Physical activity in leisure time: impact on mortality

Risks and benefits

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PERSONAL BACKGROUND

Since I was 14 years of age I competed in track and field, sprint, with a best result in 100 meter of 11,0 seconds, leading to a position as one of the ten fastest in Denmark. To reach this level, I trained 3-4 days a week, 1-2 hours during each session. The training was strenuous, and often consisting of interval-running with many repetitions, which often made me dizzy, and making the whole stadium "swinging". Because of these unpleasant symptoms I asked myself: Could this kind of training be unhealthy". Then I asked my father, who was a surgeon, he was not able to answer the question, but suggested to me, that I asked Professor, Poul Brandt Rehberg, a famous zoophysiologist. Rehberg told me, that my training was not unhealthy, the brain would not get short of oxygen. Rehbergs words relieved me somewhat, but I was not convinced. So, having passed the first part of my medical studies in 1963, I introduced myself to Professor Erling Asmussen, Head of The Laboratory for the Theory of Gymnastics, and asked him:" Do top athletes have more or less ill-health than non-athletes"? Asmussen was not sure, but allowed me to study this question in his laboratory: Thus I worked two evenings a week for two years at The Polioinstitute: My results were somewhat in favor of former top-athletes, but it was not possible to draw firm conclusions (Schnohr 1968), (Publication 1).

After my graduation in 1968 I participated in an Epidemiology field research training programme lasting nine weeks at California State Department of Public Health in Berkeley. Here Dr. Robert Dyar, Dr J. E. Dunn and, Professor Roy Acheson (Yale, New Haven) introduced me to epidemiology. The stay resulted in a publication about survival rates of nasopharyngeal cancer (Schnohr 1970).

On my return from Berkeley I initiated Eremitageløbet, the first jogging-race in Europe (maybe also outside Europe). The main purpose of this activity was to motivate the sedentary Danes to be more physically active during leisure time (Schnohr 1969). To support this jogging-campaign I asked Professor Tybjærg Hansen, Head of Medical Department B at Rigshospitalet and Chairman of The Danish Heart Foundation, to be the starter of Eremitageløbet. Tybjærg accepted the invitation.The first race was arranged on 28. September 1969, where 2344 participants finished the 12,1 kilometer distance. Unfortunately a 46 year old naval officer died of myocardial infarction a few hours after the race. As the initiator I felt responsible for his death and asked Professor Tybjærg Hansen if this kind of competition maybe was too strenuous and thus dangerous to the general population, and if so, should we stop Eremitageløbet? Tybjærg's advice was to continue. So we did, and after the 39th race in 2007, 508,994 men and women from 4 to 96 years of age have finished the race, approximately 50 have accomplished all 39 races. During the years there have been 6 deaths of which at least four could have been prevented if these persons had been medically examined. In the year 2000 we were able to publish data from The Copenhagen City Heart Study about mortality in joggers (Schnohr et al. 2000 – publication 3).

In 1970 I moved to St. Elisabeth Hospital and supported by Chief physician Johannes Mosbech, head of the medical department, I started "The Amager women study", based on the hypothesis that younger persons getting myocardial infarction were more biologically aged than age-matched controls. This was Tibblins hypothesis, he would conduct the study in men in Göteborg and suggested that I did the same in women in Copenhagen (Schnohr 1976). When I and a laboratory technician performed the examinations in 1973, Professor Tybjærg Hansen visited me to see how the study proceeded. When analysing the data it became clear to me that the number of participants were too small to give a definite answer (Schnohr 1976, 1976 and 1980), so Professor Tybjærg Hansen invited me to enlarge this study in his department at Rigshospitalet

During the same year, 1973, I participated in the, "Ten-day International Teaching Seminar on Cardiovascular Epidemiology and Prevention", Section on Epidemiology and Prevention of the International Society and Federation of Cardiology (now: World Heart Federation). The teachers were: Professor Geoffrey Rose and Professor J.N. Morris (London), Professor Ancel Keys and Professor Henry Blackburn (Minneapolis), Professor Rose Stamler and Professor Jeremiah Stamler (Chicago), and Statistician Richard Remington (Houston). The seminar was most inspiring, and changed my course from surgery to preventive and clinical cardiology (Schnohr 1973). In 1978 I became a member of the Executive Committee of the Scientific Council on Epidemiology and Prevention of The International Society and Federation of Cardiology, and in 1982 Geoffrey Rose invited me to be the secretary (1982-1986).

In 1973 I moved to Professor Tybærg Hansen's department to set up a larger study, "The Copenhagen Health and Ageing Study" with the same hypothesis as of "The Amager women study". I got the funding, engaged a secretary, and was ready to begin, but then Dr. Gorm Jensen returned to the department after half a year at The London School of Hygiene and Tropical Medicine. Tybjærg Hansen introduced us and suggested that we began to work together in the field of cardio-vascular epidemiology and prevention. I cancelled my "ageing-study", and Gorm Jensen and I began to organize The Copenhagen City Heart Study. This was the beginning of a fruitful collaboration, which have lasted ever since.

AIMS OF THE STUDY

The main purposes of the present thesis was:

1. To evaluate if top athletes and joggers have increased risk of death
2. To describe the relation between physical activity in leisure time and mortality in the general population
3. To evaluate if the level of physical activity in leisure is related to the level of well-being, with emphasize on joggers

RISKS AND BENEFITS OF EXERCISE IN ATHLETES – A HISTORIC GLIMPSE

Athletes in ancient time

The Greek physician Hippokrates (460 B.C.–377 B.C.), wrote about athletes that: "... the truth is however, that no one is in a more risky state of health than they" (Medicorum Graecorum 1821).

Six centuries later Galen (129 AC–199 AC) wrote that: "While athletes pursue their profession their body remains in a dangerous state. When they give up their professions, they fall into a state even more dangerous. Some die shortly after, others live a little longer, but never reach old age, or if they do they resemble exactly the priests of Homer: "Limping, deformed, and squint-eyed" (Walsh 1930, Bøje 1942).

The most famous case of sudden death in connection with running was Pheidippides, a soldier who in 490 B.C. was believed to have run from Marathon to Athens, a distance of about 40 km, to bring news of the Athenian victory over the Persians; then he expired. Some experts believe this is a myth and favours another version: that after his run from Marathon to Athens Pheidippides continued to Sparta for help. He ran the distance from Athens to Sparta, 220 km, in 48 hours (Nilsson 1943).

These statements from ancient time offered no stimulation to my running career.

Athletes in modern time

Sudden death and longevity in athletes

Sports activity in adolescents and young adults is associated with an increased risk of sudden death, with a striking male predominance, male/female ratio of 10:1. The incidence rate of sudden death during competitive sports activity has been reported to be 2.3 in 100,000 athletes per year and significantly lower 0.9 in 100,000 per year among non-athletes, with an estimated relative risk of 2.5 (95% CI 1.8-3.4); $P<0.0001$) (Corrado et al. 2003). The authors concluded, that sports was not in itself the cause of enhanced mortality, but it triggered cardiac arrest in those athletes who were affected by cardiovascular conditions predisposing to life-threatening ventricular arrhythmias during physical exercise. Doping could also be a possible cause. An increase in sudden deaths among Swedish orienteers due to myocarditis has been reported. One of the cases was studied before the sudden death occurred; the victim had a Chlamydia pneumoniae infection (Wesslén et al 1996).

Finnish male world class athletes competing during 1920-1965 in track and field athletics, cross-country skiing, soccer, ice hockey, basketball, boxing, wrestling, weight lifting, and shooting, in all 2613 individuals, were matched with 1712 men, selected from the Finnish Defence Forces. The author found that life expectancy was highest for endurance athletes and second highest for team athletes, both groups had significantly longer life expectancy than the reference population (Sarna et al. 1993).

Author's publications in athletes

(1) "An investigation of previous athletes"

When the study was started in 1963 little information was at hand in the literature about the fate of previous top-athletes later in life. I examined 45 previous top-athletes all had been Danish champions, many of them Scandinavian, Olympic or World champions. They represented sports either within greatest demands on "muscular speed", "muscular power" or "the condition" (endurance). They had practised sports for 10-15 years training 3-6 times weekly, some of them for as long as six hours in one session. The top-athletes were selected by journalist Evald Andersen, who was the editor of "Idrætsliv", Dansk Idræts-Forbunds official magazine. Unfortunately I am not able to describe the response rate (in 1964 this was of minor importance). The top-athletes helped me to select a person at the same age, who also in his youth was active within the same discipline, but only on the average level, and further to select a non-athlete, so I also investigated 53 average athletes and 46 non-athletes (control group). All participants were men.

I invited the men at random to the examination, but I knew who were the top-athletes. The examination included: height, weight, pulse rate, blood pressure and electrocardiogram at rest and immediately after bicycle-work, estimated maximal oxygen uptake, vital capacity and muscular strength in the majority of the larger muscle groups. After each examination lasting two hours I offered the participant a good cigar.

The results showed that the previous top athletes in general had better physical values than the previous average athletes and their values were better than the non-athletes, but the differences found were not significant. My conclusion was: An individual who practises sport when young, either as a top athlete or an average athlete, will not be in poorer physical state later in life than an individual who never practised sports (Schnohr 1968 – publication 1).

As these athletes might be a selection of "the last survivors" and thus not representative of all athletes I had to continue my studies.

(2) "Longevity and causes of death in male athletic champions"

The former athletic champions consisted of 307 men born between 1880 and 1910 with biographies in the Danish Sportslexicon (Lundqvist Andersen et al., 1944). Information about 297 (response rate 96.7%) was obtained from the population register of the Copenhagen Community, the Department of medical statistics of the Danish National Board of Health, and the Danish National Archives. All athletes had been Danish champions, recordholders or members of national teams. Some had obtained World records; several had Olympic medals and World championships. The number of deaths at 25-49 years, 50-64 years, and 65-80 years was compared with the expected number of deaths in the general population being 25 years of age or older. The ratio of observed to expected deaths was 0.61 in the life period from 25 to 49 years, 1.08 from 50 to 64 years and 1.02 from 65 to 80 years, thus the athletic champions had a significantly lower mortality than the general population under the age of 50 years ($P<0.05$); after 50 years the mortality was the same (Schnohr 1971 – publication 2).

This study convinced me, that athletics even at a high level were not harmful to health.

Next step was to explore the relation between ill-health and different levels of physical activity in leisure-time in the general population. These questions were my main reason to engage in the design and conductance of The Copenhagen City Heart Study.

RISKS AND BENEFITS OF EXERCISE IN THE GENERAL POPULATION

The pioneering studies

Physical activity and coronary heart disease

Shifts from hunting and gathering to agriculture, and then to industry have changed physical activity patterns markedly since stone age. At that time a good physical condition was necessary for most people to meet the demands for survival. This is not the case in modern times, as we are surrounded by mechanical devices which eliminate the need for expending physical effort in most of the daily tasks. This might appear to be a good thing, but in fact there may be an ill-health danger due to lack of exercise. In 1910 some 15 per cent of all deaths in Denmark were due to cardiovascular diseases. In 1970 these disorders accounted for more than 50 per cent of the deaths. The explanation of this rise is multifactorial, but lack of physical exercise is one of the reasons.

In a study based on 31,000 London Transport men Morris and his group published in 1953 the first major report showing, that coronary mortality in men performing physically heavy work was less than half of those doing light work, i.e., the mortality was more than twice as high in the London's busdrivers compared to the conductors (Morris et al, 1953). This original finding, that conductors were relatively protected against coronary heart disease led to the hypothesis, that men in physically active jobs suffer less coronary heart disease than comparable men in sedentary jobs. This hypothesis was met with considerable scepticism by medical scientists – the conventional thinking at that time, in 1950's, held that coronary heart disease resulted from hypertension, hypercholesterolaemia, and obesity, and that lack of physical activity had nothing to do with the incidence of heart disease (Paffenbarger et al. 2001). In 1973 Morris et al. stated, that vigorous exercise, but not moderate exercise, in leisure-time apparently protected against coronary heart disease. These results were based on 16,882 male executive grade civil servants in Great Britain. Vigorous exercise was defined as peaks of an energy output of 7.5 kcal. or more per minute (Morris et al 1973). In 1978 the same group again found a clear association between vigorous exercise and incidence of coronary heart disease, but only a weak relation between total physical activity scores and coronary mortality. The physical activity score was based on a seven-page handwritten account of two days physical activity provided by each participant (Chave et al. 1978).

The above cited papers by Morris and coworkers were the pioneering work of physical activity and coronary heart disease.

Death during jogging and other vigorous exercise in population studies

Jogging became popular in the United States and other countries in the 1970's. After a couple of years reports of death during running were published (Opie 1975, Noakes et al 1979, Thompson et al. 1979, Waller et al. 1980, Thompson 1982, Sisovick et al. 1984). One author stated that athletes capable of covering the marathon distance are immune to coronary atherosclerosis (Bassler 1976), but others described atherosclerosis in marathon runners (Opie 1975). It was recommended, that physicians and exercising adults should be aware of this fact and give appropriate attention to possible prodromal symptoms. In Rhode Island twelve men died while jogging, eleven from heart attacks. Five of these men were known to have heart disease. The incidence of death during jogging was estimated to be one per 396,000 man hours of jogging, which is seven times the estimated heart attack rate during sedentary activities. Thus jogging increased the risk of dying for the heart patient (Thompson et al.1982). It is known that exercise can provoke malignant ventricular arrythmias and sudden cardiac death (Siscovick et al.1984). Coronary heart disease appeared to be the major killer of conditioned runners aged 40 years and over who died while running (Waller et al 1980).

Some were convinced of health benefits of regular moderate physical exercise, but were concerned about extravagant claims made by exercise enthusiasts. With the explosive growth of jogging as a sport, there was an urgent need for definitive data on the risk-versus-benefit ratio of endurance exercise.

During the years 1989-1998, 49,219 men and 24,403 women participated in Vasaloppet, a long-distance ski race of 90 kilometers. All subjects were followed until 31 December 1999. Overall 410 deaths occurred compared with 851 expected, yielding an standardized mortality ratio of 0.48 (95% CI: 0.44-0.53). The authors concluded that participants in long-distance skiing races have lower mortality. The extent to which this is due to physical activity, related lifestyle factors, genetics or selection bias has to be assessed (Farahmand et al. 2003). The same group have later studied mortality during Vasaloppet, and found the total number of deaths (all men) was 13. The mortality rate during skiing was 2.6 deaths per million person-hours, i.e. one death per 53,700 starters in the races. The expected number of deaths was 1.68, yielding an standardized mortality ratio of 7.7 (95% CI: 4.1-13-2). Thus there was a marked increase in acute mortality during the race, but this short-term excess mortality is by far out-weighed by long-term protective effects of exercise on mortality (Farahmand et al. 2007).

A prospective, nested case-crossover study of 288 cases of sudden death within the Nurses' Health Study including 69,693 women without prior cardiovascular disease and followed-up from 1986 to 2004, found that the absolute risk of sudden death associated with moderate to vigorous exertion was exceedingly low: 1 per 36.5 million hours of exertion. The reduction in risk remained significant only among women who exercised 4 or more hours per week, adjusted relative risk was 0.41 (95% CI: 0.20-0.83), whereas no reduction was seen in the groups >0-1.9 or 2-3.9 hours per week. In all, it was concluded that sudden death during exertion is an extremely rare event in women (Whang et. al. 2006).

Physical activity in leisure time and all-cause mortality in population studies

Observational studies based on one examination

Table 1 presents an overview of 15 major population studies concerning physical activity and mortality, nine of men only (Paffenbarger et al. 1986, Leon et al. 1987, Lee et al.1995, Haapanen et al. 1996, Rosengren et al. 1997, Hakim et al. 1998, Bijnen et al. 1998, Smith et al. 2000,Yu et al. 2003), one of women only (Sherman et al. 1994) and five of men and women (Kujala et al. 1998, Andersen et al. 2000, Barengo et al. 2004, Buksch et al. 2005, Schnohr et al. 2007). All with only one assessment of physical activity in leisure time at baseline.

When assessing physical activity in leisure-time all studies used their own questionnaires, as there was no standard-questionnaire upon which all would agree. Participants were ranked according to their levels of physical activity its duration and intensity.

The overall finding was that sedentary men and women had the highest all-cause mortality during follow-up varying from 7 to 26 years in the different studies.

