

CHAPTER VI

EXERCISE

Professor TD Noakes, Dr EV Lambert

INTRODUCTION

There is a growing realization that regular participation in physical activity may be one of most cost-effective interventions for the prevention of certain chronic disease and should therefore be more widely promoted in all communities in all countries.

Exercise and the prevention of coronary heart disease

Five researchers have contributed significantly to our understanding of the relationship between physical activity level and coronary heart disease. Jeremy Morris, Ralph Paffenbarger, David Siscovick, Ken Cooper and Steven Blair and their colleagues concluded separately that people who actively exercise are less likely to suffer from heart attacks.

Morris's studies

Probably the first important study suggesting that physical inactivity may be an important risk factor for coronary artery disease was reported in 1953 by Prof. Jeremy Morris and his associates at the London School of Tropical Medicine.¹ They found that conductors on the London Transport System had a 30% lower incidence of heart disease than did the sedentary bus drivers. A similarly favourable result was found for postmen when compared to less active postal clerks, who performed sedentary work.

Critical analysis revealed that physical inactivity was not the only difference between the groups. The bus drivers were more overweight, had higher blood pressures, had higher blood cholesterol levels, and smoked more than the conductors. These differences were already present before the groups were employed, suggesting that persons likely to develop heart disease chose sedentary occupations, while healthy persons chose active occupations.^{2,3}

Tim Noakes (M.D., F.A.C.S.M.), is Professor in the Liberty Life Chair of Exercise and Sports Science and Director of the MRC/UCT Bioenergetics of Exercise Research Unit, Department of Physiology, University of Cape Town Medical School. He is also co-founder with Morné du Plessis of the Sports Science Institute of South Africa. He has participated in rowing, long distance running, including marathon and ultra-marathon races. In recent years he has been more active in cycling and triathlon events. Academically, he has published in many of the world's leading scientific journals and is on the Editorial Boards of 7 international scientific publications. He is a Fellow of the American College of Sports Medicine. In 1972 he was elected a Fellow of the University of Cape Town for sustained excellence in original scientific work. He received the Medical Research Council Publications Award for the best publication record in the previous 3 years by a Medical scientist in 1993. He was also a finalist for the Burroughs Wellcome Gold Medal award for Medical Research on two occasions. His book 'Lore of Running' is in its third edition in South Africa and the United States and is widely praised as the most complete book of its kind yet written. Noakes is also co-author of 'Running Injuries', 'Lore of Cycling, Running your best' and 'Rugby without Risk'.

Estelle Lambert is a Senior Lecturer in the MRC/UCT Bioenergetics of Exercise Research Unit at the University of Cape Town Medical School. She is also Director of Lifestyle Wellness Programmes at the Sports Science Institute of South Africa. Her M.Sc. she completed at the University of South Carolina and her Ph.D. degree in Physiology at the University of Cape Town. Her areas of research include: factors associated with energy balance and obesity, fat metabolism during exercise, obesity in children, regional fat distribution, weight cycling, relapse in weight control, the role of exercise in weight control, assessment of physical activity in south Africa, associations with physical activity and chronic diseases of lifestyle and associations between low birth weight and CDL. She is keen protagonist for the role of physical activity and health promotion in South Africa's health and epidemiological transition.

In essence, these studies showed that there are important physical and psychological factors that determine what occupations people will choose, and the extent to which they will be physically active either at work or in their leisure time. Some of these physical and psychological variables then influence the risk that those persons will suffer heart attacks, independent of whether or not they exercise.

In an attempt to exclude the possibility that persons likely to be at increased risk of heart attack might choose sedentary occupations, Morris's group next studied 16 882 British civil servants, all of whom were involved in sedentary occupations and who were quite similar in respect of their coronary risk factors. This group was then subdivided on the basis of whether or not they performed vigorous exercise in their leisure time. Vigorous exercise was classified as swimming, tennis, hill-climbing, running or jogging, mountain walking or fast cycling, but these authors did not quantify how often or for how long it was necessary to be vigorously active.

In 1973, this group published their first findings: the heart attack rate in the vigorously active group was one-third of that in the less active group.⁴ A subsequent study⁵ showed that vigorous exercise in leisure time even offered a measure of protection for smokers and those with high blood pressure but, for obvious reasons, those sub-groups had a higher heart attack rate than did non-smoking, vigorously active civil servants whose blood pressures were normal.

More recently, Morris's group⁶ reported that after 13 years of study, the heart attack rate in the vigorously active civil servants was less than one-half that of their inactive colleagues. Furthermore, a degree of protection was even present for fat civil servants of small stature who smoked, or who had high blood pressure, diabetes or even chest pain. Whereas the heart attack rate in the active groups stayed the same between the ages of 40 to 60 years, the rate in the inactive group more than doubled during those years.

