by change in fitness (n=370):										
Losers (n=109):										
Examination 1	44.7 $\pm$ 7.7	176.7 $\pm$ 6.9	80.1 $\pm$ 11.3	25.9 $\pm$ 3.3	132 $\pm$ 16	81 $\pm$ 10	909 $\pm$ 164	11.5 $\pm$ 2.1	5.7 $\pm$ 1.2	1.7 $\pm$ 0.8
Examination 2	50.2 $\pm$ 7.7	175.7 $\pm$ 6.9	81.1 $\pm$ 11.6	26.3 $\pm$ 3.4	131 $\pm$ 18	82 $\pm$ 10	771 $\pm$ 159	9.6 $\pm$ 2.0	5.9 $\pm$ 1.3	1.5 $\pm$ 0.7
Stable (n=78):										
Examination 1	43.9 $\pm$ 7.3	176.4 $\pm$ 6.3	79.8 $\pm$ 9.8	25.6 $\pm$ 2.7	134 $\pm$ 17	81 $\pm$ 11	891 $\pm$ 156	11.3 $\pm$ 1.9	6.1 $\pm$ 0.9	1.9 $\pm$ 0.8
Examination 2	49.1 $\pm$ 7.3	176.0 $\pm$ 6.8	79.6 $\pm$ 10.1	26.7 $\pm$ 2.8	131 $\pm$ 18	81 $\pm$ 12	891 $\pm$ 163	11.3 $\pm$ 1.9	5.8 $\pm$ 0.8	1.7 $\pm$ 0.8
Small gain (n=76):										
Examination 1	43.1 $\pm$ 7.2	176.0 $\pm$ 6.0	80.9 $\pm$ 12.5	26.0 $\pm$ 3.2	142 $\pm$ 22	87 $\pm$ 13	864 $\pm$ 174	10.7 $\pm$ 2.0	6.3 $\pm$ 1.0	1.8 $\pm$ 0.8
Examination 2	48.1 $\pm$ 7.3	176.0 $\pm$ 5.9	80.5 $\pm$ 12.7	26.1 $\pm$ 3.1	138 $\pm$ 24	87 $\pm$ 13	921 $\pm$ 184	11.6 $\pm$ 2.0	6.1 $\pm$ 1.0	1.8 $\pm$ 0.9
Large gain (n=107):										
Examination 1	45.4 $\pm$ 8.6	174.4 $\pm$ 5.7	80.5 $\pm$ 11.6	26.5 $\pm$ 3.5	139 $\pm$ 17	85 $\pm$ 10	758 $\pm$ 176	9.5 $\pm$ 2.3	6.4 $\pm$ 1.2	1.9 $\pm$ 1.4
Examination 2	50.4 $\pm$ 8.9	174.2 $\pm$ 5.9	79.4 $\pm$ 11.3	26.3 $\pm$ 3.8	133 $\pm$ 18	82 $\pm$ 9	986 $\pm$ 216	12.5 $\pm$ 2.8	6.3 $\pm$ 1.3	2.0 $\pm$ 1.4

*Lipid data were for men volunteering for lipid screen, which was not obligatory part of initial examination; this subsample did not differ significantly from whole sample in any measurements at first or final examination.

Conversion: SI to traditional units—Serum cholesterol: 1 mmol/l $\approx$ 38.6 mg/100 ml. Serum triglycerides: 1 mmol/l $\approx$ 88.5 mg/100 ml.

ACTIVE VERSUS INACTIVE MEN

Of the 339 men who completed the activity questionnaire, 115 (34%) were classified as active. The active and inactive groups (table I) were closely matched in all variables at the initial examination, and during the three-month course the groups achieved similar increases in mean working capacity. Five years later, however, the mean PWC_{150} had fallen to the pre-course value in the inactive group ($10.5 \pm SD$ 2.2 kpm/min/kg body weight), whereas in the active group the value was 17% higher (12.3 ± 2.4 kpm/min/kg). Hence the effect of two hours or more a week of moderate to heavy exercise was comparable to that of the supervised fitness programme.

Changes in physical risk factors and smoking habits did not differ significantly between the groups. Thus while being active was associated with increased fitness, there was no evidence of a beneficial effect on any risk factor for coronary heart disease.

Half of the active men had continued with twice-weekly training at the institute for fitness, so that the "typical" exercise patterns in their activity questionnaires were known to have been consistent over the five years. At the end of the period there was no significant difference in any study variable between those men and the men said to be active elsewhere. This suggested that most of the active men did not become more active and substantially fitter shortly before (and perhaps in preparation for) the second examination. Thus we believe that, as intended, we were observing the relation between long-term adherence to training and risk factors.