The studies demonstrated in general a graded, inverse relationship between physical activity in leisure-time and mortality, however U-shaped relations have been reported (Paffenbarger et al. 1986, Leon et al. 1987). In all studies the largest difference in mortality was seen between the sedentary, and the moderately active group. Although in some of the studies only vigorous activity was associated with lower mortality (Lee et al. 1995, Bijnen et al. 1998, Yu et al. 2003). In Lee's study of Harvard alumni (mean age: 46 years; vigorous activity was defined as ≥6 METs), and examples of vigorous activities included brisk walking, jogging or running, swimming laps, playing tennis and shovelling snow. In a study of elderly men aged 64-84 years vigorous activity was defined as ≥4 kcal/kg per hour (4 METs), examples of vigorous activity included brisk walking, cycling at normal or high speed and gardening (Bijnen et al. 1998)). In this study it was estimated that 12% of deaths among the elderly men during 10 years follow-up could have been avoided by a physically active lifestyle during leisure time. In Yu's study from Belfast including 1975 men aged 49-64 years it was found that only habitual leisure exercise of vigorous intensity is associated with a significantly reduced risk of all cause and cardiovascular death.

Among Finnish twin pairs the odds ratio of death was 0.66 (95% CI: 0.46-0.94) in occasional exercisers and 0.44 (95% CI: 0.23-0.83) in conditioning exercisers compared with those who were sedentary. Conditioning exercisers reported exercising ≥6 times per months, for a mean duration of at least 30 minutes and with a mean intensity corresponding to at least vigorous walking increasing to jogging. It was concluded, that leisure time physical activity is associated with reduced mortality, even after genetic and other familial factors were taken into account (Kujala et al. 1998).

An analysis from the Whitehall study concerning physical activity and mortality assessed the level of activity on the basis of two simple questions: (1) "Compared with other men of your age do you tend to walk slower, faster or about the same pace?" (2) "Do you have any hobbies or sports?" According to the answers participants were classified into: inactive, moderately active and active during leisure. Walking pace demonstrated a significant inverse relation with all-cause mortality (Smith et al. 2000).

From a Copenhagen study it should be mentioned, that 783 women and 6,171 men, who were bicycling to work (average 3 hours per week), had a 40% lower mortality after multivariate adjustment, including leisure-time physical activity. The study also underlined that physical activity is as important in old age as it is in the younger age and in both sexes and may be even more important in elderly women (Andersen et al. 2000).

In a large representative study (3,742 men and 3,445 women) in Germany moderate physical activity in leisure time was inversely associated with all cause mortality among women, but not among men (Bucksch et al. 2005).

Observational studies based on two or several examinations

Table 2 gives an overview from ten large population studies, four of men only (Paffenbarger et al. 1993, Wannamethee et al 1998, Bijnen

Table 1. Physical activity in leisure time and mortality in population studies. Based on one examination.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Paffenbarger 1986, USA	Harvard alumni 16,936 men 35-74 years	12-16 years 1413 deaths	Questionnaire Postal 1962 or 1966 kcal/week	 <500 kcal/week 500-999 1000-1499 1500-1999 2000-2499 2500-2999 3000-3499 ≥3500	RR 1 0.78 0.73 0.63 0.62 0.52 0.46 0.62	 P for trend <0.0001	Age
Leon 1987, USA	MRFIT 12,138 men 35-74 years Initially 361,662 men were screened in 1973-1976, 35-57 years	7 years 488 deaths out of 12,138	Minnesota questionnaire 62 questions 1973-76 Tertiles mean, min/day	1: 16 min/day 2: 48 min/day 3: 134 min/day	1 0.73 (0.59-0.91) 0.87 (0.70-1.07)		Age, diastolic blood pressure, cholesterol, cigarettes, special intervention or usual care
Scherman 1994, USA	Framingham Heart Study Began 1948, general population 5209 men and women 30-62 years	16 years 319 deaths out of 1404 women	Questions about activity; Interview Quartiles	Least active 2nd 3rd Most active	1 0.93 (0.70-1.23) 0.65 (0.47-0.90) 0.68 (0.49-0.94)		Age, systolic blood pressure, cholesterol, cigarettes, pulmonary disease, Metropolitan life insurance chart weight, glucose intolerance, left ventricular hypertrophy, obstructive pulmonary disease cancer.
Lee 1995, USA	Harvard alumni 17,321 men mean age 46 years	22-26 years 3728 deaths	Questionnaire Postal 1962-1966 kcal/week	 <150 kcal/week) 150-399 400-749 750-1499 ≥1500	Vigorous activity (activity (≥6 METs) 1 0.88 (0.82-0.96) 0.92 (0.82-1.02) 0.87 (0.77-0.99) 0.87 (0.78-0.97)	Non-vigorous activity (activity (<6 METs) 1 0.89 (0.79-1.01) 1.00 (0.89-1.12) 0.98 (0.88-1.12) 0.92 (0.82-1.02)	Age, Quetelet's index, cigarettes, hypertension, diabetes, early parental deaths (<65 years)
Haapanen 1996, Finland	Finnish cohort random sample 1072 men	11 years 168 deaths	Questionnaire self-administered 23 questions, 1980 kcal/ week	>2100 1500-2100 800-1500 ≤800	1 1.74 (0.87-3.50) 1.10 (0.55-2.21) 2.74 (1.46-5.14)	P 0.117 0.784 0.002	Age, disease or symptoms that prevented participation in physical activity, marital and employment stauts, smoking
Rosengren 1997, Sweden	Primary Prevention Study in Göteborg Random sample of all men in Göteborg born in 1915-1925 except 1923 This analysis: 7142 men 47-55 years	20 years 2140 deaths	Questionnaire Postal Graded 1-4	Sedentary (1) Moderately active (2) Regular exercise (3+4)	1 0.84 (0.77-0.93) 0.83 (0.77-0.90)		Age, diastolic blood pressure, cholesterol, smoking, alcohol abuse, BMI, diabetes, manual versus non manual occupational class
Hakim 1998, USA	Honolulu Heart Program Since 1965 followed 8006 Japanese men, island Oahu This analysis : 707 non-smoking retired men, 61-81 years	12 years 208 deaths	Daily distance walked at exam. 1980-82	Less than 1.6 km/day More than 3.2 km/day	40.5 % died 23.8 % (P<0.001)		Age
Bijnen 1998 Netherlands	The Zutpen Elderly Study, random sample 802 men 64-84 years	10 years 373 deaths	Questionnaire Tertiles, physical activity 1985	Lowest Middle Highest Lowest Middle Highest	1 0.80 (0.63-1.02) 0.77 (0.59-1.00) Heavy-intensity (≥4 kcal/kg/ hour) 1 0.82 (0.64-1.04) 0.65 (0.50-0.86)	P for trend 0.04 Non-heavy-intensity (<4 kcal/kg/ hour) 1 0.86 (0.67-1.10) 0.93 (0.72-1.20)	Age, CVD, cancer, diabetes mellitus, lung disease, cigarettes, alcohol

Table 1 to be continued next page

Table 1. Continued.

Author year, country	Study- Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Kujala 1998 Finland	Finnish Twin Cohort All same-sex twin pairs born in Finland before 1968 This analysis includes 7925 men and 7977 women 25-64 years	18 years 1253 deaths	Questionnaire mailed 1975 conditioning Exercisers ≥6 times/months and occasional Exercisers <6 times/months	Sedentary Occasional exercisers Conditioning exercisers	1 0.73 (0.50-1.07) 0.56 (0.29-1.11)	P for trend 0.06	BMI, hypertension, smoking, alcohol
Smith 2000 UK civil servants	Whitehall study Executive-grade Office workers 6702 men 40-64 years	25 years 2867 deaths	Questionnaire 1969-1970	Walking pace: Slower Same Faster	RR 1.87 (1..6-2.1) 1.21 (1.1-1.3) 1	 P<0.001	Age, work grade, systolic blood pressure, smoking, BMI, FEV1 glucose intolerance, diabetes, forced expiratory volume in one second, ischaemia
Two questions	1: Do you walk slower, faster or at same pace as men of your age? 2: Hobbies or sports?			Leisure activities Inactive moderately active Active	RR 1.20 (1.1-1.3) 1.07 (1.0-1.2) 1	 P<0.001	
Andersen 2000, Denmark	HCPB Copenhagen City Heart Study, Glostrup Population Study, random samples of the general. population and Copenhagen Male Study, male employees 17,265 men and 13,375 women 20-93 years	14.5 years 5668 men and 2881 women died	Questionnaire self-administered graded 1-4		Men Moderate vs. Low High vs. Low Women Moderate vs. Low High vs. Low	 0.72 (0.66-0.78) 0.71 (0.65-0.78) 0.65 (0.60-0.71) 0.59 (0.52-0.67)	Age, systolic blood pressure, cholesterol, triglycerides, smoking, BMI, education
Mortality rates were also calculated in the age groups: 20-44, 45-64 and 65 years and older. There was a trend towards increased benefit with increasing age.							
Yu 2003, Belfast	The Caerphilly study 1975 men 49-64 years	10 years 252 deaths	Questionnaire interviewer kcal/day Intensity Tertiles	Leisure-time physical activity and mortality			Age, combined light and moderate intensity activity, diastolic blood pressure, BMI, smoking, social class, parental deaths, diabetes mellitus, job physical activity class
		Kcal/day Light/moderate Heavy intensity	Lowest 1 1	Middle 0.95 (0.69-1.31) 0.87 (0.65-1.17)	Highest 1.04 (0.76-1.43) 0.61 (0.43-0.86)	P for trend 0.798 0.006	
		(Heavy intensity: jogging, climbing stairs, swimming)					
Barengo 2004, Finland	North Karelia Project FINNMONICA/ Finrisk studies random samples 15,853 men 16,824 women 30-59 years	20 years 3410 men and 1862 women died	Questionnaire self-administered	Leisure time physical activity and total mortality Low Moderate High	 Men HR 1 0.91 (0.84-0.98) 0.79 (0.70-0.90)	 Women HR 1 0.89 (0.81-0.98) 0.98 (0.83-1.16)	Age, study year, BMI, systolic blood pressure, cholesterol, education, smoking, other physical activity
Bucksch 2005, Germany	National Health Survey former West Germany 3742 men and 3445 women 30-69 years	12-14 years 643 men and 300 women died	Questionnaire Postal graded 1-4 kcal/week	 Lowest 2nd 3rd Highest	Men 1 0.98 (0.76-1-17) 0.80 (0.63-1.00) 0.91 (0.74-1.13) P=0.20	Women 1 0.79 (0.57-1.08) 0.68 (0.50-0.94) 0.57 (0.41-0.79) P<0.001	Age, sport index, social class, smoking, BMI, CVD- risk factor index, alcohol, chronic disease index, dietary factors

Table 1 to be continued next page

Table 1. Continued.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Schnohr (6) 2007	3204 men 4104 women 20-93 years	12 years 742 men and 649 women died	Questionnaire self-administered 1991-1994 Walking Duration and Intensity	Risk of deaths in relation to duration and intensity of walking			Age, number of sports activities, BMI, systolic blood pressure, antihyp. med., cholesterol, HDL-, smoking, education, income, alcohol, diabetes
					Men HR	Women HR	
				Duration			
				<0.5 h/day	1	1	
				0.5-1 h/day	0.87 (0.68-1.10)	1.00 (0.77-1.30)	
				1 – 2 h/day	0.95 (0.75-1.12)	1.04 (0.80-1.36)	
				>2 h/day	0.89 (0.69-1.14)	0.80 (0.59-1.10)	
				Intensity			
				Slow	1	1	
				Average	0.54 (0.45-0.67)	0.75 (0.61-0.92)	
				Fast	0.43 (0.32-0.59)	0.48 (0.35-0.66)	

et al. 1999, Schnohr et al. 2000), and four of women only (Lissner et al. 1996, Rockhill et al. 2001, Gregg et al. 2003, Trolle-Lagerros et al. 2005), and two of both men and women (Schnohr et al. 2003 and 2006). In these studies all participants had their physical activity in leisure time assessed at least twice.

In all studies the sedentary men and women had the highest, adjusted all-cause mortality.

In the Harvard alumni study those who at the first examination (1962 or 1966) as well as in the second in 1977 reported moderately vigorous sports activities (swimming, tennis, squash, handball, jogging), had a significantly lower mortality than persons displaying lower intensity physical activity. Men who had stopped a moderate vigorous physical activity had an increased total mortality, and men who had become physically active had decreased the relative risk of death significantly (Paffenbarger et al. 1993).

In Swedish women the mortality was significantly higher in subjects who decreased their leisure-time activity over 6 years, RR 2.07 (95% CI: 1.39-3.09), but there was no evidence of decreased mortality in association with increasing leisure time activity, compared with no changes, RR: 1.11 (95% CI: 0.67-1.86). Women with regular medium levels of physical activity had a significantly lower total mortality than the women with low levels, and a slight additional risk reduction was observed at higher activity levels (Lissner et al 1996).

Among 4,311 healthy British men examined in 1978-80, when they were 40-59 years of age, and re-examined in 1992 mortality decreased with increased physical activity in leisure time (Wannamethee et al. 1998).

The Zutpen Elderly Study investigated associations of physical activity in 1985 and 1990 with all-cause mortality in Dutch men (mean age 75.1 years). Compared with men who had a physically active lifestyle at both examinations, mortality increased for men who became sedentary, to a relative risk of 1.72 (95% CI: 1.04-2.85), and men who remained sedentary had the highest relative risk on 2.01 (95% CI: 1.19-3.39). 23% of all-cause mortality could be attributed to not maintaining a physically active lifestyle in both survey years. (Bijnen et al. 1999).

The Nurses' Health Study is a prospective cohort study established in 1976 when 121,701 female registered nurses aged 30-55 years answered a mailed questionnaire about their medical histories and lifestyles. Subsequent questionnaires requesting updated information on risk factors and medical events have been mailed every 2nd year. The follow-up rate between 1976 and 1996 was 98%. Levels of physical activity in leisure time was first assessed in 1980, and then updated every 2nd year until 1990. Deaths that occurred after the completion of the 1982 survey and before 1996 were included. The repeated information of physical activity provided a more accurate estimate of average activity level during the years, leaving an average physical activity level for each of the women, categorized as: Less than 1 hour and uptill 7 hours or more per week of physical activity strenuous enough to build up a sweat. There was an inverse relationship between total mortality and level of total physical activity. Adjusted relative risk of all-cause mortality for 7 hours or more of activity per week was 0.71 (95% CI: 0.61-0.82) compared to less than 1 hour. The greatest decrease in adjusted relative risk of death occurred between less than 1 hour and 1-1.9 hours of activity per week: 0.82 (95% CI: 0.76-0.89). When analysing relative risks of mortality from specific causes the following adjusted relative risks were found: 0.23 (95% CI: 0.11-0.50) for respiratory deaths, 0.46 (95% CI: 0.33-0.64), for non-cancer, non-cardiovascular disease and non-diabetes deaths taken as a whole, 0.69 (95% CI: 0.49-0.97) for cardiovascular deaths and 0.87 (95% CI: 0.72-1.04) for cancer deaths. Surprisingly, the strongest inverse relation was found between physical activity and respiratory death (Rockhill et al. 2001).