Morris and colleagues⁶ have concluded that "vigorous exercise is a natural defence of the body with a protective effect on the ageing heart against ischaemia and its consequences".

In their most recent publication,⁷ Morris and his colleagues have addressed the question of how much exercise one should undertake, and of what type, to gain protection from heart disease. They found that the risk of both fatal and non-fatal heart attacks was least in civil servants who exercise vigorously at least twice a week. Non-vigorous activities, including walking, provided no beneficial effect even in those who walked up to 7 hours a week. Vigorous activities included participation in sports and games like running and jogging, cycling, rugby, squash, badminton, tennis, football, boxing, swimming, hockey and rowing; and in recreational activities like aerobics, calisthenics, hill-climbing and gardening (digging, tree-felling). Non-vigorous activities included golf, dancing and table-tennis.

Paffenbarger's studies

The next outstanding studies in this field are those of Prof. Ralph Paffenbarger and his colleagues.⁸⁻¹⁴ A lay review of Prof. Paffenbarger's work can be found in James Fixx's second Book of Running.¹⁵

In the early 1950s, Paffenbarger chose to study two populations: people who were vigorously active in their occupations (the San Francisco Longshoremen Study)^{8,9,12} or in their leisure time (the Harvard Graduate Study).¹⁰⁻¹⁴

The reasons for studying these groups were the following. First, excellent medical data have been collected years earlier on both groups. It was possible for Paffenbarger to begin a study on subjects whose medical histories were known for up to 40 years previously. He was therefore able to start a project covering the life span of his experimental subjects, but which would be completed in his own lifetime. In the Harvard Graduate Study, for example, Paffenbarger was able to study subjects who had initially enrolled at Harvard as early as 1916.

Second, at least in the case of the San Francisco Longshoremen, there was no initial self-selection of the nature of work undertaken on the basis of whether they preferred manual or sedentary work, as all Longshoremen had to perform hard manual labour at work for a minimum initial 5-year period. In fact, most Longshoremen continued in heavy work for much longer - an average of 13 years.¹² It is fair to conclude that because they could not choose initially whether or not they were physically active at work, all must have had similar attitudes to exercise. Hence the reason why some subsequently changed to sedentary work was not because they were initially too weak or too ill, or unwilling to do manual labour.

In this study, Paffenbarger and his colleagues found that those Longshoremen who performed heavy manual labour had a far lower risk of fatal heart attack than did less active Longshoremen. As in the studies of Morris and his colleagues, the risk was reduced even in Longshoremen who had other coronary risk factors. Protection increased with increasing level of workday energy expenditure (Fig. 1), so that the risk of fatal heart attack was reduced by 50% for a weekly energy expenditure of 39 900 kJ (9500 kcal).

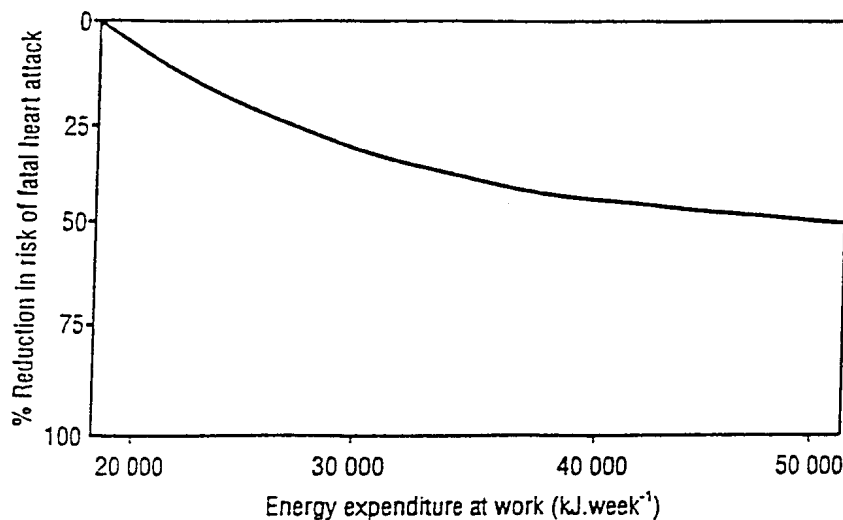


Figure 1. The risk of fatal heart attack falls with increasing energy expenditure at work.

In the Harvard Graduate Study, Paffenbarger, *et al.*¹⁰ graded leisure-time activity according to the following classification: ten stairs climbed every working day each week = 118 kJ.week⁻¹; one city block walked every working day each week = 235 kJ.week⁻¹; participation in light sports = 21 kJ.min⁻¹, and participation in vigorous exercise = 42 kJ.min⁻¹.

Using this classification, they found that men who reported climbing 50 or more steps each working day had a 20% lower risk of first heart attack than men who climbed less; those who walked five or more blocks daily were at 21% lower risk than those who walked less; and those who reported vigorous sporting activity in leisure time had a 27% lower risk than those who did not exercise vigorously.¹² Interestingly, participation in light sporting activity did not influence cardiac risk.