To examine the possibility of a threshold effect of activity on risk factors we graded the subjects according to change in fitness over the five years. Those declining 5% or more in PWC_{150} were classed as "losers," those losing or gaining under 5% as "stable," those gaining 5% to less than 15% as "small gain," and those gaining 15% or more as "large gain." We assumed that the different grades correlated positively with the vigour and frequency of exercise. If true then we should expect increasing proportions of active men to feature across the losers, stable, small gain, and large gain categories compared with inactive men; table V shows that this was the case. Of the 370 men, 109 (29%) declined in fitness, 78 (21%) were stable, 76 (20%) gained slightly, and 107 (29%) gained substantially (table I). Changes in

TABLE V—Percentages of active versus inactive men in groups classified by change in fitness

	Losers	Stable	Small gain	Large gain
Inactive men	38	23	17	22
Active men	5	15	35	45

$\chi^2 = 37.6$; $p < 0.001$.

PWC_{150} /kg body weight ranged from a mean loss of 17% to a mean gain of 32%, with no sign of a systematic relation with change in risk factors. Regression analysis of each risk factor on change in fitness, controlling for initial fitness and other sources of variance, confirmed this; the percentage of risk factor variance accounted for by change in fitness was close to zero for systolic and diastolic blood pressure, serum cholesterol concentration, and Quetelet's index, and 1.06 (not significant) for serum triglyceride concentration.

Discussion

Subjects from middle and upper middle classes seeking to improve their health probably present good prospects for a change in behaviour; such socioeconomic groups have better attitudes to physiological hygiene and maintain more favourable living habits than the community as a whole.¹⁵ This bias in our study and the lack of longitudinal data on Australians make it difficult to interpret the apparent stability in physical variables over the five years; it might be a departure from expected population trends as a result of the intervention, especially with respect to weight and fitness, which have been shown in other longitudinal studies to increase and decrease respectively with age.¹⁶⁻¹⁸ (When fitness defined as maximal oxygen uptake was predicted for our subjects from PWC_{150} ,¹⁹ thus allowing for the decline in maximum heart rate with age, there was still no significant decline in the fitness of the whole group.) It seems

unlikely that a sample of moderately high-risk subjects of presumably affluent life style should stabilise irrespective of age, with 73% maintaining the same or losing weight and 70% maintaining or gaining fitness. Alternatively such health-conscious populations might be relatively stable anyway, or possibly changes in life style occurred that were not specific to the intervention but were associated with the substantial decline in mortality from coronary heart disease noted in Australia and other affluent communities.²⁰⁻²²

The social bias in our study is less problematical when interpreting the interrelations between physical activity, change in fitness, and risk factors. Physically our subjects were quite typical of a large proportion of Australians,²³⁻²⁶ and for this reason, and because of the controls inherent in the study, we are fairly confident that the findings on those interrelations can be extended broadly to sedentary Australian men. The most important findings were that being active or inactive and improving or declining in fitness bore little association with risk factors for coronary heart disease.

Only a third of our subjects were continuing with training five years after the initial programme, which is not encouraging when the good potential of the group for a change in life style is considered. The adherence rate (34%; 116/339), however, is fairly typical of such intervention studies²⁷⁻²⁸ and emphasises the difficulty of inducing a permanent change in patterns of activity. Nevertheless, little research has been conducted on the social psychology of exercise maintenance,²⁸ and probably more effective methods of inducing adherence will be developed.

That the programme produced no overall change in smoking habits agrees with other reports.²⁷⁻²⁹

Our findings are contrary to reports that exercise reduces risk factors for coronary heart disease. Most such studies, however, have been either cross-sectional or based on only a few months of training.³⁰ Two well-controlled studies conducted over one and a half years²⁹⁻³¹ yielded results similar to ours: training had no effect on cholesterol concentration, blood pressure, or smoking; physical fitness significantly increased; and body weight was unchanged. Five-year follow-up to the study of Pyörälä *et al.*²⁷ showed that exercise intervention had little lasting effect on life-style habits and health indices, which included body weight, new symptoms related to heart disease, and other new diseases. Interestingly, the incidence of coronary heart disease was the same for the original experimental and control groups and for men graded as least and most active at follow-up.