In another U.S.-study 7553 white women, 65 years or older at entry, were examined at baseline 1986-1988 and again in 1992-1994. It

Table 2. Physical activity in leisure time and mortality in population studies. Based on two or several examinations.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Paffenbarger 1993, USA	Harvard alumni 10,269 men 45-84 years	9 years 476 deaths	Questionnaire Mailed 1962 or 1966 and 1977 kcal/week	Moderately vigorous sports activity (≥4,5 METs and >2000 Kcal/week)			Age, smoking, hypertension, BMI parental deaths <65 years
				1962 or 1966	1977	RR	P value
				No	No	1	
				Yes	No	1.15 (0.73-1.71)	0.608
				No	Yes	0.77 (0.58-0.96)	0.015
				Yes	Yes	0.71 (0.55-0.96)	0.011
				Physical activity index ≥2000 kcal/week			
				No	No	1	
				Yes	No	1.10 (0.78-1.50)	0.543
				No	Yes	0.85 (0.65-1.13)	0.256
				Yes	Yes	0.82 (0.63-1.08)	0.124
Lissner 1996, Sweden	Gothenborg Prospective study of women, random sample of 1405 women 38-60 years	20 years 424 deaths	Questionnaire Oral/physician Graded 1-4 Work and Leisure time 1968-1969 and 1974-1975	Leisure-time 1968-1969	RR		Age
				Medium (2) vs. Low (1)	0.56 (0.39-0.82)		Findings largely unaffected by inclusion of smoking, alcohol consumption, educational level, BMI, waist, hip ratio, dietary fat intake, systolic and diastolic blood pressure, cholesterol, triglycerides, peak expiratory flow
				High (3+4) vs. Low (1)	0.45 (0.24-0.86)		
	Compared with no change in physical activity in leisure-time from 1968-1969 and 1974-1975:				Increased activity	1.11 (0.67-1.86)	
					Decreased activity	2.07 (1.39-3.09)	
Wannamethee 1998, UK	British Regional Heart Study Men selected from general practices in 24 British Towns This analysis: 4311 healthy men 52-72 years	4 years 219 deaths	Questionnaire Oral/nurse 1978-1980 and 1992	Inactive/occasionally active at both exam		1	Age, smoking, social class, BMI, self-perception of health
				At least light activity in 1978-80, but inactive in 1992		0.75 (0.50-1.14)	
				Inactive in 1978-80 but at least light activity in 1992		0.55 (0.36-0.84)	
				At least light activity at both exam		0.58 (0.41-0.82)	
Bijnen 1999 Netherlands	The Zupten Elderly Study 472 men, random sample of all men 65-85 years (mean: 75.1) living in Zutpen	5 years 118 deaths	Questionnaire designed for retired men	Physically active, walking or bicycling for 20 minutes ≥3 times per week. All-cause mortality			Age, CVD, cancer, lung diseases, diabetes functional status, smoking. alcohol
				1985	1990	RR	
				Yes	Yes	1	
				No	Yes	1.36 (0.78-2.36)	
				Yes	No	1.72 (1.04-2.85)	
				No	No	2.01 (1.19-3.39)	
				P trend for change from yes-yes to no-no: 0.004			
23% of all-cause mortality could be attributed to not maintaining a physically active lifestyle in both surveys.							
Schnohr (3) 2000	4658 men 20-79 years	20-22 years 1302 deaths	Are You a jogger? yes/no: in 1976-78 and in 1981-83	Jogging at none or only at one examination:		1	Diabetes, smoking, household income, education, alcohol systolic blood pressure, cholesterol, HDL, BMI
				Jogging at both examinations 5 years apart:		0.39 (0.19-0.73)	
Rockhill 2001, USA	Nurses'Health Study 121,701 women 30-55 years	12 years 4746 deaths	Questionnaire mailed, since 1980 and every 2-4 years including one question about physical activity, hours per week of physical activity that build up a sweat	Physical activity (updated every 2 years, 1980-1992) and all-cause mortality 1982-1996			Age, smoking, alcohol, height, BMI, hormone use
					Hours/week	RR	
					< 1	1	
					1-1.9	0.82 (0.76-0.89)	
					2-3.9	0.75 (0.69-0.81)	
					4-6.9	0.74 (0.68-0.81)	
					≥7	0.71 (0.61-0.82)	

Table 2 to be continued next page

Table 2. Continued.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Schnohr (4)	3220 men	17-19 years	Questionnaire	Men			Age, sex, smoking, cholesterol, HDL-,
2003	3803 women	1424 men and	Self-administered	1976-1978	1981-1983	RR of death	systolic blood pressure, diabetes, alcohol,
	20-79 years	1301 women	1976-1978 and	Low	Low	1	BMI, education, and income
		died	1981-1983	Moderate	Moderate	0.71 (0.57-0.88)	
				High	High	0.61 (0.48-0.76)	
			Low <2 h/week				
			Moderate 2-4	Women			
			High >4 h/week	Low	Low	1	
			Light physical	Moderate	Moderate	0.64 (0.52-0.79)	
			activity	High	High	0.66 (0.51-0.85)	
				Men			
				Low	High	0.64 (0.47-0.87)	
				High	Low	1.82 (1.27-2.61)	
				Women			
				Low	High	0.72 (0.50-1.05)	
				High	Low	no risk reductions	

Men with high physical activity survived 5.0 years and men with moderate activity 3.5 years longer than men with low activity at both examinations.
For women the figures was 4.5 and 4.3 years, respectively.
If men 65-79 years of age increased there physical activity from low to moderate/high, they survived 4.4 years longer than men with low activity at both examinations.
For women the fig. was 3.4 years.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Gregg	Study of osteoporotic	6.7 years	Questionnaire	Mortality risk by change in physical activity at follow-up			Age, smoking, BMI, stroke, diabetes,
2003, USA	fractures (SOF)	1029 deaths	Harvard alumni			HR	hypertension, self-rated health
	7553 women		Oral				
	≥65 years		1986-1988 and	Sedentary	Sedentary	1	
	recruited from population-		1992-1994	Sedentary	Active	0.52 (0.40-0.69)	
	based lists in 4 US		kcal/week	Active	Active	0.68 (0.56-0.82)	
	communities			Active	Sedentary	0.92 (0.77-1.09)	
Trolle-Lagerros	Norwegian-Swedish	11.4 years	Questionnaire by staff				Age, education, BMI, alcohol, smoking,
2005, Norway.	Women's Lifestyle	1313 deaths	Physical activity				country of origin
Sweden	and Health Cohort Study		at age 14, 30 and				
	51,217 Norwegian		at enrolment 1991-1992				
	women, 30-39 years		5-point scale				
	from entire Norway						
	and 47,882 Swedish		Physical activity	At age 14	At age 30	1991-1992	
	women, 30-49 years of						
	age from the Uppsala		None	1	1	1	
	Health Care Region		Low	0.95 (0.66-1.38)	0.79 (0.55-1.15)	0.78 (0.61-1.00)	
			Moderate	0.96 (0.69-1.34)	0.90 (0.64-1.28)	0.62 (0.49-0.78)	
			High	0.88 (0.62-1.25)	0.98 (0.68-1.42)	0.58 (0.44-0.75)	
			Vigorous	1.06 (0.75-1.51)	0.96 (0.65-1.44)	0.46 (0.33-0.65)	
			P for trend	0.62	0.22	<0.0001	
Schnohr (5)	2136 men	17-19 years	Both	1976-1978	1981-1983	RR	Age, sex, smoking, cholesterol, HDL-,
2006	2758 women	927 men and	Sexes				systolic blood pressure, anti-hyp.med
	20-79 years	860 women	Combined	Low	Low	1	diabetes, alcohol, BMI, education, income,
		died	Questionnaire	Moderate	Moderate	0.78 (0.68-0.89)	FEC_1
			Self-administered	High	High	0.75 (0.64-0.87)	
			1976-1978 and				
			1981-1983			Test for trend 0.001	

Men with unchanged high physical activity survived 6.8 years longer, and men with moderate activity 4.9 years longer than sedentary men.
For women the figures were 6.4 and 5,5 years, respectively.

Table 3. Physical fitness and mortality in population studies. Based on one examination.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results			Adjusted for
Blair 1989, USA	Cooper Clinic Dallas Aerobics Center Longitudinal Study 10,224 men and 3120 women	8 years 240 men and 43 women died	Physical fitness Maximal treadmill exercise test 1970-1985	Fitness group quintiles	Men RR	Women RR	Age
				1 (low)	3.44 (2.05-5.77)	4.65 (2.22-9.75)	Findings hold after adjustments for cholesterol, blood pressure, smoking, glucose, family history of CHD and length of follow-up
				2	1.37 (0.76-2.50)	2.42 (1.09-5.37)	
				3	1.46 (0.81-2.63)	1.43 (0.60-2.17)	
				4	1.17 (0.63-2.17)	0.76 (0.27-2.11)	
				5 (high)	1	1	
Group 1 (low) corresponds to a maximal oxygen uptake of ≤21 ml/kg(min, group 5 (high) to 42, From 28 ml/kg/min and above the relative risk of death is reduced. Decline in deaths rates with higher levels of fitness is more pronounced in older individuals							
Sandvik 1993, Norway	Employees from 5 companies in Oslo 2014 healthy men 40-59 years	16 years 271 deaths	Physical fitness Maximal exercise test on bicycle Ergometer Quartiles		RR		Age, smoking, systolic blood pressure, vital capacity, lipids, glucose, resting heart rate, BMI, physical activity level
				1 (low)	1		
				2	0.92 (0.66-1.28)		
				3	1.00 (0.71-1.41)		
				4	0.54 (0.32-0.89)		
Gulati 2003, USA	St James Women Take Heart Project 5721 women Mean age: 52 Responded to advertisements Chicago	8 years 180 deaths	Exercise capacity Treadmill test METs		HR		Framingham Risk Score
					<5 METs	3.1 (2.1-4.8)	
					5-8 METs	1.9 (1.3-2.9)	
					>8 METs	1	

The Framingham Risk Score-adjusted mortality risk decreased by 17% for every 1-MET increase.

was found that higher levels of total physical activity at baseline was associated with lower all-cause mortality (from Quintile 1 (<163 kcal/week) to quintile 5 (>1907 kcal/week); the hazard rates were 1 to 0.68 (95% CI: 0.59-0.78)). Compared with women who were sedentary at both visits, the sedentary women who became active had significantly reduced rates of mortality due to all causes 0.52 (95% CI: 0.40-0.69), cardiovascular disease 0.64 (95% CI: 0.42-0.97) and cancer 0.49 (95% CI: 0.29-0.84). This trend was weaker in women at least 75 years of age and those with a poor health status (Gregg et al. 2003).

During 1991-1992, 51,217 Norwegian women 34-49 years old from the entire country of Norway and 47,882 Swedish women 30-49 years old from Uppsala Region were enrolled in a prospective study with regard to mortality through year 2003. The women provided information on physical activity level at age 14, 30 years and at enrolment. During an average of 11.4 years of follow-up, 1,313 women died. Risk of death decreased with increasing physical activity at enrolment, and was reduced by half in the highest category (out of five) compared with the lowest, adjusted relative risk 0.46 (95% CI: 0.33-0.65). The data indicated that physical activity at enrolment into the study was the crucial determinant of subsequent mortality, whereas physical activity at the ages of 14 and 30 were less relevant except to the extent that it predicts physical activity later in life (Trolle-Lagerros et al. 2005).

Physical fitness and all-cause mortality in the general population
Observational studies based on one examination

In contrast to physical activity, published studies on physical fitness and all-cause mortality are few (Table 3).

Cooper Clinic has reported on physical fitness and all-cause and cause-specific mortality in 10,224 men and 3,120 women. Physical fitness was measured by means of maximal treadmill exercise test. Age-adjusted all-cause mortality rates declined across physical fitness quintiles for both sexes (Blair et al. 1989).

In a study including 1960 healthy men 40–59 years of age living in Oslo, physical fitness measured as the total workload performed on a bicycle ergometer, was measured at baseline, and conventional cardiovascular risk factors were assessed. The adjusted relative risk of death from all-causes was in the highest quartile compared to the lowest 0.54 (95% CI: 0.32-0.89) (Sandvik et al. 1993).

The St. James Women Take Heart Project in Chicago comprised 5,721 asymptomatic women 35 years and older (mean age: 52 years), who responded to advertisements on television news and printed media to participate in this study in 1992. Baseline examinations included a symptom-limited stress electrocardiogram, using the Bruce protocol. Exercise was measured in MET's. Framingham Risk Score-adjusted hazards ratios of deaths associated with MET levels of <5, 5-8 and >8 were 3.1 (95% CI: 2.0-4.7), 1.9 (95% CI: 1.3-2.9) and 1.0, respectively (1 MET equals 3.5 ml oxygen consumption per kilogram of body weight per minute). For every 1-MET increase the adjusted mortality risk decreased by 17%. (Gulati et al. 2003).

Observational studies based on two examinations

The following studies were based on two assessements (Table 4):

In a study of 9,777 men with two clinical examinations 4.9 years apart to assess change or lack of change in physical fitness and with a mean follow-up of 5.1 years, it was found, that men who maintained or improved adequate physical fitness were less likely to die from all causes and from cardiovascular disease than persistently unfit men, age-adjusted relative risk 0.33 (95% CI: 0.23-0.47) (Blair et al 1995).

A Norwegian study assessed physical fitness by a bicycle exercise test on 1428 healthy men aged 40-60 years at two surveys, in 1972-75 and 7 years later. There was an inverse relation between all-cause mortality and physical fitness, the adjusted relative risks were 0.45 (95% CI: 0.29-0.69) for the most fit (upper quartile) compared to

Table 4. Physical fitness and mortality in population studies. Based on two examinations.

Author year, country	Study-Population	Follow-up Deaths	Assessment of physical activity	Main results 1st Exam.	2nd Exam.	RR	Adjusted for
Blair 1995, USA	Cooper Clinic Dallas Institute for Aerobic Research 9777 men, 20-82 years, who completed two preventive examinations from 1970 through 1989	5.1 years 223 deaths	Physical fitness Maximal treadmill exercise test 1970-1989 Quintiles	Unfit	Unfit	1	Age
				Unfit	Fit	0.56 (0.41-0.75)	
				Fit	Unfit	0.52 (0.38-0.70)	
				Fit	Fit	0.33 (0.23-0.47)	
For each minute increase in maximal treadmill time between examinations, there was a corresponding 7.9% (P=0.001) decrease in risk of mortality.							
Erikssen 1998, Norway	Apparently healthy working men in Oslo. 1428 men 40-60 years	12-15 years 238 deaths	Physical fitness exercise test bicycleergometer Total work capacity divided by weight, 1972-1975 and 1980-1982 Quartiles			RR	Age, smoking, resting heart, systolic blood pressure, vital capacity
					Q1	1	
					Q2	0.72 (0.52-0.99)	
					Q3	0.48 (0.33-0.71)	
					Q4	0.45 (0.29-0.69)	
There was a graded inverse relation between changes in physical fitness and mortality irrespective of physical fitness at first examination, 1972-1975.							

the lowest fit (lowest quartile). Further there was a graded, inverse relation between changes in physical fitness and mortality irrespective of the level of physical fitness at the first survey (Erikssen et al. 1998).

THE COPENHAGEN CITY HEART STUDY – ØSTERBROUNDERSØGELSEN

History – main purposes

In 1975 Dr. Gorm Jensen and myself, together with Cand.act. Jørgen Nyboe and with Professor A. Tybjærg Hansen as our mentor, planned a large cardio-vascular population study, which we named "Østerbroundersøgelsen", in English "The Copenhagen City Heart Study" (Jensen 1984, Appleyard et al. 1989, Schnohr et al. 2001).

The original purpose of the study was to focuse on prevention of coronary heart disease. During the years many other aspects have been added to our study: Stroke, pulmonary diseases, heart failure, arrhythmia, alcohol, arthrosis, eye diseases, allergy, epilepsia, dementia, stress, vital exhaustion, social network, sleep-apnoe, ageing and genetics.

Methods

Study population

The primary population was a random sample of almost 20,000 men and women 20 – 93 years old, drawn from a population of approximately 90,000 inhabitants aged 20 years or older living within 10 wards (the entire of Østerbro and 1/3 of Nørrebro) surrounding Rigshospitalet, Copenhagen. The sample was age-stratified within 5-year age groups and drawn as of January 1st, 1976 from the Copenhagen Population Register, by using the unique personal identification number. 19,329 persons, 9,145 men and 10,184 women, were invited for examination (Appleyard et al. 1989).

Individuals selected for the study were invited according to their date of birth, converting the date to a six-digit number (day, month, year of birth). These numbers were used in ascending order, starting with individuals born on January 1st, February 1st etc. and ending with December 31th.

This order of invitation ensured that subsets of the sample examined during any period of time would constitute a random subsample.

Three weeks prior to the examination, the individuals selected were invited by letter (signed by Professor Tybjærg Hansen, Dr. Gorm Jensen and the author) to participate in a health examination, Østerbroundersøgelsen at Rigshospitalet. The letter described the main purpose of the study: prevention and treatment of cardio-vascular diseases. Attached to the invitation was a postage-paid postcard, by means of which the person could confirm the appointment, change the date or decline to participate. If the postcard had not been returned a week prior to the examination, a second invitation was posted. If the persons did not show up, a re-invitation was sent 6 months later. No further attempt to contact the non-responders was made.

The first survey lasted 25 months from February 27th, 1976, to March 31th, 1978. Of the 19,329 subjects invited, 14,223 men and women 20-93 years of age were examined (response rate: 73.6%).