When total leisure-time physical activity was calculated, it was found that risk of first heart attack fell with increasing leisure-time physical activity and was 39% lower in those expending more than 8400 kJ of energy in leisure-time exercise each week (Fig. 2).

There were 7 other important findings in this study. First, a leisure-time energy expenditure of less

than 8400 kJ per week was as strong a risk factor for first heart attack as were the three established coronary risk factors - smoking, hypertension and hypercholesterolaemia. Thus, these data found that physical inactivity was as important a risk factor for coronary heart disease as the three established major risk factors. This view is now widely accepted.^{16,17}

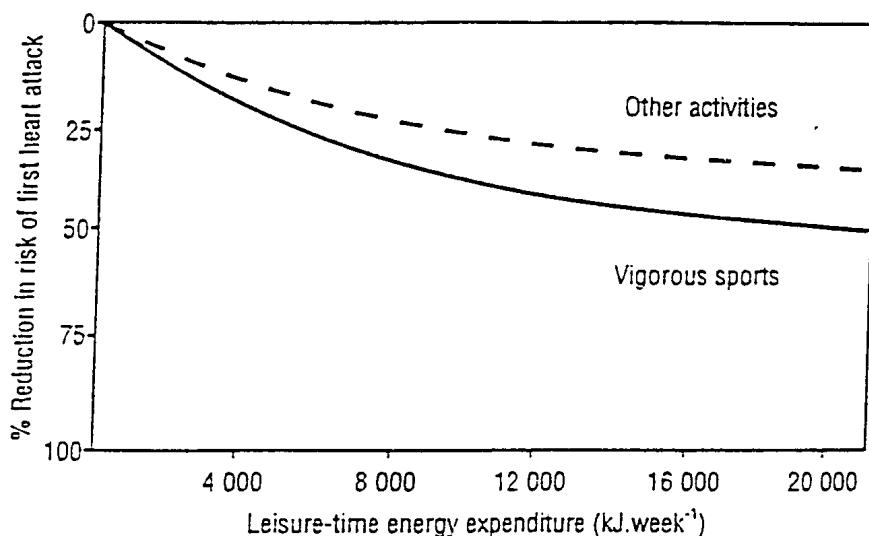


Figure 2. The risk of first heart attack falls with increasing levels of leisure-time physical activity.

Second, only Harvard graduates who remained active after graduation were protected from heart attack. The genetic athletes who won fame and glory on the Harvard sports fields in their college days had a reduced heart attack rate only if they continued to exercise vigorously in the years following their graduation. This suggests strongly that it is continued exercise for life, not genetic ability, that is associated with a subsequent reduction in heart attack risk. In the words of Paffenbarger and his colleagues, "... if it is postulated that Varsity sports participation reflects at least in part, a selective attribute of personal health (cardiovascular fitness), the present findings show that such a selection alone is insufficient to explain lower heart attack risk in later adult life."¹⁰ More recent findings suggest that, if anything, the health of the former university athletes tend to deteriorate rather more rapidly with age than does that of those who were not athletic at university. This is possibly because the body type of the university athlete proficient in sports like football and baseball is more likely to be mesomorphic (muscular). Possibly mesomorphy is not associated with longevity or good health in later life.¹⁸

Third, as other studies show, exercise offered protection even in the face of other coronary risk factors. Thus, Harvard graduates who were short in stature, had a parental history of heart attack or hypertension, who smoked, were overweight, had high blood pressure and a history of diabetes or stroke, were still at a 50% lower risk of heart attack if they expended more than 8400 kJ energy week⁻¹ in leisure-time activities, than were alumni with the same risk factors who did not exercise.

Fourth, alumni who reported vigorous leisure-time exercise had a lower risk of fatal heart attack at all levels of total weekly energy expenditure (Fig. 2). Thus, additional benefit seemed to be gained by including vigorous exercise in the exercise sessions.

Fifth, those graduates who had suffered a heart attack but who reported 8400 or more kJ.week⁻¹ of leisure-time energy expenditure had a 29% lower heart attack fatality rate than did those graduates who had also suffered heart attacks but who did not exercise as vigorously.

Sixth, vigorously active graduates had a 27% lower risk of high blood pressure than did less active alumni.¹¹ The heavier the graduate, the greater was the degree to which exercise reduced the risk of developing hypertension.

Seventh, Paffenbarger, *et al.*¹² calculated that if five risk factors for heart attack (physical inactivity, cigarette smoking, obesity, high blood pressure and a family history of heart attack) were removed from all Longshoremens and Harvard alumni, the risk of heart attack would be reduced by 88% and 67% in each group respectively.