The most unexpected observation in our study was that serum triglyceride concentrations did not fall with training. Such a reduction with both acute exercise and training seemed to have been virtually proved.³²

Our findings do not support the view that risk factors for coronary heart disease in healthy men are improved by taking up regular aerobic exercise. Our criterion of "active," however, was moderate, and possibly a more stringent criterion, with higher levels of fitness, would yield different results. Also we confined the study to "classical" risk factors, and in future consideration should include other factors attracting interest, such as cardiac stability,³³ clotting and fibrinolytic activity,³⁴⁻³⁶ and lipid fractions, notably high-density lipoprotein cholesterol.³²

We cannot exclude the possibility that physical activity protects against coronary heart disease since we made no direct observations of heart disease. Nevertheless, if there is such an effect then (a) classical risk factors might not be sensitive enough to detect it in healthy men studied for only five years, and (b) the protective mechanisms influenced by training may to some extent be independent of those risk factors. Epidemiological evidence supports the second possibility.³⁶ With respect to the first probably the effects of training on risk factors are most fruitfully observed incorporating the everyday challenges that might eventually compromise cardiovascular health. For example, blood pressure, lipid concentrations, and cardiac function might be measured during psychological stress, or triglycerides after a fatty meal, rather than resting and fasting.

This sort of procedure, much like electrocardiogram stress-testing, might provide clearer information about adaptive abilities, which health-promotion regimens are designed to protect; it might also serve as a profitable extension of conventional epidemiological methods, the limitations of which have been emphasised.³⁷

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ONE HUNDRED YEARS AGO The *Boston Medical and Surgical Journal* for April 29th gives an account of a curious case of suicide by decapitation, which bears a strong general resemblance to a case reported in the *American Practitioner* for August 1876, an abstract of which was given in the *BRITISH MEDICAL JOURNAL* for September 23rd of that year. In the present case, a young man, who, with his father, worked a small farm, slept with his father in an old barn on the place one Saturday night; and on Sunday morning, the father started to go to their home, which was at a distance, remarking to his son, who had not risen from the hay where he was lying, that he should come back on Monday morning, and that in the meantime he too had better go home to the house. On Monday, when the father returned, about midday, he found his son lying dead on the floor of the barn, with his head completely severed from his body, or attached only by a portion of the skin at the front of the neck. The decapitation had been performed by a rough sort of guillotine, which the self-ordained victim must have spent the whole Sunday in constructing. There was reason for thinking that the deed was consummated between seven and eight o'clock on Monday morning. The young man must have been unconscious, if not dead, from the effects of ether at the moment when the blade descended. The *Boston Herald* gives the following description of the guillotine as constructed.

"This machine was improvised from material found in the barn, and its plan of operation was as follows. Two uprights, three by four joist, twelve feet in length, extended from the floor of the lower storey to the ceiling, to which they were securely spiked. The lower ends of the uprights were mortised in a solid piece of hard wood, about eight by twelve inches in size, and some three and a half feet in length. In the

centre of this bed-piece was chiselled out, apparently with a very dull implement, a groove sufficiently deep and wide to admit the entrance of a man's neck. Fitting between the uprights, in an easy sliding position, was a square piece of two-inch plank, to the lower edge of which was securely fastened the blade of a carpenter's ordinary broad axe, sharpened to a keen edge. The bottom of this slider rested upon a lever fifteen inches in length, working upon a pin secured in the left upright, and from the end of which, suspended by a cord three feet in length, was a water-pot, which had been filled with water. On the top of the slider was a box containing fifty pounds of stone. The bottom of the watering-pot, which was an ordinary twelve or fourteen quart vessel, such as is commonly used on a farm, had been perforated with holes, so that the water might leak out and release the lever, thereby allowing the sliding block with the axe attached to fall. The axe, after being released, had a fall of six and a half feet. In order to render the uprights more firm and prevent any lateral motion, a piece of scantling was mortised in between them at about eighteen inches from the top. At the base of the uprights were two holes, through which was thrust a broom-handle, which effectually imprisoned the neck of the victim and prevented any attempt to remove it. In front of the machine, on the floor, was a small piece of timber, about two feet long, six or seven inches wide, and four inches thick. In the end, next to the bed-piece of the guillotine, was gouged a cavity large enough to hold about two quarts, and in it was found about a pint of ether. This ether came directly under the nose of the victim, which rested upon the floating lid of a cigar-box. On each side of this, with the ends firmly braced against the bed-piece in order to steady it, was a large box filled with stones and dirt." (*British Medical Journal*, 1880.)