The second survey was carried out 5 years later, and lasted 29 months from April 6th 1981 to September 7th 1983. All subjects who were originally invited in 1976 and still alive, and a new sample of 500 men and women 20-25 years of age, were invited, i.e. 18,089 men and women, and a total of 12,698 subjects were examined (response rate: 70.2%).

The third survey was carried out 10 years after the second, and lasted 36 months from October 1st 1991 to September 16th 1994. Again all subjects who were originally invited and a new sample of 3,000 men and women 20-49 years of age were invited, i.e. 16,563, and a total of 10,135 subjects were examined (response rate: 61.2%).

The fourth survey lasted 22 months from September 17th 2001 to 11th July 2003. All subjects previously invited as well as a new sam-

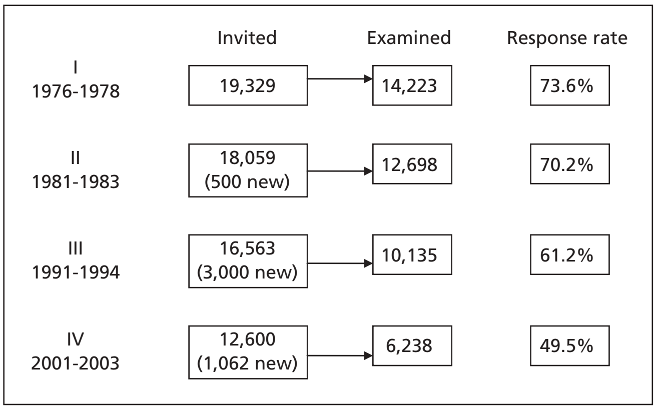


Figure 1. Persons invited and examined in the Copenhagen City Heart Study.

ple of 1062 men and women 20-29 years of age, were invited, i.e. 12,600, and a total of 6,238 subjects were examined (response rate: 49.5%) (Figure 1).

Thus the total number of participants invited to the first four examinations was: 19,329 + 500 + 3,000 + 1,062 = 23,891 men and women (Figure 1).

Of the original 14,223 examined at the first examination 3,092 (21.7%) have been examined in all four examinations, and of the 5,106 non-responders from the first survey in 1976-1978, 1,698 responded and were examined in one or more of the following surveys.

Examination procedures for the first examination 1976-1978

Established procedures for cardiovascular epidemiological surveys were employed (Rose & Blackburn 1968). A self-administered questionnaire, concerning symptoms and diseases, use of medicine, familial disposition, socioeconomic status, smoking and drinking habits, physical activity at work and during leisure time, and contact with the health care system was filled in when the participants arrived at the examination. During the examination, the questionnaire was checked by the staff. In case of "chest pain on effort" or "pain in the legs on walking uphill", Rose's questionnaires concerning angina pectoris and intermittent claudication, respectively, were filled in as interviews by the staff. A copy of these questionnaires have been published (Jensen 1984, Appleyard 1989).

Examinations were performed at three different workplaces, each lasting 6-8 minutes per station per person examined:

First station:

Blood sample, non-fasting plasma: cholesterol, HDL-cholesterol, triglycerides and glucose.

Pulmonary function test: forced expiratory volume in one second and forced expiratory volume.

Xantelasmata and ear-lobe crease was noted.

Second station:

Height, weight.

12-lead resting electrocardiogram.

Arcus senilis, other signs of ageing (degree of grey hair, baldness, and wrinkles at crows foot area).

Third station:

The questionnaire was checked.

Blood pressure (left arm, London School of Hygiene sphygmomanometer at all four examinations).

The results were explained to the participant, and later mailed to the general practitioner, whom the participant was asked to contact after two weeks, in order to get the results of the blood sample analyses, or earlier in case of any abnormal findings.

Procedures in the following examinations: 1981-1983, 1991-1994 and 2001-2003

The three subsequent examinations included the same investigations as the first, but we added several new investigations especially to the third examination: Laboratory investigations:

Microalbuminuria and renal creatinine clearance, lipoprotein (a), apolipoprotein A1, apolipoprotein B, fibrinogen, plasminogen activator, plasminogen activator inhibitor, factor VII and DNA-analyses (Schnohr et al. 2001). To the fourth examination the following were included: Echocardiography, including tissue Doppler, pulsewave-velocity, ankle-arm blood pressure and almost "total biochemical analyses", among them the following should be mentioned:

Brain natriuretic peptide (BNP), homocystein, high sensitive C-reactive proteine, glycosylated haemoglobin (HbA1c), lipase, uric acid, DNA, and messenger RNA. Additional plama was stored at –20 and –80 from each patient for future analyses.

As of December 1989 the Study changed venue to Clinic of Occupational Medicine (Arbejdsmedicinsk klinik), Rigshospitalet, Tagensvej, (chief: Professor, dr. med Finn Gyntelberg), where the third examination took place. In June 1997 however, the clinic moved to H:S Bispebjerg University Hospital, and consequently we followed Professor Gyntelberg to perform the fourth survey there in 2001-2003.

Follow-up of all-cause mortality

Information on death was obtained from the National Central Person Register, using the unique personal identification number. The completion rate of follow-up was almost 100 percent, as less than 0.1% were lost to follow-up.

Statistical methods – adjustments for potential confounders

To assess the independent contribution of physical activity to death, we used Cox's proportional hazards regression analysis with age as the underlying timescale and delayed entry accordingly, thereby adjusting for age. We tested for interaction between physical activity and sex. When we analysed men and women together we performed a sex-stratified Cox analysis, thus assuming the same effect of covariates in men and women but allowing for different baseline hazards. Relative risks were calculated as proportional hazards ratios (Clayton D, Hills M 1993).

The model included smoking, total cholesterol, HDL-cholesterol, systolic blood pressure, diabetes mellitus, alcohol consumption, body mass index, education, household income. In one study (5) we also adjusted for FEV_1 (5) and in another for number of different sports activities (6).

To estimate the difference in remaining lifetime between subjects in different physical activity groups Kaplan-Meier plots were constructed, with age as timescale and for which subjects were not included until they reached age 50. Tests for trend were done by linear, logistic or Cox regression.

The statistical analyses in authors publications were performed during the years by: Jørgen Nyboe, Jan Parner, Henrik Scharling and Jacob Marott. The analyses were performed by the statistical software packages SAS (SAS System for Windows, release 8.02; SAS Institute INC., Cary, North Carolina, USA) and Stata (Stata statistical Software: Release 6.0; Stata Corporation, College Station, Texas, USA).

Estimating physical activity in leisure time
Methods used in other surveys

More than 30 different methods have been used to assess physical activity. These methods can be grouped into seven major categories:

- Calorimetry
- Job classification
- Survey procedures (questionnaires)
- Physiological markers

– Behavioural observation
– Mechanical and electronic monitors
– Dietary measures

No single instrument fulfils the criteria of being valid, reliable, and practical while not affecting behaviour. Very precise instruments tend to be impractical on a population basis. Surveys are the most practical approach in large-scale studies, although little is known about their validity and reliability. Despite the difficulty of measurement, relatively strong associations have been found between physical activity and health, suggesting that, with improvements in assessment technique, even stronger associations should be seen (Laporte 1985).

Survey procedures or questionnaires have four components: The first is the time-frame, which the subjects are asked to remember, from 5 minutes to a year or more. The second is the detail and nature of the physical activities, including frequency, duration and intensity of specific activities. The third is the mode of data collection: Personal interview, telephone interview, self-administration, mail surveys, diary surveys or combinations of these. The fourth is a summary index based on a calculated estimate of kilocalories expended or a scale that rank-orders persons according to their level of physical activity in leisure time (Laporte 1985).

In 1967 Yasin et al. published their method of measuring habitual levels of leisure activity in British Civil Servants. The subjects were seen four times, once every 3 or 4 months, and were asked how they spent their leisure time for 2 consecutive days. An experienced interviewer obtained a complete record of 2 days' activity in about one hour that is 4 hours per person examined. The relation between calorie intake and skinfold thickness was estimated from a week's dietary survey in which food was weighed. Active men had thinner skinfolds and consumed more daily calories/kg body weight than inactive men. Stability of customary activity level was demonstrated by interviewing a group of 117 men four times within a year. In terms of three activity levels, active, middle and inactive, and comparing the first weekend day to all 8 survey days, gross misclassifications occurred in only three cases of the 117 (Yasin et al 1967).

Morris and colleagues modified Yasin's interview so that it could be self-administered. Their subjects were classified by a diary filled out on the day it arrived without warning by mail. Activities recorded were those carried out on a specified weekend day and a specific week day. Participants were asked to record activities in 5 minutes intervals for the 24 hours of each specified day (Morris et al. 1973).

In general the questionnaires regarding physical activities in leisure-time have been time-consuming, often more than 1-2 hours per participant: e.g., British Civil Servants (Yasin et al.1967), The Minnesota Leisure time physical activity questionnaire (Taylor HL et al. 1978), The Framingham Study (Kannel et al. 1979), Five-City Project, California (Blair et al. 1985), North Karelia and Kuopio (Salonen et al. 1982), Tecumseh, Michigan study (Montoye HJ et al. 1984), and the Stanford Heart Disease Prevention Program (Sallis et al. 1985).

Several of the studies validated their questionnaires against estimation of caloric expenditure, caloric intake, oxygen consumption, physical activity diary, work capacity, accelerometer, resting heart rate, plasma HDL-cholesterol, plasma triglycerides, blood pressure, body mass index, waist circumference or waist/hip-index (Montoye 1984, Aadahl et al. 2003, Barengo 2006, Aadahl et al. 2007).

Method used in this survey

We used a questionnaire prepared by Astrid Lindholm, Nils Lundgren and Bengt Saltin in collaboration with the National Institute of Public Health, Stockholm (Saltin et al. 1968).

The questionnaire had been designed to allow an estimate of *lifetime* physical activity, both occupational and recreational.

The recreational questions were as follows (Figure 2).

Physical activity in leisure time and all-cause mortality in The Copenhagen City Heart Study

Authors publications in brief:

(3) "Mortality in joggers: population based study of 4658 men"

The purpose of this paper was to analyse if jogging e.g. running in a slow or moderate speed is associated with an increased risk of death. The study was initiated because of the death of a 46 year old naval officer in the first Eremitageløb (Eremitagerace) in 1969.

The analysis was based on the first (1976-78) and second (1981-83) examinations, and included men only, as there were too few women-joggers in 1976-78. At the first examination 217 men reported active jogging (4.7%), and of these, 96 were still actively jogging in 1981-83. Overall, 4,335 men were non-joggers at both examinations. Only jogging discriminated the two groups within physical activity in leisure time.

Crude estimates of death rates showed a higher mortality among non-joggers (1297/4335 = 30%) than among joggers (5/96 = 5%). For those who were joggers at one, but not the other examination the mortality was 15% (Schnohr et al. 2001).

The influence of jogging on time to death was assessed by a Cox proportional hazards regression model, with age as the time axis. In addition to jogging the model included diabetes, smoking, household income, education, and alcohol as potential confounding variables, and systolic blood pressure, plasma total cholesterol, plasma HDL-cholesterol and body mass index as intermediate variables.

There were no adjustments for participation in other forms of physical activity, as the main purpose was to investigate specifically if jogging increased risk of deaths.

A significant effect of jogging was found only for the group that were joggers at both examinations. The relative risk of death in persistent joggers was significantly lower than in non-joggers or those who jogged at only one of the two examinations: RR 0.39 (95% CI: 0.19-0.73); P=0.005).

Thus: Regular jogging is not associated with increased mortality, but with increased longevity (Schnohr et al. 2000 – publication 3).

(4) "Changes in leisure-time physical activity and risk of death: An observational study of 7,000 men and women"

Publication (4) included 7,023 healthy persons, 3,220 men and 3,803 women aged 20-79 years at the start of follow-up in 1981-1983. The physical activity in leisure time was assessed in 1976-78 and 1981-83. "The Copenhagen City Heart Study Leisure time Physical Activity Questionnaire" allowed us to subdivide the population into four groups, in which Group I was defined as light physical activity in leisure time <2 hours, Group II as light physical activity 2-4 hours, Group III was defined as light physical activity >4 hours a week or vigorous physical activity 2-4 hours per week causing perspiration or exhaustion, and Group IV was defined as vigorous physical activity >4 hours per week or regular heavy exercise or competitive sports several times per week. In all analyses Group IV was due to small numbers combined with Group III to: High level; Group I was: Low level; and Group II: Moderate level.

Men consistently engaging in moderate or high physical activity in leisure-time had significantly lower risks of death than men reporting low physical activity at both examinations.

Using Kaplan-Meier plots we calculated gained years of expected lifetime from age 50. Men with high physical activity in leisure-time survived 5.0 years and men with moderate activity 3.5 years longer than men with a low activity level at both examinations. For women the figures were 4.4 and 4.3 years, respectively (figures not shown in the text).

Men who increased their leisure time physical activity from low to moderate/high had a significantly lower risk of death than men reporting low physical activity at both examinations.

If men 65-79 years of age increased their physical activity in leisure time from low to moderate/high from 1976-1978 to 1981-1983, they survived 4.4 years longer than men with low activity at both

Figure 2. The Swedish recreational questions and the changes to The Copenhagen City Heart Study LTPA-Questionnaire.

Spare-Time Physical Activity

Group I	Group II	Group III	Group IV
Almost completely inactive: reading TV watching movies, etc	*Some physical activity during at least 4 hours per week:* riding a bicycle or walking to work, walking or skiing with the family, gardening.	*Regular activity: such as heavy* gardening, running, calisthenics, tennis etc.	*Regular hard physical training for competition* in running events, soccer, racing, European handball, etc. Several times per week.

	Activity during at least 7 months per year corresponding to group:				Activity during 2 to 6 months corresponding to group:			
	I	II	III	IV	I	II	III	IV
Age								
20-30	------	------	------	------	------	------	------	------
30-40	------	------	------	------	------	------	------	------
40-50	------	------	------	------	------	------	------	------
50-60	------	------	------	------	------	------	------	------
Over 60	------	------	------	------	------	------	------	------

This Swedish questionnaire was validated in 20-42 years old men by assessing maximal oxygenuptake. Maximal oxygen uptake was positively correlated with increasing level of physical activity in leisure time (42 years old: I, II, III and IV: 36, 36, 38 and 44 max. O2 ml/kg/min). No correlation was found to different occupational groups (Saltin 1977).

In The Copenhagen City Heart Study this questionnaire was used as basis for our own questionnaire, but we changed it as follows:

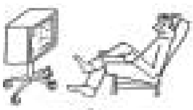
* We asked for physical activity in leisure time within the last year (not lifetime)
* In each of the four groups we introduced hours per week of physical activities:

	Group I	Group II	Group III	Group IV
Light physical activity	< 2 hours	2-4 hours	> 4 hours	
Vigorous physical activity:			2-4 hours	> 4 hours

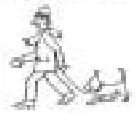
* In Group III we have introduced the terms: perspiration or exhaustion.
* We added drawings representing the different levels of physical activity in leisure time.

Thus our questionnaire ended up – after valuable discussions with Bengt Saltin - as the following:

Physical activity in leisure time within the last year:



Group I: Almost completely sedentary (e.g. reading, watching television or movies) or light physical activity < 2 hours per week



Group II: Light physical activity 2-4 hours per week

Group III: Light physical activity > 4 hours per week or more vigorous activity for 2-4 hours per week (e.g. brisk walking, fast biking, heavy gardening, sports that cause perspiration or exhaustion).

Group IV: Highly vigorous physical activity >4 hours per week or regular heavy exercise or competitive sports several times per week.

In 1976-78 the following question was included: Are you a jogger or competetion runner?
In 1981-1983 we also asked for hours per week of jogging and bicycling.
In 1991-94 and 2001-2003 we further added questions regarding physical activity in leisure time, including both duration and intensity of walking and bicycling.
In 2001-2003 frequency of jogging was introduced.

We have now renamed this questionnaire to:

"The Copenhagen City Heart Study Leisure Time Physical Activity Questionnaire" or
"The Copenhagen City Heart Study LTPA-Questionnaire"

examinations. For women the figure was 3.4 years (not shown in text).

If men decreased their physical activity from high to low, the risk of death was increased significantly. In contrast this was not the case among women.

We concluded that maintaining or adopting a moderate or higher degree of physical activity in leisure-time was associated with a lower risk of death across a wide range of ages in both sexes (Schnohr et al. 2003 – publication 4).