More recently, Paffenbarger and his colleagues¹³ have shown that the longevity of alumni who exercised vigorously for life is increased. Thus, graduates who continue to expend more than 84 000 kJ per week in leisure-time physical activity from the age of 35 years onwards, enjoyed a 2½-year gain in life expectancy. Those who began vigorous exercise only after 50 years had a 1-2-year extension in longevity.

A number of other studies support this conclusion that physical activity probably increases longevity by 1-2 years.^{19,20}

Paffenbarger's study group has now lived sufficiently long for the effect of recent changes in physical activity patterns to be evaluated. Indeed, this information provides one of the strongest tests of the general hypothesis that physical activity reduces the risk of heart disease. For if recent changes in physical activity do not produce changes in line with the findings described above, then there might be a serious flaw in these findings.

Fortunately, Paffenbarger's most recent study¹⁴ has shown that Harvard alumni who had increased their levels of habitual physical exercise to more than 8400 kJ (2000 kcal) per week some time between 1977 and 1985, reduced their heart attack risk by 26%, identical to the reduction enjoyed by those who had always exercised at that level and increased their longevity by up to 1 year. These effects were equivalent to those achieved by stopping smoking. In contrast, the heart attack risk of alumni who stopped regular vigorous exercise increased by 20%. This detrimental effect was *greater* than the effect of taking up smoking!

An important conclusion from this most recent study is that it is never too late to start exercising and never a good time to stop.

Siscovick's studies

Siscovick and his colleagues²¹⁻²³ have collected detailed information on all persons dying suddenly during a 1-year period in Seattle, Washington. They then excluded from their analysis all those persons who were ill, who had been off work or who had experienced any symptoms before their sudden deaths. They were left with a total of 145 sudden deaths in a group of persons who were, to all intents and purposes, absolutely healthy right up to the moment that they suddenly died.

Analysis of these data showed that those persons who exercised vigorously on a regular basis had an overall risk of sudden death approximately two-thirds lower than that of the non-exercisers (Fig. 3). Interestingly, the risk that the smaller number of sudden deaths in the exercising group would occur while these persons were exercising was increased acutely (vertical line in Fig. 3), for the duration of the exercise bout, above the overall risk of the non-exercisers. Thus, although the total group of exercisers had a reduced risk of sudden death, that subset of exercisers with advanced heart disease who would ultimately die suddenly, were more likely to die while they were exercising than when they were at rest.

This finding explains why the sudden death of athletes usually occurs during exercise and why such events must not be construed to indicate that exercise is dangerous and should therefore be avoided. In fact, if the exercisers were to stop exercising, their risk of sudden death would increase

threefold as shown in Fig. 3.

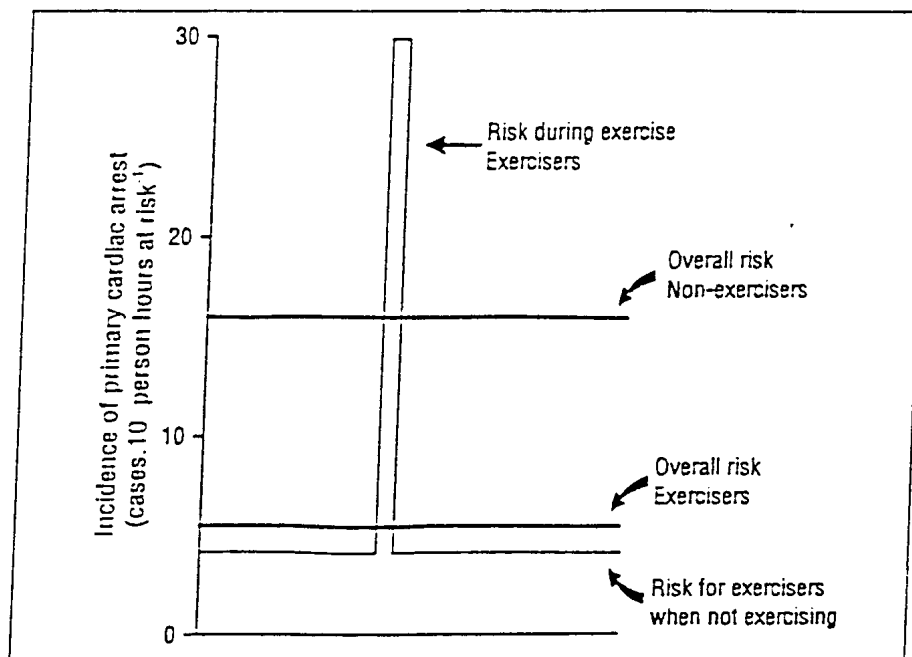


Figure 3. Habitual exercise reduces the overall risk of primary cardiac arrest. Note that the risk of cardiac arrest is steeply elevated during exercise in those regular exercisers who are at risk of sudden death.