(5) "Long-term physical activity in leisure time and mortality from coronary heart disease, stroke, respiratory diseases, and cancer. The Copenhagen City Heart Study"

This analysis comprised 2,136 men and 2,758 healthy women aged 20-79 years with unchanged physical activity in leisure time from 1976-1978 to 1981-1983, and with all covariates included in the multivariate analyses: smoking, total cholesterol, HDL-cholesterol, systolic blood pressure, diabetes mellitus, alcohol consumption, body mass index, education, income and forced expiratory volume (% predicted).

Compared to low physical activity adjusted relative risks for all-cause mortality in both sexes combined were for moderate physical activity in leisure time 0.78 (0.95% CI: 0.68-0.89) and for high 0.75 (0.95% CI: 0.64-0.87). For cardiovascular disease the figures were for moderate activity 0.71 (95%CI: 0.51-0.99) and for high 0.56 (95% CI: 0.38-0.82), and for cancer the figures were for moderate activity 0.77 (0.95% CI: 0.61-0.97) and for high 0.73 (0.95% CI: 0.56-0.95) for both sexes combined.

Gained years of expected lifetime from age 50 were calculated. Men with high physical activity in leisure time survived 6.8 years longer, and men with moderate activity 4.9 years longer than sedentary men. For women the figures were 6.4 and 5.5 years respectively (Schnohr et al 2006 – publication 5).

In the third survey 1991-1994 the questionnaire also included questions about intensity when walking and bicycling (slow, average, fast), but unfortunately not so for jogging.

The 6th publication deals with walking:

(6) "Intensity versus duration of walking: Impact on mortality: the Copenhagen City Heart Study"

Relative intensity and duration of walking was recorded in 7,308 healthy women and men aged 20-93 at the third examination (1991-1994). Duration of walking was graded into four levels: <0.5 hour, 0.5-1 hours, 1-2 hours and >2 hours on average per day. Intensity of walking was graded in three levels: slow, average and fast, based on the individual's own perception of intensity. Besides walking habits we asked the participants about duration per week (minutes) of other types of exercise: cycling, jogging, gymnastics, swimming, tennis, badminton, soccer, handball, fitness centre, weightlifting and other forms of physical activity (open answers).

We moreover adjusted for age, body mass index, systolic blood pressure, cholesterol, HDL-cholesterol, smoking, education, income, alcohol and diabetes. Further we adjusted for additional sports activities (no, one, two or more activities), which meant that we have focused on a single activity, namely walking and not a global measure of physical activity, which most previous studies have used.

During an average of 12 years of follow-up, 742 men and 649 women died. For both sexes we found a strong significant inverse association between walking-intensity and risk of death, but only a weak inverse association between walking-duration and the risk of death.

The findings suggested that the relative intensity and not the duration of walking for both sexes was of most importance in relation to all-cause mortality. Walking duration had almost no effect on mortality, except for men walking more than 2 hours a day (Schnohr et al. 2007 – publication 6).

(7) "Stress and life dissatisfaction are inversely associated with jogging and other types of physical activity in leisure time – The Copenhagen City Heart Study"

This cross sectional study of 5,479 men and 6,549 women 20-79 years of age has shown that men as well as women being physically active in leisure time are less prone to stress and life dissatisfaction than sedentary persons.

It seems that those who were vigorously physically active, e.g. joggers, had the lowest level of stress and life dissatisfaction, but it should be underlined that the largest advantage was seen between the low (<2 hours of light physical activity in leisure time per week) and the moderate group (2-4 hours of light activity per week). We adjusted for differences in baseline characteristics, where the trend was, that more physically active persons smoked less and had a higher socio-economic status than the sedentary (Schnohr et al. 2005 – publication 7).

DISCUSSION

Athletes and all-cause mortality

Top-athletes may be considered as persons with superior constitution and superior health, but still for centuries the belief among physicians and laymen has been that strenuous physical activity could be harmful to health and thus reduce life expectancy.

Former Danish top-athletes had a significantly lower mortality under the age of 50 years than the general population, but after 50 years of age the mortality was the same (publication 2). This finding could be explained by the fact that strenuous training for several years protects the athlete, but only during the training period, and that some years later when the person becomes sedentary, the positive effects of training are reduced. If the top-athlete had a lower mortality risk due to the genetic constitution and not due to training, it would be reasonable to believe, that this lower mortality would be life-long.

It should be emphasized, that the lower mortality under the age of 50 among the Danish top-athletes could be caused by other factors than training, as it in this paper was not possible to adjust for confounding factors and selection-bias.

Thus, the author's findings might be inconclusive, but point to a lower mortality in former top-athletes.

Twentyfive years later a Finnish study reported a significantly increased life expectancy for endurance athletes (Sarna et al. 1993), and in 2003 only rare cases of sudden death among athletes were reported, 2.3 in 100,000 per year among athletes and 0.9 in 100.000 per year among non-athletes (Corrado et al. 2003). Most often cardiac diseases have been the reason for sudden death among athletes. Sometimes infections have been the main cause (Wesslén 1996).

The author concludes that top-athletes have lower all-cause mortality than the general population. It is unclear if this is an effect of selection or a protective effect of training. However, no adverse effect on longevity can be detected.

Joggers and all-cause mortality

Death during jogging has been reported since the early 1970's (Opie 1975, Noakes et al. 1979, Thomson et al. 1979 and others), but it was also stated that marathon runners are immune to coronary atherosclerosis (Bassler 1976).

Due to the cardiac death of a 46 year old naval officer in the first Danish jogging-competition (Eremitageløbet) in 1969, the author wanted to analyse the risk of death in jogging in the general population. In publication 3, based on data from the first (1976-1978) and the second (1981-1983) Copenhagen City Heart Study-survey, it was found, that men reporting active jogging at both examinations had a significantly lower relative risk of death than non-joggers or those who jogged at only one of the two examinations, RR 0.39 (95% CI: 0.19-0.73; P=0.005).

This study was the first to demonstrate, that regular jogging was not *associated with increased mortality in men, as shown by the significantly lower mortality in joggers compared with non-joggers.*

Physical activity, physical fitness and mortality
One, two or several examinations
Duration, intensity and frequency

Based on 44 papers Lee and Skerrett concluded: "The preponderance of evidence suggests that risk of dying during a given period continues to decline with increasing levels of physical activity rather than displaying a threshold or L-shaped relation. This inverse dose-response relation has been shown in men and women, and in younger and older subjects. Fewer data are available regarding the volume of physical activity needed to reduce all-cause mortality. It appears that minimal adherence to previous physical activity recommendations, which will generate expenditure on the order of 1000 kcal per week, results in decreased all-cause mortality rates with reductions in the order of 20-30%. To isolate the effect of duration or frequency of physical activity on all-cause mortality rates, it is imperative to hold volume of physical activity constant. No data are available to answer if frequent, shorter bouts have different effects on all-cause mortality, than fewer and longer?" (Lee I-M et al. 2001), but Lee has yet suggested: "Even a little is good; more may be better" (Lee I-M 2007).

Spare data exist regarding the components that contribute to the volume of physical activity: intensity, duration and frequency. The importance of absolute versus relative intensity of effort also remains to be solved (Shepard et al. 2001.

Table 1 presents 15 population studies addressing the relation between physical activity in leisure time and all-cause mortality. All studies, including The Copenhagen City Heart Study are based on only one examination, and all have used their own questionnaires to assess physical activity in leisure time. The different levels of physical activity in leisure time (low, moderate and high) have been a combination of duration and intensity of several, different physical activities and sports.

Based only on a single estimation of physical activity in leisure time, and with a long follow-up, the general findings were a significant higher mortality in the group with low physical activity in leisure time at baseline, compared to moderate or high. In some studies a U-formed relation was seen (Paffenbarger et al. 1986, Leon et al. 1987), suggesting that moderate physical activity is preferable to high, e.g. high could be harmful to health. In contrast, some studies only reported lower mortality if the activity was vigorous (Lee et al 1995, Bijnen et al. 1998, Yu et al. 2003).

In a large study from Germany the volume of moderate physical activity in leisure time was inversely associated with all-cause mortality in women, but not in men. There was no clearcut explanation for this discrepancy (Bucksch et al. 2005).

The general trend in most of these studies was that the effect was similar in both sexes and all age-groups with some few exceptions.

Most studies reported the greatest difference in men as well as women in the mortality between the sedentary group and the moderately active group, suggesting that only minor physical activity in leisure time is necessary to reduce risk of death. Another suggestion could be, that the sedentary group had increased overt or underlying diseases. In four of the studies none of the participants were excluded from analyses, but in the eleven others participants with cardiovascular disease, stroke, cancer, lung- and musculoskeletal diseases were excluded, suggesting that the participants were healthy at the beginning of follow-up. It seems that the same trend was found in all studies, with or without exclusion of participants with diseases or with repeating the analyses after including a lag period of 2 to 6 years at the beginning of follow-up (Sherman et al. 1994, Yu et al. 2003, Schnohr et al 2003 and 2007).

Table 2 presents 9 population studies based on two or several examinations. Seven of the studies excluded participants with cardiovascular disease, stroke, cancer, lung- and musculoskeletal diseases. The associations between low, moderate and high physical activity in leisure time and mortality are almost of the same strength as found in the studies with only one assessment of physical activity suggesting that participants in general maintain their average physical activity over several years.

The author's experience of analysing joggers was different, as 217 men were jogging in 1976-1978 and five years later only 96 (44%) were still jogging. The relative risk of death in persistent joggers was significantly lower than that in non-joggers or in those who jogged at only one of the examinations, but if we had based the analyses on one examination only, no significant difference between joggers and non-joggers would have been found (Schnohr et al. 2000). These findings could have been due to small numbers or the fact that only 44% of the joggers continued after 5 years. Jogging is a vigorous activity with risk of especially musculoskeletal injuries, which could explain the discontinuation.

In another publication (4) we have seen that participants being 20-79 years of age in 1981-1983 (mean age 55 years) have changed activity levels between the first and second examination 5 years apart (Authors publication 4, Table 2).

The figures show that participants in the Moderate and the High groups continue to be in either of these groups, whereas there is a shift from Low to Moderate and High.

We have no information about changes in physical activity in leisure time of the general population during this period, but our figures show a shift from sedentary to a more active physical activity in leisure time, which suggests that our findings maybe underestimate the differences in relative risk of death between the participants in the Low group compared with participants in the Moderate and High group.

In some of the studies a trend was found pointing towards an extra benefit of vigorous activity in men (Paffenbarger et al 1993, Lee et al. 1995, Bijnen et al. 1998, Schnohr et al. 2000) and women (Lissner et al. 1996, Trolle-Lagerros at al. 2005), but in others moderate activity seemed to be preferable (Wannamethe et al. 1998).

Table 3 presents three studies based on a single maximal exercise test. The follow-up was from 8 to 16 years. A strong and graded association was found between physical fitness and mortality in two of the studies (Blair et al. 1989, Gulati et al. 2003), but in the Norwegian study the protection was only seen in the highest quartile (Sandvik et al 1993). Gulati calculated that for every increase in exercise capacity by 1 MET (3,5 ml O_2 consumption/kg/min), the risk of death was reduced by 17% ($P<0.001$).

Table 4. The study from Cooper Clinic found, that men being unfit at both visits had the highest death rate, men who were fit at both visits had the lowest death rate, and men who changed fitness status had intermediate rates. Overall, men being initially unfit and becoming fit had a 44% lower age-adjusted relative risk of all-cause mortality 0.56 (95%CI: 0.41-0.75) (Blair et al. 1995).The same improvement was found in a Norwegian study (Erikssen et al. 1998).

Blair et al. have stated, that it is not possible to conclude whether physical activity or physical fitness is the most important for health, but obviously there is a high correlation between the two measures. They also wrote, that from a public health policy perspective it is clear that recommendations and programmes should be designed to

Authors publication 4, Table 2.

1976-1978	1981-1983	Men	Women
High	High	65%	50%
	Moderate	29%	43%
	Low	6%	7%
Moderate	High	34%	26%
	Moderate	54%	62%
	Low	13%	13%
Low	High	23%	15%
	Moderate	42%	47%
	Low	35%	38%

promote physical activity and not fitness (Blair et al. 2001). The Copenhagen Male Study have found, that being very fit, provides no protection against ischaemic heart disease or all-cause mortality in sedentary men (Hein et al. 1992).

At a symposium in Canada concerning physical activity and health it was agreed upon that there is a dose-response relationship between volume of physical activity and all-cause mortality in men and women. The slope of this inverse relationship between physical activity and all-cause mortality is not well defined, but in most of the studies the relationship appears to be linear. The minimal effective dose is not well defined, but physical activity expending 1000 kcal per week (1000 kcal equals 3-4 hours of walking at moderate speed) is associated with as much as 30% reduction in all-cause mortality rates. It is suggested that volumes of physical activity as low as 500 kcal per week might demonstrate a slight favourable effect on all-cause mortality, but this requires further study (Kesaniemi et al. 2001).

Based on the 30 population studies discussed in this review it seems reasonable to state, that findings based on one or two examinations, or based on different physical activity questionnaires or physical fitness estimations, were similar namely:

Sedentary people or people with a low maximum oxygen uptake have a significantly higher all-cause mortality than others.

One might argue that it seems somewhat unlikely, that a single estimate of physical activity in leisure time has prognostic significance in relation to risk of death during several years of follow-up. For comparison we have found the same prognostic significance for a single casual blood pressure measurement (Schnohr et al. 2002)

In the work of postponement of cardiovascular disease and of premature death physical activity in leisure time is of importance, and it seems not appropriate, that the level of physical activity is not included in any of the risk factor programmes e.g. The Framingham Heart Study (Anderson et al. 1991), the Danish PRECARD programme (Thomsen et al. 2001) or the European Score system (Graham et al. 2007). Hopefully physical activity will be included in the programmes in near future, since we advise patients and the general population to be physically active.

"The Copenhagen City Heart Study LTPA-Questionnaire"

Group II (Moderate level) is relatively well-defined: "Light physical activity 2-4 hours per week", but Group I (Low level) is a combination of almost completely sedentary or <2 hours of light physical activity per week. Due to small numbers in Group IV, Group III and IV together were always combined in our analyses (High level), being a combination of light activity for more than 4 hours per week or more vigorous activity 2-4 hours per week and further more heavy exercise and vigorous activity. It should be underlined, that the assessment of the intensity of physical activity: sedentary, light, more vigorous, highly vigorous or regular heavy exercise or competitive sports, was based on the participant's own perception. We found that a relative scale of intensity may be more appropriate than an absolute scale, when the age-span is large, as in our population (20-93 years), and the participants having wide differences in levels of physical fitness.

From publications 4 and 5 it can be concluded:

Sedentary persons or persons exerting less than 2 hours of light physical activity in leisure time per week (Low) have a significantly higher all-cause mortality than persons with light physical activity 2-4 hours per week (Moderate). The mortality was almost the same in the Moderate and High groups.

These data from our two first examinations did not enable us to differentiate between duration, intensity or frequency of physical activity in leisure time.

First in the third examination, 1991-1994, we introduced duration and intensity of walking and bicycling, and in the fourth examination, 2001-2003, intensity and frequency of jogging were introduced in the questionnaire.

From the study of walking (publication 6) it was concluded: *Walking at low intensity up to more than 2 hours per day had almost no effect on mortality, whereas increasing the intensity was of most importance in relation to all-cause mortality. Thus the relative intensity and not the duration is of most importance in relation to all-cause mortality.*

Limitations of the studies

Validation of the questionnaire

The Swedish questionnaire has proved to discriminate between men with low physical activity in leisure time and their more active counterparts with respect to maximal oxygen uptake (Saltin 1977).

We used our questionnaire without any validation assuming it would discriminate the participants between the different levels of physical activity in leisure time. In all our papers published regarding physical activity in leisure time we have found significant differences in all-cause mortality between persons categorized in the different levels of physical activity in leisure time, but this is of course not a validation of our questionnaire. To further support the validity of our questionnaire the author analysed the association between the self-reported levels of physical activity in leisure time and a number of variables well-known to be associated with physical activity.

Table 5 shows significant associations between higher levels of physical activity in leisure time and lower levels of: Resting heart rate, body mass index, waist circumference, waist/hip ratio, and non-fasting triglycerides and higher levels of: HDL-cholesterol for both men and women in all age groups.

As all the above studied variables correlate significantly with physical activity in leisure time, it is likely that our questionnaire, "The Copenhagen City Heart Study LTPA-Questionnaire", has an acceptable validity.

Association versus causation

The observed inverse association between physical activity in leisure time and mortality might be explained by the fact that individuals being physically active are more healthy, have a healthier lifestyle, and thus live longer than sedentary persons. Sedentary persons may have a low physical activity due to subclinical diseases resulting in both sedentary habits and increased mortality. We have tried to adjust for this latter problem by repeating the analyses after including a lag period of 2 years, and have found similar results.

Selection-bias (non responders), controlled trials, potential confounders adjusted for, and unmeasured potential confounders will be discussed in the following.

Non-responders (selection-bias)

In "The Study of Men born in 1973", 973 men all 50 years of age were selected at random, and 855 (88%) of these men were examined by Gösta Tibblin in Göteborg in 1963. The 118 non-responders differed from the responders in several ways: their income was lower, significantly fewer were married, several had excessive alcohol intake, the percentage of invalidity pension was higher and several had a negative attitude towards medical care in general. There were no significant differences in morbidity (Tibblin 1965). In 1964 Hagerup initiated the Glostrup study with a population of 515 men and 461 women all 50 years of age. A total of 436 men and 366 women participated in the study, 88% of the invited. The main reason for non-attendance appeared to be of social and psychological nature. With regard to cardiovascular diseases, the non-responders seemed not to differ from responders (Hagerup 1974).

In the first examination of The Copenhagen City Heart Study in 1976-1978, 14,223 men and women were examined, non-responders counted for 5,106 persons. Dr. Gorm Jensen reported in his thesis from 1983 the following table (Jensen G, thesis, Table 1.3).

At the end of the first examination, 1976-1978, a random sample of non-responders were visited in there homes in order to evaluate

Table 5. Physical activity in leisure time in relation to: Resting heart rate, BMI, waist, waist/hip ratio, HDL-cholesterol, non-fasting triglycerides and systolic blood pressure (mean ± SD). The Copenhagen City Heart Study, 1991-1994.

Age	N	Group I	N	Group II	N	Group III	N	Group IV	p-trend
Resting heart rate, men (beats/min)									
20-39	59	69.6 (1.4)	256	71.0 (0.8)	308	67.4 (0.6)	104	63.3 (1.2)	0.0000
40-59	197	75.8 (1.0)	753	73.7 (0.5)	508	70.0 (0.6)	57	67.6 (1.6)	0.0000
60-79	241	77.8 (1.0)	865	74.4 (0.5)	635	73.0 (0.5)	69	69.2 (1.6)	0.0000
80+	35	78.4 (2.8)	94	73.9 (1.2)	47	70.9 (1.4)	4	79.8 (8.4)	0.0368
Resting heart rate, women (beats/min)									
20-39	60	72.9 (1.3)	408	71.5 (0.6)	304	69.6 (0.7)	35	64.5 (1.9)	0.0001
40-59	179	75.3 (1.0)	994	72.9 (0.4)	497	71.2 (0.5)	28	72.9 (2.0)	0.0001
60-79	350	75.8 (0.7)	1598	74.5 (0.3)	623	73.4 (0.5)	41	69.8 (1.7)	0.0003
80+	70	75.6 (1.5)	141	75.3 (1.1)	30	72.1 (2.1)	2	81.5 (0.5)	0.4291
BMI, men (kg/m^2)									
20-39	59	26.1 (0.6)	258	24.4 (0.2)	309	23.7 (0.2)	104	24.2 (0.3)	0.0002
40-59	197	26.8 (0.3)	754	26.6 (0.1)	507	25.8 (0.2)	57	25.8 (0.4)	0.0001
60-79	243	26.8 (0.3)	865	26.8 (0.1)	637	26.5 (0.1)	69	27.5 (0.5)	0.5072
80+	35	26.5 (0.8)	95	25.2 (0.3)	47	24.7 (0.5)	4	24.6 (2.2)	0.0234
BMI, women (kg/m^2)									
20-39	59	24.4 (0.6)	401	22.9 (0.2)	301	22.4 (0.2)	35	22.4 (0.4)	0.0003
40-59	178	26.7 (0.4)	996	25.4 (0.1)	496	24.5 (0.2)	28	24.5 (0.8)	0.0000
60-79	350	27.2 (0.3)	1600	25.9 (0.1)	622	25.3 (0.2)	41	24.6 (0.7)	0.0000
80+	69	26.0 (0.5)	140	25.3 (0.4)	31	24.4 (0.8)	2	22.8 (0.1)	0.0576
Waist, men (cm)									
20-39	59	92.7 (1.5)	258	87.7 (0.6)	309	84.8 (0.5)	104	84.4 (0.8)	0.0000
40-59	196	96.8 (1.0)	754	95.7 (0.4)	509	93.0 (0.4)	57	92.4 (1.2)	0.0000
60-79	242	99.8 (0.8)	863	98.3 (0.4)	638	96.5 (0.4)	69	98.4 (1.2)	0.0003
80+	35	97.9 (2.3)	94	93.6 (0.9)	47	94.0 (1.3)	4	93.1 (7.2)	0.1263
Waist, women (cm)									
20-39	56	80.5 (1.6)	393	75.7 (0.5)	298	73.9 (0.5)	35	73.5 (1.0)	0.0000
40-59	178	86.1 (1.0)	997	82.2 (0.4)	497	79.2 (0.5)	28	80.3 (2.2)	0.0000
60-79	348	89.0 (0.7)	1595	84.8 (0.3)	622	82.8 (0.5)	41	80.0 (1.8)	0.0000
80+	69	86.9 (1.5)	139	85.5 (1.0)	31	82.4 (2.0)	2	83.4 (4.2)	0.0879
Waist/hip, men (cm/cm)									
20-39	59	0.92 (0.01)	258	0.89 (0.00)	309	0.88 (0.00)	104	0.87 (0.01)	0.0000
40-59	196	0.96 (0.01)	754	0.95 (0.00)	509	0.93 (0.00)	57	0.93 (0.01)	0.0000
60-79	242	0.98 (0.01)	863	0.97 (0.00)	638	0.96 (0.00)	69	0.97 (0.01)	0.0000
80+	35	0.97 (0.02)	94	0.95 (0.01)	47	0.95 (0.01)	4	0.96 (0.05)	0.3525
Waist/hip, women (cm/cm)									
20-39	56	0.82 (0.01)	393	0.79 (0.00)	298	0.78 (0.00)	35	0.78 (0.01)	0.0001
40-59	178	0.84 (0.01)	997	0.82 (0.00)	497	0.81 (0.00)	28	0.81 (0.02)	0.0000
60-79	348	0.86 (0.00)	1595	0.84 (0.00)	622	0.83 (0.00)	41	0.82 (0.01)	0.0000
80+	69	0.86 (0.01)	139	0.86 (0.01)	31	0.84 (0.01)	2	0.86 (0.03)	0.1975
HDL, men (mmol/l)									
20-39	59	1.23 (0.04)	257	1.29 (0.02)	306	1.35 (0.02)	100	1.43 (0.03)	0.0000
40-59	194	1.32 (0.03)	744	1.36 (0.02)	507	1.42 (0.02)	57	1.42 (0.05)	0.0020
60-79	259	1.42 (0.03)	884	1.38 (0.02)	641	1.41 (0.02)	69	1.52 (0.05)	0.2434
80+	50	1.41 (0.06)	106	1.47 (0.04)	48	1.35 (0.06)	4	1.60 (0.20)	0.7545
HDL, women (mmol/l)									
20-39	58	1.60 (0.06)	404	1.69 (0.02)	301	1.75 (0.02)	33	1.70 (0.08)	0.0284
40-59	174	1.66 (0.04)	990	1.69 (0.01)	490	1.81 (0.02)	27	1.72 (0.08)	0.0001
60-79	391	1.65 (0.03)	1649	1.73 (0.01)	627	1.80 (0.02)	39	1.85 (0.09)	0.0000
80+	98	1.62 (0.05)	173	1.72 (0.04)	33	1.63 (0.08)	2	2.45 (0.15)	0.1721
Non-fasting triglycerides, men (mmol/l)									
20-39	59	1.89 (0.17)	257	2.16 (0.25)	302	1.75 (0.07)	100	1.34 (0.07)	0.0183
40-59	191	2.82 (0.24)	742	2.41 (0.11)	505	2.02 (0.06)	57	1.92 (0.24)	0.0001
60-79	256	2.35 (0.19)	881	2.13 (0.05)	641	2.06 (0.05)	69	2.09 (0.19)	0.0384
80+	47	2.14 (0.32)	105	1.75 (0.09)	48	1.71 (0.11)	4	1.55 (0.46)	0.0962
Non-fasting triglycerides, women (mmol/l)									
20-39	59	1.80 (0.41)	404	1.27 (0.04)	302	1.13 (0.04)	33	1.11 (0.09)	0.0003
40-59	174	1.71 (0.07)	983	1.61 (0.03)	489	1.53 (0.04)	27	1.71 (0.38)	0.0720
60-79	383	2.11 (0.08)	1634	1.87 (0.02)	619	1.76 (0.04)	39	1.70 (0.18)	0.0000
80+	95	2.09 (0.13)	167	1.79 (0.06)	32	1.74 (0.13)	2	1.15 (0.06)	0.0118
Systolic BP, men (mm Hg)									
20-39	59	126.8 (1.6)	258	124.8 (0.8)	308	125.5 (0.7)	104	127.6 (1.2)	0.2970
40-59	198	134.4 (1.4)	754	137.5 (0.7)	509	134.8 (0.8)	57	134.5 (2.4)	0.3357
60-79	268	149.4 (1.4)	890	149.5 (0.7)	643	149.0 (0.8)	70	148.8 (2.3)	0.6648
80+	53	145.7 (3.8)	107	150.4 (2.3)	48	148.0 (3.5)	4	125.8 (11.1)	0.8317
Systolic BP, women (mm Hg)									
20-39	60	115.6 (1.7)	408	115.0 (0.6)	303	115.0 (0.7)	35	115.7 (1.6)	0.9622
40-59	180	131.0 (1.3)	994	130.5 (0.6)	497	127.4 (0.8)	28	120.4 (2.6)	0.0003
60-79	396	148.7 (1.1)	1676	148.5 (0.6)	630	146.8 (0.9)	41	139.6 (3.5)	0.0249
80+	102	150.6 (2.4)	175	159.8 (1.8)	33	154.9 (3.1)	2	146.0 (17.0)	0.0727

Jensen G, thesis, Table 1.3

Age	Responders	Non-responders	Response (%)
Men			
20-29	283	157	64
30-39	737	365	67
40-49	1441	603	70
50-59	2013	778	72
60-69	1579	482	77
70-79	385	143	73
80-	73	107	41
total	6,511	2,635	71
Women			
20-29	327	134	71
30-39	806	260	76
40-49	1702	461	79
50-59	2792	756	79
70-79	374	166	69
80-	55	129	30
total	7,712	2,472	76
Total	14,223	5,107	74

whether the non-responder group differed significantly from the responder group with respect to cardiovascular diseases. The sample comprised 121 men and 102 women. It was only possible to visit and examine 37 men (response 31%) and 30 women (response 29%) in their homes. The age-composition of non-responders did not differ from the responders. It was found that the prevalence of possible ischaemic heart disease was not appreciably greater among non-responders than among the responders, but non-responders had a highly significant excess mortality of approximately 80%, especially in the elderly age-groups (Jensen 1984).

Our response rates are higher than the rates of many other larger population studies. The response rate in the famous Framingham Study initiated in 1948 was 69%. Even with this lower response rate the Framingham Study has been one of the leading within cardiovascular epidemiology and prevention and among many other valuable findings the term coronary heart disease risk factors was launched in 1961 (Kannel et al. 1961).

A high response rate is not of major importance when assessing risk-factors for morbidity and mortality, but when estimating morbidity and mortality in the general population, the non-responders could possibly introduce selection-bias. It should be underlined, that the persons taking part in The Copenhagen City Heart Study was a random sample of the general population, and not a self-selected sample.

Controlled trials

A large controlled trial of physical exercise in leisure time and mortality would be valuable, but those exercise intervention studies reported, have not been able to answer the question of whether increased physical activity can protect middle-aged men at high risk of coronary heart disease, and all-cause mortality. A pilot study was carried out in the Laboratory of Physiological Hygiene, Minneapolis, Minnesota in the late 1960's in which middle-aged men at high risk of coronary heart diseases were randomly assigned to a supervised physical activity programme or a control group for 18 months. Because of the high dropout rate, 50 per cent in the first 6 months, and the large expense for facilities, equipment, and supervising personnel, it was concluded that a national primary coronary heart disease prevention trial using exercise was not feasible (Leon & Blackburn, 1977).

In a Cochrane Review concerning physical activity for primary prevention of disease Karmisholt et al. have concluded that "Exercise can have important benefits, but there is a need for large trials that live up to accepted standards and include measurement of harms, in particular for trials that compare exercise with drugs" (Karmisholt et al. 2005). I agree it would be of value to conduct a controlled trial of lets say 20,000 sedentary men and women, half of them randomised to a minimum of 30 minutes daily physical activity, while the other half had to continue their sedentary life for at least 5 years. Such a trial would not be feasible when the end-point is mortality, nor would it be ethical.

Based on a large number of reviews and meta-analyses, it was concluded "The popular belief that only randomized, controlled trials produce trustworthy results and that all observational studies are misleading does a disservice to patient care, clinical investigation, and the education of health care professionals (Concato et al., 2000). Several authors have found that observational studies and randomized controlled trials usually produce similar results (Benson et al. 2000).

Variables adjusted for in author's studies

In the studies based on data from The Copenhagen City Heart Study we have adjusted for the following variables related to all-cause mortality to diminish confounding:

Age, sex, smoking, plasma total cholesterol, plasma HDL-cholesterol, systolic blood pressure, diabetes mellitus, alcohol consumption, body mass index, education, household income, forced expiratory volume, number of sports activities.

Age, sex and longevity

Age and sex is the most important determinant for all-cause mortality (Scheifeld 1958, Videbæk et al. 2004).

Smoking

In the famous study by Doll and Hill from 1954 calculating mortality of 24,000 doctors in relation to their smoking habits, the resulting rates reveal a significant and steadily rising mortality from deaths due to cancer of the lung as the amount of tobacco smoked increased (Doll et al. 1954).

In a study with pooled data from three population studies in Copenhagen (The Copenhagen City Heart Study, The Glostrup Population Studies and the Copenhagen Male Study), comprising 17,669 men and 13,525 women, it was found that lost years of expected life in women for heavy smokers was 9.4 years, and for light smokers 7.4 years compared to never smokers. Corresponding loss of life expectancy in men was 9.2 years and 6.0 years respectively (Prescott et al. 1998).

Smoking and physical activity have a substantial negative and positive effect, respectively on longevity. A 65 year old man, "never-smoker and high-physical activity", has a remaining lifetime of 16.2 years compared to a "smoker and low-physical activity", who had 9.5 years, that is 6.7 years of shorter life. Another interesting comparison is between "smoker and high physical activity" and "never smoker and low physical", the residual years of living are 12.9 and 11.1, respectively, suggesting almost similar life expectancy. The same figures were true for women. (Ferrucci et al. 1999).

In another study from The Copenhagen City Heart Study it has been shown, that only 3 to 5 cigarettes a day significantly increase all-cause mortality (Prescott et al. 2002).

Plasma total cholesterol, HDL-cholesterol and triglycerides

In the 1950's Ancel Keys formulated the hypothesis that the serum cholesterol was an important determinant of coronary heart disease. This was confirmed by analyses of the Seven Countries Study (Keys 1970). These findings have been verified by many (Kannel et al 1971, Rose et al. 1986, Gotto et al. 1990, Neaton et al. 1992, Schnohr et al. 2002).

The Framingham Heart Study later reported that the relationship between total cholesterol and all-cause mortality was positive (ie, higher cholesterol level associated with higher mortality) at age 40 years, negative at age 80 years, and negligible at ages 50 to 70 years (Kronmal et al. 1993). Similar findings have been reported from other groups (Schatz et al 2001, Schnohr et al. 2002, Iversen et al. 2007).

The Tromsø Heart Study was one of the first to report, that a high HDL-cholesterol was associated with significantly lower risk of coronary heart disease (Miller et al. 1977), other studies have confirmed this finding (Stensvold et al. 1992). HDL-cholesterol level has also been inversely related to the risk of thromboembolic stroke (Curb et al. 2004).