The studies of Siscovick and his colleagues therefore confirm the finding that the risk of sudden death is reduced in persons who exercise regularly and suggest that this is almost certainly not due to the presence of confounding variables. However, they also show that there is an increased likelihood that those persons who have heart diseases despite their regular exercise, will die during their short period of exercise. Were such persons to avoid all exercise, however, their overall risk of sudden death would be increased, not decreased. Interestingly, the degree of benefit is actually greater, the higher the level of coronary risk; persons who are at low risk of dying suddenly from coronary heart disease benefit less from vigorous physical exercise than do those who are at high risk either because of a family history of heart disease, or because they are smokers or have other risk factors already described.

As Siscovick, *et al.*²³ have stated: "Efforts to discourage clinically healthy persons at risk of primary cardiac arrest from continuing to engage in vigorous exercise may be inappropriate."

Blair and Cooper's studies

Many consider that one of the greatest influences on the physical fitness boom that began in the 1970s was the publication in 1968 of Dr Ken Cooper's classic book, *Aerobics*.²⁴

Cooper's next significant contribution was to establish the Cooper Clinic in Dallas, Texas. Initially the principal function of the clinic was to perform screening medical evaluations of those wishing to improve their health, and to prescribe exercise training programmes and provide a facility, with expert supervision, for those who wished to increase their physical activity.

Realising that the information gleaned through these screenings would be of great value if the health

of the participants were to be followed into later life, Cooper initiated the Institute for Aerobics Research, housed on the grounds of the Cooper Clinic. He hired epidemiologist Dr Steven Blair to begin the mammoth project of following up the future health of the Cooper Clinic patients, in much the same way that Morris and Paffenbarger had followed up their respective study populations.

In 1989 Blair and his team²⁵ reported their first important findings. Participants who were judged to be physically fit on the basis of their treadmill running performance at the initial screening test had lower mortality from all causes of death, from heart disease and from cancer at combined sites, than did those who were judged unfit on their initial assessment. As in the studies of Morris and Paffenbarger, risk reduction occurred even in the presence of risk factors, so that those at high risk benefitted the most from increased levels of physical fitness. Furthermore, sporting activity at high school or college was not associated with any alteration in risk.²⁶

In summary there is now convincing evidence that those who exercise sufficiently vigorously probably do have a reduced heart attack risk. The evidence is sufficiently strong that "the relative risk of inactivity appears to be similar in magnitude to that of hypertension, hypercholesterolaemia, and smoking."¹⁷ Furthermore, lack of physical activity may, with smoking, be the most important contributor to heart disease in our populations.²⁸ Hence the medical profession should expend the same effort promoting physical activity as it currently does to ensure the removal of the three other major coronary risk factors.

Exercise and the prevention of other chronic diseases

Besides coronary heart disease, there are a number of chronic diseases, the prevalence of which are decreased in persons who are physically active. Included among these diseases are hypertension,^{11,27} non-insulin dependent diabetes mellitus (NIDDM)²⁹⁻³¹ so that exercise may play a greater role in the prevention than the treatment of NIDDM,⁽³²⁾ cerebrovascular stroke,^{33,34} obesity,³⁵ cancer especially of the colon³⁶ and perhaps of the breast in women.³⁶

Additional benefits of exercise include the ability to improve psycho-social health by reducing state and trait anxiety³⁷ and depression³⁸ and by improving mood, self esteem and other indices of psychological well-being.³⁹ In addition the reduction in muscle power and strength that occur with age are due more to reduced levels of physical activity than to the ageing process per se⁴⁰ and, even in the elderly, can be reversed by a vigorous strength training programme⁴¹ as occurs also in the young.

South African studies of exercise and the prevention of chronic diseases

There are no systematic South African studies of the role of physical activity in the prevention of the chronic diseases listed above. But limited data are available on physical activity patterns and risk factors and disease prevalence in defined South African populations.

One of the more novel studies of the link between physical activity and risk for chronic diseases of lifestyle was that of Walker, *et al.*⁴² In that study, the blood lipid profiles of black African schoolchildren who lived "far" from school (walking on average, 10 km/day) were compared to those living near to the school (<22.4 km). Serum HDL cholesterol concentrations were significantly higher in school boys who lived far from school compared to those who lived near (1.71 ± 0.25 mmol/l vs. 1.83 ± 0.26 mmol/l, respectively). This despite the finding that the mean serum HDL cholesterol concentrations were higher in black schoolchildren than in white schoolchildren.

In a more recent study of the urban black African population in the greater Cape Town area, Levitt, *et al.*⁴³ related various lifestyle and demographic factors to diabetes prevalence. In this study, occupational and leisure-time physical activity were quantified using an ordinal scale of 3 levels (none, minimal-to-moderate, and vigorous). In a sample of 1 000 black African men and women,

the prevalence of non-insulin-dependent diabetes mellitus (NIDDM) was 8.0%. Age, obesity, upper-segment fat distribution and the number of years spent in an urban area were significant and independent risk factors for NIDDM. Conversely, gender, family history, alcohol intake and reported physical activity were not associated with diabetes prevalence. In this population, 21% of the men (n = 214) and only 1% (n = 503) of the women sampled (total n = 717) reported vigorous levels of occupational and leisure-time activity. However, 54% of the women and 40% of the men sampled reported minimal-to-moderate levels of physical activity.

In 1994, Sparling, *et al.*⁴⁴ published the results of reported occupational and leisure-time activity in a sub-sample of 200 black African men living in the Cape Town area who formed part of the BRISK study.⁴⁵ In this cross-sectional analysis, occupational physical activity was classified using an ordinal scale of 3 categories comprised 'primarily sitting, standing', 'a lot of walking', or 'hard physical work'. Respondents were also asked to categorize non-work, or leisure-time activity as 'no exercise', 'light activity', or 'strenuous activity more than twice per week'.

Approximately 25% of the subjects reported that their jobs involved 'a lot of walking', while 18% reported that their jobs involved hard physical work, and 57% reported that they had mainly sedentary occupations. Furthermore, 71% of the sample grew up in a rural environment, and only 17% had access to their own automobile or had an automobile within the family.

In the CORIS survey of risk factors and lifestyle in a rural, white, Afrikaner community of South Africa, only 1% of men reported vigorous or hard physical activity for their occupations, and 54% indicated that their jobs involved 'a lot of walking'.⁴⁶

In that study, there was a decrease in vigorous occupational activity in older age groups. However, there was no apparent dose-response relationship between levels of physical activity and health benefits (blood pressure, blood lipid profiles or body mass index). Those men reporting jobs which involved a 'lot of walking' had the most favourable coronary risk profile, in a sub-sample of men with a low overall risk for coronary heart disease.

These data suggest that the tools for assessing physical activity in black South African men and women are not culturally-specific, and also lack sensitivity to detect a dose-response relationship between the morbidity of chronic diseases of lifestyle and physical activity. Alternatively, these data may suggest that conventional associations between physical activity and risk factors for chronic disease may not be as straightforward in populations who have only been exposed to an urban environment later in adult life, who may have had an irregular or limited food supply during some phase of development, or whose overall risk profile is regarded as 'cardio-protective', or low-risk.

Future directions and research priorities in studies of exercise and health in South Africa

1. Identify the habitual physical activity patterns in the different South African communities.

One of the great paradoxes in modern South Africa is that although the nation is considered to be 'sports mad', levels of habitual physical activity certainly in urbanised South Africans are no better than in similarly urbanised populations in other countries.

In truth, we are a nation of spectators. Furthermore formal sports participation in the previously disadvantaged communities is hampered by a lack of facilities and of a culture of physical education in schools.

Thus a first priority would be to establish the habitual physical activity patterns of the different South African communities. The complexity of this research has already been identified in previous South African research in this area.^{44,46}

2. Determine the factors that influence physical activity patterns in different communities.

It is certain that the first section of this research programme will confirm that levels of physical activity are generally low, certainly in most urbanised South African populations. This will invite the more important research question, which is to establish why levels of physical activity are low in this nation as they are in most Western nations. The impact of urbanisation on physical activity patterns in those communities undergoing rapid urbanisation, needs also to be addressed.

An obvious difference between the different South African communities is the extent to which physical education is taught in the schools and the opportunity that the youth in those communities have to participate in organised and recreational physical activity.

3. Determine the beneficial effects of exercise in populations other than middle-aged, urbanised upwardly mobile, affluent, white males.

Although there would seem to be little relevance in studying the value of exercise in the prevention or treatment of those conditions for which the scientific studies completed in Europe and North America already shows clear benefit, South African researchers could make a unique contribution by studying these effects in groups other than middle-aged, predominantly affluent upwardly-mobile, white males, the population studied in the majority of the reported studies in this field. South Africa does offer the unique opportunity to study the benefits of exercise in a wide range of different communities of different ethnic origin, of different levels of affluence and with different degrees of urbanisation. Collaboration with researchers in the Northern Hemisphere who do not enjoy access to such populations, should be actively nurtured as a matter of priority by the bodies that administer South African research.

4. Co-ordination of efforts to promote physical activity in the different communities.

The return of South Africa to international sport has inspired efforts to promote sport and to identify and develop the talent of athletes in the formerly disadvantaged communities. This effort has come largely from those sports with the necessary financial backing.

There is a need for these efforts to be co-ordinated more effectively and the health-promoting function of sport, as opposed to its capacity to inspire national unity through the development of national sporting heroes. There is an opportunity to co-ordinate the development of these two crucial national effects of exercise.