A review of 29 Western prospective studies including 262, 525 participants reported moderate and highly significant associations between fasting triglyceride values and coronary heart disease risk (Sarwar et al. 2007). The Copenhagen City Heart Study has reported that non-fasting elevated triglycerides were highly significantly associated with increased risk of myocardial infarction, ischaemic heart disease and death in men and women, especially in women. It seemed that the association between triglycerides and end-points was stronger for non-fasting than for fasting triglycerides. (Nordestgaard et al. 2007, Bansal et al. 2007).

HDL-cholesterol increases and triglycerides decrease significantly by exercise, whereas total cholesterol only decreases insignificantly, except for marathon running (Kiens et al. 1980, Hartung et al. 1980, Kraus et al. 2002, Pedersen et al. 2006, Kodama et al. 2007).

Systolic blood pressure

Raised blood pressure is the single most important cause of death worldwide and the second major cause of disability next to childhood malnutrition (Feng et al. 2007, Lopez et al. 2006).

Based on a meta-analysis of individual data for one million adults in 61 prospective studies (including The Copenhagen City Heart Study) it was concluded: Throughout middle and old age, usual blood pressure is strongly and directly related to vascular and overall mortality without any evidence of a threshold down to at least 115/75 mm Hg (Prospective Studies Collaboration 2002).

Most clinicians have stated that the hazards of hypertension to the cardiovascular apparatus derives principally from the diastolic component, but in 1971 The Framingham Study published a stronger association of systolic than of diastolic pressure with risk of coronary heart disease (Kannel et al. 1971).

A Danish study has shown that the blood pressure level did not predict the risk of ischemic heart disease in those with high triglycerides (>1.59 mmol/l) and low HDL-cholesterol (<1.18 mmol/l) (Jeppesen et al. 2000).

In a review Klarlund Pedersen and Saltin describe a great number of studies all showing a decrease in systolic as well as diastolic blood pressure as a consequence of exercise (Pedersen et al. 2006). In a Study based on participants in The Copenhagen City Heart Study the same effect was found a long time ago (Kiens et al. 1980).

Diabetes mellitus

The incidence of type 2 diabetes mellitus is increasing worldwide suggesting that modifiable risk factors such as obesity and physical inactivity are the main non genetic determinants of the disease. The Finnish Diabetes Prevention Study concluded that type 2 diabetes can be prevented by changes in lifestyle of both women and men at high risk of the disease. The change in lifestyle included moderate exercise for at least 30 minutes per day (Tuomilehto et al. 2001). Some years later the same group reported the results of 19 years follow up of 3,706 patients with type 2 diabetes aged 24-74 years. During follow up 1,423 deaths were recorded. Moderate and high levels of physical activity were associated with a significantly reduced risk of total and cardiovascular mortality, independent of age, education, body mass index, blood pressure, total cholesterol and smoking. The protective effect of physical activity was consistent in diabetes patients at any level of body mass index, blood pressure, cholesterol and smoking (Hu et al. 2005).

Alcohol

The relation of alcohol intake to total mortaliti is J-shaped or U-shaped. Abstainers have modestly higher mortality than moderate drinkers (Poikolainen 1995). From the Copenhagen City Heart Study-population Grønbæk have found, that alcohol intake showed a U-shaped relation to mortality and that wine intake may have a beneficial effect on all-cause mortality that is additive to that of alcohol (Grønbæk 2000 thesis and Grønbæk et al. 2000).

Body mass index

Earlier studies have found the lowest mortality among individuals close to average weight and those 10-20% below average weight (Lew et al. 1979). In a study of 527,265 U.S. men and women 50 to 71 years of age, 61,317 died during follow-up. There was a U-shaped relation between body mass index and the risk of death, with the highest risk in the lowest (<18.5 kg/m^2) (adjusted relative risk 1.97 (95% CI 1.76-2.20) and the highest (≥40.0 kg/m^2) (adjusted relative risk 1.83 (95% CI 1.70-1.97) for men. For women the figures were 2.03 (95% CI 1.84-2.25) and 1.94 (95% CI 1.79-2.09), respectively. Men and women with body mass index between 23.5 and 29.9 had almost the same lower adjusted relative risk of death (Adams et al. 2006).

A Danish study found as expected a statistically significantly inverse association between physical activity in leisure-time and obesity: the more the activity the lower the odds ratio of concurrent obesity. The study did not support that physical inactivity in the long term is associated with the development of obesity, but it indicated that obesity may lead to physical inactivity. (Petersen et al. 2004). Evidence from randomized controls trials supports exercise as an effective intervention in reducing abdominal fat in overweight subjects, especially when imaging methods (CT-scans) are used to measure change (Kay et al. 2006).

Education

Lack of high school education may also capture the lifetime effect of adverse social conditions increasing mortality (Muller 2002). In Copenhagen a pooled data set from three large population studies containing information on 30,635 men and women concluded, that social inequalities in mortality do not seem to be explained only by differences in effect of lifestyle risk factors, but are also related to social rank or unexamined factors (Schnohr C et al. 2004). Others have reported similar findings (Lantz et al. 1998).

Income

Several studies have reported that lower income is correlated to higher all-cause mortality (Lynch et al. 1998, Backlund et al. 1999, Ross et al. 2000, Muller 2002). Cumulated occupational social class of ancestors also seems to be an independent predictor of mortality (Osler et al. 2005).

Unmeasured variables

Even though we have adjusted for well-known risk factors residual confounding may still be of importance.

In the following several other mechanisms explaining the effects of physical activity are presented.

Maximum oxygen-uptake

Physical training with an oxygen uptake from 40 to 90% of maximum increases maximum oxygen-uptake and decreases myocardial oxygen demands for the same level of external work, and this reduces the risk of ischaemia, especially myocardial ischaemia (Åstrand et al. 1970, Pedersen et al. 2006).

Resting heart rate

The risk of sudden death from myocardial infarction was increased in subjects with a resting heart rate more than 75 beats per minute (relative risk 3.9 (95% CI: 1.9-8.0) (Jouven 2005). Increased risk with resting heart rate above 60 beats per minute has been reported (Fox et al. 2007).

A delayed decrease in the heart rate during the first minute after graded exercise is a powerful predictor of over all mortality. A reduction of 12 or less beats in the first minute was associated with relative risk of death of 4.0 (95% CI: 3.0-5.2) (Cole 1999).

Regular physical activity in leisure-time such as brisk walking, bicycling, jogging and other endurance activities causes lower resting pulse rate due to increased parasympaticus and decreased sympaticus tonus (Åstrand et al. 1970).

Metabolic fitness

A definition of metabolic fitness is proposed as the ratio between mitochondrial capacity for substrate utilisation and maximum oxygen uptake of the muscle.

Exercising with a low heart-rate is not improving maximal oxygen-uptake, but is improving metabolic fitness, the mitochondrial capacity and muscle-enzymes (acetyl-CoA, oxogluterat-dehydrogenase and cytocrom-oxidase) and enabling the muscle cells to work with lower oxygen-demand (Saltin et al. 2002, Pedersen and Saltin 2003).

Arrytmia – sudden death

In early epidemiological studies vigorous exercise was associated with decreased risk of sudden cardiac deaths (Siscovick et al 1984; Paffenbarger et al. 1975, Morris et al. 1980).

Lemaitre has since then reported that both moderate-intensity physical activity 60 minutes per week or more and high-intensity activity reduced risk of primary cardiac arrest (Lemaitre et al. 1999).

The Physicians Health Study includes 22,071 U.S. male physicians, who in 1982 were healthy and aged 40 to 84 years. To compare sudden death during and after an episode of vigorous exercise a prospective, nested case-cross over design was used. During 12 years of follow-up 122 sudden deaths were confirmed. Men who rarely engaged in vigorous exercise (less than once a week) had a relative risk of sudden death of 74.1 in the period during and 30 minutes after exertion. In comparison, men who exercised at least five times per week had a relative risk of 10.9; however, this risk was significantly higher than that during periods of lighter exertion or none. The absolute risk of sudden death associated with an episode of vigorous exertion was extremely low, 1 per 1.42 million episodes or person-hours at risk. Habitual vigorous exercise attenuated the relative risk of sudden death associated with an episode of vigorous exercise (P value for trend = 0.006 (Albert et al. 2000).

Habitual vigorous exercise increases basal vagal tone, resulting in increased cardiac electrical stability and protects against ventricular fibrillation (Hull et al. 1994).

Endothelial function

In patients with coronary heart disease four weeks of exercise training improved the endothelium-dependent vasodilatation both in epicardial coronary vessels and in resistance vessels (Hambrecht et al. 2000). Healthy subjects predisposed for type 2 diabetes mellitus show only minor signs of endothelial dysfunction. Under these almost normal vascular conditions, exercise training has little effect on endothelial function (Østergård et al. 2006).

Inflammation

There is growing evidence that the development of the atherosclerotic plaque is associated with inflammation. Data obtained in 1989-1990 and 1992-1993 from the Cardiovascular Health Study, a cohort of 5,888 men and women aged ≥ 65 years were analysed. Concentrations of the inflammation markers: C-reactive protein, fibrinogen, Factor Vlll activity, white blood cells, and albumin were compared cross-sectionally by quartile of self-reported physical activity. Higher levels of physical activity were associated with significantly lower concentrations of four out of five (not albumin) inflammation markers after adjustments for gender, cardiovascular disease, age, race, smoking, body mass index, diabetes and hypertension. One current concept regarding the patophysiologic mechanisms of the inflammation associated with atherosclerosis concerns the production of proinflammatory cytokines in response to stimuli from oxidized low density lipoproteins and macrophages associated with the atherosclerotic plaque. The proinflammatory cytokines produced during this process include interleukin-1-β, interleukin-6, and tumor necrosis factor-α. In vitro studies have shown that various combinations of these cytokines stimulate the production of the inflammation-sensitive proteins, C-reactive protein, fibrinogen and Factor Vlll, as well as leucocytosis (Geffken et al. 2001).

Regular physical activity reduces resting C-reactive protein by multiple mechanisms, including a decrease in cytokine production by adipose tissue, skeletal muscles, endothelial and blood mononuclear cells, improved endothelial function and insulin sensitivity, and possibly an antioxidant effect. This anti-inflammatory response may contribute to the beneficial effects of habitual physical activity (Kasapis et al. 2005).

Strenuous exercise induces an increase in the pro-inflammatory cytokines, tumour necrosis factor (TNF-α) and interleukin (IL-1β) and a dramatic increase in the inflammation responsive cytokine IL-6. This is balanced by the release of cytokine inhibitors (IL-1ra, sTNF-r1 and sTNF-r2) and the anti-inflammatory cytokine IL-10. It is suggested, that cytokine inhibitors and anti-inflammatory cytokines restrict the magnitude and the inflammatory response to exercise (Ostrowski et al. 1999).

Coronary heart disease patients in cardiac rehabilitation programmes would further improve endothelial dysfunction if one implement programmes making patients exercise at a higher frequency and longer duration than currently recommended e.g., 6×15 minutes cycle ergometer training at 70-80% of individual maximal heart rate five days a week, and 30 minutes daily during weekends at home (Peschel et al. 2007).

Fibrinolytic activity

Diurnal variations in fibrinolytic activity may be associated with increased incidence of cardiac events observed in the morning hours. Cortisol surges, increases in catecholamines, changes in heart rate and blood pressure, and enhanced platelet aggregation are also potential triggers for morning cardiac complications. Because most myocardial infarctions ultimately result from thrombus forming in a partially occluded artery, it appears that the fibrinolytic system could play an important role.

Several studies have found that physical exercise increases the fibrinolytic activity significantly lower resting plasminogen activator (PAI-1) and slightly higher tissue plasminogen activator (TPA) (Williams et al. 1980, De Geus et al. 1992, Szymanski et al. 1994). Szymanski concluded that changes in fibrinolytic activity appear to be influenced primarily by exercise intensity rather than duration or total caloric expenditure, and further that a significantly greater increase in plasminogen activator was seen after evening exercise compared to morning exercise.

Mental health

Higher levels of physical activity in leisure-time have been associated with the following psychological improvements:

Reduced clinical depression, reduced anxiety, reduced stress response, elevated mood state, improved cognitive function and reduced risk of dementia, both Alzheimer's disease and vascular dementia.

Mechanisms for the associations between physical activity and psychological well being have not been clearly identified. Regular exercise increases adrenal activity, which facilitates stress adaptation, and exercise enhances noradrenalin, serotonin, beta-endorphin and dopamine, which improves the mood. Other hormones rising in blood during and after exercise are thyroid hormones, cortisol, estrogen, progesterone, testosterone and leptin. Further exercise increases body temperature resulting in short time tranquilising effects (Weyerer et al. 1994, Scully et al.1998, Lawlor et al. 2001, Kull et al. 2002,Vergese et al. 2003, Weuve et al. 2004, Abbott et al. 2004).

Genetics

Differences in the genetics could be a major reason for different longevity in individuals with low physical activity compared to individuals with higher physical activity. The Finnish Twin Cohort, which comprised almost 16,000 men and women, has found that leisure-time physical activity is associated with reduced mortality, even after genetic and other familial factors were taken into account (Kujala et al. 1998).

A Canadian study reported, that both genetic and environmental factors contribute to the familial resemblance of maximal oxygen uptake in sedentary persons. The genetic heritability was less than 50% (Bouchard et al. 1998).

Sir Bradford Hill: Association or causation?

In 1965 Sir Austin Bradford Hill (Professor of Medical Statistics, University of London) suggested that the following aspects of an association be considered in an attempt to distinguish casual from non-casual associations: (1) strength, (2) consistency, (3) specificity, (4) temporality, (5) biological gradient, (6) plausibility, (7) coherence, (8) experiment and (9) analogy (Hill 1965).

Although The Bradford Hill criteria have been criticized they represent a common sense approach to the discussion of causality in epidemiological studies. The first seven of these aspects are fulfilled in author's papers, which favour a casual relationship between physical activity in leisure-time and mortality.

CONCLUSIONS

The author's studies have demonstrated that:

An individual who practises sport in his youth, either as a top athlete or an average athlete, will not be in a poorer physical state later in life than an individual who never practised sport (Publication 1).

Former Danish athletic champions had a significantly lower expected mortality from 25 years of age to 50, subsequently the mortality was similar to others. This finding demonstrates that top-athletes live longer than the general population (Publication 2).

Healthy men, who stated being joggers at two examinations five years apart, had a significantly lower mortality than non-joggers (Publication 3).

Healthy men engaging in Moderate level of physical activity in leisure time at both examinations (1976-1978 and 1981-1983) had a 3.5 years longer lifespan from age 50 than sedentary persons (Low level). Men engaging in High level of physical activity at both examinations had a 5.0 years longer lifespan. For women the figures were 4.4 years (Moderate level) and 4.3 years (High level), respectively.

Men and women 20-79 years of age, who increased their physical activity from Low (1976-1978) to Moderate/High level (1981-1983), had a significantly lower risk of death than participants reporting Low physical activity at both examinations.

If men, 65-79 years of age, increased their physical activity from Low to Moderate/High level between the two examinations five years apart, they survived 4.4 year longer than men with Low physical activity at both examinations. For women at same age the figure was 3.4 years (Publication 4).

Physical activity in both sexes was associated with significantly lower mortality from coronary heart disease, cancer and all-causes. Men with sustained high physical activity in leisure time survived 6.8 years longer, and men with sustained moderate activity 4.9 years longer than sedentary men. For women the figures were 6.4 and 5.5 years respectively (Publication 5).

The relative intensity and not the duration of walking was of most importance in relation to all-cause mortality. Walking duration had almost no effect on mortality, except for men walking more than 2 hours daily (Publication 6).

Men as well as women who are physically active during leisure time are less prone to stress and life dissatisfaction than sedentary persons. Joggers had the lowest level of stress and life dissatisfaction, but the largest advantage was seen between the Low and the Moderate group (Publication 7).

In conclusion: A great number of epidemiological studies have found, that persons being physically active in leisure time have a lower mortality than sedentary persons. Several physiological and biochemical studies have elucidated mechanisms explaining the beneficial effect of physical activity. Based on these findings the author suggest a casual relationship between physical activity in leisure time and all-cause mortality.

PERSPECTIVES OF PHYSICAL ACTIVITY IN LEISURE-TIME IN THE POPULATION

In 1965, The Presidents Council on Physical Fitness recommended 20 min of vigorous exercise three times weekly (President's Council 1965), whereas the recommendations from 1995 from the Centers for Disease Control and Prevention and the American College of Sports Medicine recommended that "every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably, all days of the week" (Pate et al 1995).