5. Cost-effectiveness of physical activity.

Increasing concern about the rising costs of medicine has focused attention on the cost benefits of different management options for specific diseases. Indeed a South African article in the late '70s suggested that physical training after heart attack might be more cost-effective than coronary artery bypass surgery,⁴⁷ a view which is slowly gathering credence.

With the growing evidence that exercise acts against a wide range of different conditions, there is an urgent need to quantify the cost savings that could be achieved by increasing habitual levels of physical activity, (i) in the entire population and (ii) in populations with different specific diseases.

As the costs of different interventions currently used in the management of, among others, coronary heart disease and hypertension are now known, and the degree of benefit that physical activity can offer in these conditions, it should be possible to calculate the cost-effectiveness of physical activity in these conditions with a high degree of accuracy.

Such calculations would add credence to the author's belief that the promotion of physical activity is the single most cost-effective intervention that any nation can undertake to promote the nation's

health and to reduce the medical costs associated with the management of certain specific chronic diseases.

REFERENCES

1. Morris JN, Heady JA, Raffle PAB, Roberts CG, Parks JW. Coronary heart disease and physical activity of work. *Lancet* 1953;II:1053-1057.
2. Morris JN, Heady JA, Raffle PAB. Physique of London busmen: Epidemiology of uniforms. *Lancet* 1956;II:569-570.
3. Oliver RM. Physique and serum lipids of young London busmen in relation to ischaemic heart disease. *Br J Indust Med* 1967;24:181-186.
4. Morris JN, Chave SPW, Adam C, Sirey C, Epstein L, Sheehan DJ. Vigorous exercise in leisure-time and the incidence of coronary heart disease. *Lancet* 1973;I:333-339.
5. Chave SPW, Morris JN, Moss S, Semmence AM. Vigorous exercise in leisure time and the death rate: a study of male civil servants. *J Epidemiol Commun Health* 1978;32:239-243.
6. Morris JN, Everitt MG, Pollard R, Chave SPW, Semmence AM. Vigorous exercise in leisure-time: Protection against coronary heart disease. *Lancet* 1980;II:1207-1210.
7. Morris JN, Clayton DG, Everitt MG, Semmence AM, Burgess EH. Exercise in leisure time: coronary attack and death rates. *Br Heart J* 1990;63:325-334.
8. Paffenbarger RS, Hale WE. Work activity and coronary heart mortality. *New Engl J Med* 1975;292:545-550.
9. Paffenbarger RS, Hale WE, Brand RJ, Hyde RT. Work-energy level, personal characteristics, and fatal heart attacks: A birth-cohort effect. *Am J Epidemiol* 1977;105:200-213.
10. Paffenbarger RS, Wing AL, Hyde RT. Physical activity as an index of heart attack risk in college alumni. *Am J Epidemiol* 1978;108:161-175.
11. Paffenbarger RS, Wing AL, Hyde RT, Jung DL. Physical activity and incidence of hypertension in college alumni. *Am J Epidemiol* 1983;117:245-257.
12. Paffenbarger RS, Hyde RT, Jung DL, Wing AL. Epidemiology of exercise and coronary heart disease. *Clinics in Sports Medicine* 1984;3:297-318.
13. Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. *New Engl J Med* 1986;314:605-613.
14. Paffenbarger RS, Hyde RT, Wing AL, Lee I-M, Jung DL, Kampert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *New Engl J Med* 1993;328:538-545.
15. Fixx JF. *James Fixx's Second Book of Running*. New York: Random House, 1980.
16. Fletcher GF, Blair SN, Blumenthal J, Caspersen C, Chaitman B, Epstein S, Falls H, Froelicher ESS, Froelicher VF, Pina IL. Statement on exercise. Benefits and recommendations for physical activity programs for all Americans. *Circulation* 1992;86:340-344.
17. Powell KE, Thompson PD, Caspersen CJ, Kendrick JS. Physical activity and the incidence of coronary heart disease. *Ann Rev Publ Health* 1987;8:253-287.
18. Sheehan GA. Longevity of athletes. *Am Heart J* 1973;86:425-426.
19. Pekkanen J, Marti B, Nissinen A, Tuomilehto J, Punsar S, Karvonen MJ. Reduction of premature mortality by high physical activity: a 20-year follow-up of middle-aged Finnish men. *Lancet* 1987;I:1473-1477.
20. Sarna S, Sahi T, Koskenvuo M, Kaprio J. Increased life expectancy of world class male athletes. *Med Sci Sports Exercise* 1993;25(2):237-244.
21. Siscovick DS, Weiss NS, Hallstrom AP, Inui TS, Peterson DR. Physical activity and primary cardiac arrest. *JAMA* 1982;248:3113-3117.
22. Siscovick DS, Weiss NS, Fletcher RH, Latsky T. The incidence of primary cardiac arrest during vigorous exercise. *New Engl J Med* 1984;311:874-877.
23. Siscovick DS, Weiss NS, Fletcher RH, Schoenbach VJ, Wagner EH. Habitual vigorous exercise and primary cardiac arrest: Effect of other risk factors on the relationship. *J Chron Dis* 1984;37:625-631.
24. Cooper KH. *Aerobics*. New York: M Evans and Co., 1968.
25. Blair SN, Kohl HW, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality. *JAMA* 1989;262:2395-2401.
26. Brill PA, Burkhalter HE, Kohl HW, Blair SN, Goodyear NN. The impact of previous athleticism on exercise habits, physical fitness, and coronary heart disease risk factors in middle-aged men. *Res Exerc Sport* 1989;60:209-215.
27. Paffenbarger RS, Jung DL, Leung RW, Hyde RT. Physical activity and hypertension: an epidemiological view. *Ann Med* 1991;23:319-327.
28. Paffenbarger RS, Hyde RT, Wing AL, Steinmetz CH. A natural history of athleticism and cardiovascular health. *JAMA* 1984;252:491-495.
29. Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS. Physical activity and reduced occurrence on non-insulin-dependent diabetes mellitus. *New Engl J Med* 1991;335:147-152.
30. Manson JE, Rimm EB, Stampfer MJ, Rosner B, Hennekens CH, Speizer FE, Colditz GA, Willett WC, Krolewski AS. Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *Lancet* 1991;338,774-778.
31. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes among US male physicians. *JAMA* 1992;268:63-67.
32. Gudat U, Berger M, Lefebvre PJ. *Physical activity, fitness and non-insulin-dependent (Type II) diabetes mellitus*. In: C Bouchard, Shephard RJ, Stephens T, eds. *Physical Activity, Fitness, and Health. International Proceedings and Consensus Statement*. Champaign, IL: Human Kinetics, 1994:669-683.
33. Kohl HW, McKenzie JD. *Physical activity, fitness, and stroke*. In: Bouchard C, Shephard RJ, Stephens T, eds. *Physical Activity, Fitness, and Health. International Proceedings and Consensus Statement*. Champaign, IL: Human Kinetics, 1994:609-621.

34. Shinnton R, Sagar G. Lifelong exercise and stroke. *BMJ* 1993;307:231-234.
35. Bouchard C, Despres JP, Tremblay A. Exercise and obesity. *Obesity Research* 1993;1:40-54.
36. Lee IM. Physical activity, fitness and cancer. In: Bouchard C, Shephard RJ, Stephens T (eds). Physical activity, fitness, and health. International proceedings and consensus statement. Champaign, IL: Human Kinetics, 1994:814-831.
37. Petruzello S, Landers D, Hatfield B, Kubitz K, Salazar W. A meta-analysis of the anxiety-reducing effects of acute and chronic exercise: Outcomes and mechanisms. *Sports Med* 1991;11:143-182.
38. Morgan WP. Physical activity, fitness, and depression. In: Bouchard C, Shephard RJ, Stephens T, eds. Physical activity, fitness, and health. Champaign, IL, Human Kinetics, 1994:851-867.
39. McAuley E. Physical activity and psychosocial outcomes. In: Bouchard C, Shephard RJ, Stephens T, eds. Physical activity, fitness, and health. Champaign, IL: Human Kinetics, 1994:551-568).
40. Bassey EJ, Harries UJ. Normal values for handgrip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clinical Science* 1993;84:331-337.
41. Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, Roberts SB, Kehayias JJ, Lipsitz LA, Evans WJ. Exercise training and nutritional supplementation for physical frailty in very elderly people. *New Engl J Med* 1994;330:1769-1775.
42. Walker ARP, Walker BF, Mngomezulu QN. Serum high density lipoprotein cholesterol levels in African schoolchildren living near or very far from school. *Atherosclerosis* 1982;41:35-40.
43. Levitt NS, Katzenellenbogen JM, Bradshaw D, Hoffman MN, Bonnici F. The prevalence and identification of risk factors for NIDDM in urban Africans in Cape Town, South Africa. *Diabetes Care* 1993;16(4):601-607.
44. Sparling PB, Noakes TD, Steyn K, Jooste PL, Bourne LT, Badenhorst C. Level of physical activity and CHD risk factors in black South African men. *Med Sci Sports Exer* 1994;26:896-902.
45. Steyn K, Fourie J, Bradshaw D. The impact of chronic diseases of lifestyle and their major risk factors on mortality in South Africa. *SAMJ* 1992;82:227-231.
46. Noakes TD, Benadé AJS, Jooste PL, van Zyl F. Analysis of the physical activity patterns of a rural Afrikaner population in the south-western Cape. *SAMJ* 1986;69(13):803-806.
47. Noakes TD. Criticisms of exercise after heart attack - variations on an old theme? *SAMJ* 1982;62:238-240.