Thus in 1965 vigorous exercise was recommended to the public, but in 1995 a moderate level was advocated. The author would advocate for the 1965 recommendations, as we have found that, relative fast intensity or speed is preferable to relative slow duration, thus brisk walking is preferable to slow.

Based on authors studies, the general recommendations to the adult general public would be:

First step: From physical inactivity to light physical activity in leisure time

The optimal would be to motivate all sedentary persons to get up from the television-armchair, and begin walking, bicycling or other light physical activities 2-4 hours a week in moderate speed. This would not only increase lifespan, but also well-being. Elderly persons seem to benefit even more than younger, so it is never too late to take up physical exercise.

Second step: Regular vigorous physical activity

After some months with light physical activity, one should increase the physical activity to more than 4 hours a week, and further include some fast sessions of brisk walking, jogging or other vigorous physical activity several times weekly.

SUMMARY

Hippokrates and Galen both stated that athletes lived in a risky state of health and never reached old age. In the 20th century sudden death during vigorous exercise has been registered, but mainly in men with heart diseases. Since jogging became popular in the 1970's reports of death during jogging were published. Several physicians advocated, that jogging could be dangerous to health.

The aims of the present studies were: 1) to evaluate if top-athletes and joggers have increased risk of death, 2) to describe the relation between physical activity in leisure time and mortality in the general population, and finally 3) to evaluate if the level of physical activity in leisure time is related to the level of well-being, with emphasize on joggers.

Studies concerning death during jogging and other vigorous exercise, and population studies including different levels of physical activity in leisure time and mortality, are presented.

The author's studies (3-7) of physical activity and mortality were based on data from The Copenhagen City Heart Study. This study is a prospective population study comprising a random sample of 19,329 men and women, 20-93 years of age, drawn from the Copenhagen Population Register as of January 1st, 1976. The first survey was carried out in 1976-1978 (participation rate 73,6%). The original purpose of the study was prevention or postponement of coronary heart disease. During the years many other aspects have been added: Stroke, pulmonary diseases, heart failure, arrhythmia, alcohol, arthrosis, eye diseases, allergy, epilepsia, dementia, stress, vital exhaustion, social network, sleep-apnoe, ageing and genetics.

A self-administered questionnaire concerning symptoms and diseases, use of medicine, familial disposition, socioeconomic status, smoking and drinking habits, physical activity during work and during leisure time, and contact with the health care system was filled in by the participants. During the examination the questionnaire was checked by the staff.

Conclusions

An individual who practises sport in his youth, either as a top athlete or an average athlete, will not be in poorer physical state later in life than an individual who never practised sport (Publication 1).

Former Danish athletic champions had a significantly lower expected mortality from 25 years of age to 50, subsequently the mortality was similar to others. This finding demonstrates that top-athletes live longer than the general population (Publication 2).

Healthy men, who stated being joggers at two examinations five years apart, had a significantly lower mortality than non-joggers. Thus vigorous exercise seems to be favourable (Publication 3).

Healthy men 20-79 years of age engaging in Moderate level of physical activity in leisure time at both examinations (1976-1978 and 1981-1983) had a 3.5 years longer lifespan from age 50 than sedentary persons (Low level). Men engaging in High level of physical activity at both examinations had a 5.0 years longer lifespan. For women the figures were 4.4 (Moderate level) and 4.3 (High level), respectively.

Men and women 20-79 years of age, who increased their physical activity from Low (1976-1978) to Moderate/High (1981-1983) had a significantly lower risk of death than participants reporting Low physical activity at both examinations. If men 65-70 years of age increased their physical activity from Low to Moderate/High level between the two examinations five years apart, they survived 4.4 years longer than men with low physical activity at both examinations. For women at the same age the figure was 3.4 years. Thus it is never too late to take up physical exercise. Due to small number of deaths in the younger age groups it was not possible to calculate differences in survival. We concluded, that all men and women should be encouraged to engage in physical activity at least at a moderate level (Publication 4).

Physical activity in both sexes was associated with significantly lower mortality from coronary heart disease, cancer and all-causes. Men with sustained High level physical activity in leisure time survived 6.8 years longer, and men with moderate activity 4.9 years longer than men with Low activity level. For women the figures were 6.4 and 5.5 years, respectively (Publication 5).

The relative intensity and not the duration of walking was significantly associated to all-cause mortality. Thus our general recommendation to all adults would be that brisk walking is preferable to slow (Publication 6).

Men as well as women who are physically active in leisure time are less prone to stress and life dissatisfaction than sedentary persons. Joggers had the lowest level of stress and life dissatisfaction, but the largest advantage was seen between the Low and Moderate level of activity (Publication 7).

The observed inverse association between physical activity in leisure time and mortality might be explained by the fact that individuals being physically active are more healthy, have a healthier lifestyle, and thus live longer than sedentary persons. This important matter is discussed in the thesis.

NUMBER OF JOGGERS AND SEDENTARY PERSONS IN DENMARK SINCE 1969

The first jogging campaign in Denmark began with Eremitageløbet in 1969, which was the first jogging-race in Europe. This yearly race was the main event promoting jogging to the Danes, and thus hopefully postpone coronary heart disease. The campaign was initiated by private persons and implemented in collaboration with the newspaper B.T. The expenses were minor, but the outcome large. In 1969 there were only few joggers in Denmark, the number has been estimated to be around 10,000 at that time. Since then the number of joggers have increased immensely to more than a million, and the number of jogging-races in Denmark, are approximately 900 (in 2007). Of great importance for this campaign was the support by The Danish Heart Foundation, which chairman Professor Tybjærg Hansen started the race and participated in the race the first 25 years. In 1970 The Heart Foundation launched a pamphlet "Motion – en daglig hjertestyrkning" to motivate the sedentary Dane to start up with exercise, emphasizing jogging. The pamphlet was printed in 160,000 copies, and was also translated to English ("Man is made to move"). In 1975 the pamphlet was revised and printed in 100, 000 copies, and in 1985 the Heart Foundation launched a third pamphlet to once more motivate for jogging, this was printed in 355,000 copies.

Based on the percentage of joggers aged 20-79 years in The Copenhagen City Heart Study the following numbers of joggers in Denmark have been estimated:

1976-1978:	140,000
1981-1983:	325,000
1991-1994:	449,000
2001-2004:	1,205,000 million men and women

A Gallup-investigation concluded, that 600,000 adults were joggers in Denmark in 1983. This finding points to our figures as underestimating the number of joggers in Denmark.

Based on figures from The Copenhagen City Heart Study the percentage of sedentary Danes has declined since 1976-1978

Percent of sedentary Danes (Almost completely sedentary or < 2 hours of light physical activity in leisure time per week).

Age-groups	1976-1978	1981-1983	1991-1994	2001-2003
Women				
20-24	7,1	8,9	4,9	3,2
50-54	18,6	17,1	10,1	8,0
70-74	30,4	26,3	14,8	9,3
Men				
20-24	14,3	2,2	4,0	7,0
50-54	19,0	15,0	12,0	12,3
70-74	22,2	17,9	12,8	7,1

Since 1976 the percentage of sedentary Danes has decreased 2-3 folds, more so in women than in men.

The National Institute of Public Health
has found the same tendency:

Sedentary persons (%).

1987	1994	2000	2005
21.2	15.5	16.3	12.9

Thus the percentage of sedentary Danes has decreased within the last 30 years, but it should be underlined, that 10 to 15% of middle-aged and elderly men, and 10-15% of elderly women are still sedentary. Thus the results from The Copenhagen City Heart Study show that adult Danes are more physically active now, compared to the 1970's. As this review is concerning men and women 20 years or older, I am not going to comment on the physical behaviour in the Danish children.

The Copenhagen City Heart Study Leisure time Physical Activity Questionnaire, 1976-1978:

40. Hvis De skal anføre Deres FYSISKE AKTIVITET I FRITIDEN **herunder transport til og fra arbejde** indenfor det sidste år, i hvilken gruppe mener De så, De skal placeres (sæt kun ét kryds):

I. Næsten helt fysisk passiv
eller
let fysisk aktiv i mindre end 2 timer pr. uge .... ☐
f. eks. læsning, fjernsyn, biograf.

II. Let fysisk aktivitet fra 2–4 timer pr. uge .... ☐
f. eks. spadsereture, cykelture, let havearbejde, let motionsgymnastik.

III. Let fysisk aktivitet i mere end 4 timer pr. uge
eller
mere anstrengende fysisk aktivitet i 2–4 timer pr. uge . ☐
f. eks. hurtig gang og/eller hurtig cykling (hvor man overhaler andre), tungt havearbejde, hård motionsgymnastik, hvor man sveder eller bliver forpustet.

IV. Mere anstrengende fysisk aktivitet i mere end 4 timer
eller
regelmæssig hård træning og evt. konkurrencer flere gange pr. uge .... ☐

41. Er De motions- eller konkurrenceløber .... Ja ☐ Nej ☐

The Copenhagen City Heart Study Leisure Time Physical Activity Questionnaire, 1981-1983:

49b. Hvis De skal anføre Deres FYSISKE AKTIVITET I FRITIDEN **herunder transport til og fra arbejde** indenfor det sidste år, i hvilken gruppe mener De så, De skal placeres (sæt kun ét kryds):

1. Næsten helt fysisk passiv
eller
let fysisk aktiv i mindre end 2 timer pr. uge .... ☐
f. eks. læsning, fjernsyn, biograf.

2. Let fysisk aktivitet fra 2–4 timer pr. uge .... ☐
f. eks. spadsereture, cykelture, let havearbejde, let motionsgymnastik.

3. Let fysisk aktivitet i mere end 4 timer pr. uge
eller
mere anstrengende fysisk aktivitet i 2–4 timer pr. uge ☐
f. eks. hurtig gang og/eller hurtig cykling (hvor man overhaler andre), tungt havearbejde, hård motionsgymnastik, hvor man sveder eller bliver forpustet.

4. Mere anstrengende fysisk aktivitet i mere end 4 timer
eller
regelmæssig hård træning og evt. konkurrencer flere gange pr. uge .... ☐

50. Er De motions- eller konkurrenceløber .... Ja ☐ Nej ☐

Hvis ja, hvor mange timer løber De gennemsnitligt per uge ☐ timer

51. Hvor mange timer cykler De gennemsnitligt om ugen:

i vinterhalvåret ☐

i sommerhalvåret ☐

The Copenhagen City Heart Study Physical Activity in Leisure time Questionnaire, 1991-1994

90. Anfør Deres FYSISKE AKTIVITET I FRITIDEN
(Herunder transport til og fra arbejde inden for det sidste år). (Sæt kun ét kryds)

1. Næsten helt fysisk passiv eller let fysisk aktiv i mindre end 2 timer pr. uge
f.eks. læsning, fjernsyn, biograf ¹☐

2. Let fysisk aktivitet fra 2-4 timer pr. uge
f.eks. spadsereture, cykelture, let havearbejde, let motionsgymnastik ²☐

3. Let fysisk aktivitet i mere end 4 timer pr. uge eller mere anstrengende fysisk aktivitet i 2-4 timer pr. uge.
f.eks. hurtig gang og/eller hurtig cykling tungt havearbejde, hård motions gymnastik, hvor man sveder eller bliver forpustet. ³☐

4. Mere anstrengende fysisk aktivitet i mere end 4 timer eller regelmæssig hård træning og evt. konkurrencer flere gange pr. uge ⁴☐

	Ja	Nej
Hvis kryds ved 3 eller 4:		
Indgår der vægtløftning eller tungere styrketræning?	☐	☐

The Copenhagen City Heart Study Physical Activity in Leisure time Questionnaire, 1991-1994

91. Anfør det antal timer De CYKLER OG GÅR i gennemsnit pr. dag

GANG	Sommer	Vinter	
Aldrig	☐	☐	0
under ½ time	☐	☐	1
½- 1 time	☐	☐	2
1- 2 timer	☐	☐	3
over 2 timer	☐	☐	4

CYKLING	Sommer	Vinter	
Aldrig	☐	☐	0
under ½ time	☐	☐	1
½- 1 time	☐	☐	2
1- 2 timer	☐	☐	3
over 2 timer	☐	☐	4

Mit gangtempo er:

Langsomt	☐	1
Almindeligt	☐	2
Hurtigt	☐	3
Meget hurtigt	☐	4

Mit cykeltempo er:

Langsomt	☐	1
Almindeligt	☐	2
Hurtigt	☐	3
Meget hurtigt	☐	4

92. Dyrker De:	Ja	Nej	**Hvis Ja:** Antal minutter pr. uge
Motionsløb	☐	☐	________
Gymnastik	☐	☐	________
Svømning	☐	☐	________
Tennis	☐	☐	________
Badminton	☐	☐	________
Fodbold	☐	☐	________
Håndbold	☐	☐	________
Helsestudie	☐	☐	________
Vægtløft	☐	☐	________
Andet: ________			________

93. Hvorledes bedømmer De Deres fysik i forhold til Deres jævnaldrende:

	Samme	Bedre	Dårligere
Kondition	☐ 1	☐ 2	☐ 3
Muskelstyrke	☐	☐	☐

	Ja	Nej
94. Har De inden for det sidste år ændret Deres motionsvaner markant?	☐	☐

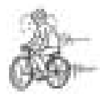
Hvis Ja: Mere motion ☐ 1 Mindre motion ☐ 2

The Copenhagen City Heart Study Leisure time Physical Activity Questionnaire, 2001-2003:

61. Angiv Deres FYSISKE AKTIVITET I FRITIDEN (herunder transport til og fra arbejde) **indenfor det sidste år (Sæt kun ét kryds)**

I. Næsten helt fysisk passiv eller let fysisk aktiv i mindre end 2 timer pr. uge
f.eks. læsning, fjernsyn, biograf ☐

II. Let fysisk aktiv fra 2 - 4 timer pr. uge
f.eks. spadsereture, cykelture, let havearbejde, let motionsgymnastik ☐



III. Let fysisk aktiv i mere end 4 timer pr. uge eller mere anstrengende fysisk aktivitet i 2 - 4 timer pr. uge
f.eks. hurtig gang og/eller hurtig cykling, tungt havearbejde, hård motionsgymnastik, hvor man sveder eller bliver forpustet ☐

IV. Mere anstrengende fysisk aktivitet i mere end 4 timer pr. uge eller regelmæssig hård træning og evt. konkurrencer flere gange pr. uge ☐

	Ja	Nej
Hvis kryds ved III eller IV: Indgår der vægtløftning eller tungere styrketræning ?	☐	☐
62. Har De inden for det sidste år ændret Deres motionsvaner markant ?	☐	☐

Hvis Ja: Til mere motion ☐ Til mindre motion ☐

63. Hvorledes bedømmer De Deres fysik i forhold til Deres jævnaldrende ?

Kondition:	Samme ☐	Bedre ☐	Dårligere ☐
Muskelstyrke:	Samme ☐	Bedre ☐	Dårligere ☐

64. Anfør **antal timer** De går, cykler og løber i gennemsnit, samt hvad Deres tempo er

	GANG **pr. dag**		CYKLING **pr. dag**		LØB **pr. uge**	
	Sommer	Vinter	Sommer	Vinter	Sommer	Vinter
Aldrig	☐	☐	☐	☐	☐	☐
< ½ time	☐	☐	☐	☐	☐	☐
½ - 1 time	☐	☐	☐	☐	☐	☐
1 - 2 timer	☐	☐	☐	☐	☐	☐
3 - 4 timer	☐	☐	☐	☐	☐	☐
> 4 timer	☐	☐	☐	☐	☐	☐

	Mit gangtempo er	Mit cykeltempo er	Mit løbetempo er
Langsomt	☐	☐	☐
Almindeligt	☐	☐	☐
Hurtigt	☐	☐	☐
Meget hurtigt	☐	☐	☐

Hvis De løber: Hvor mange gange løber De i gennemsnit pr. uge ? Antal: _____

Jogging. The Copenhagen City Heart Study 1976-2003. 1st examination (1976-1978), 2nd examination (1981-1983), 3rd examination (1991-94), 4th examination (2001-2003).

Examination	Jogging, % 1st	Jogging, % 2nd	Jogging, % 3rd	Jogging, % 4th	
				summer	winter
Females					
20-24	2.4	8.2	21.3	56.4	43.6
25-29	3.0	4.9	16.6	57.2	39.3
30-34	4.1	5.8	13.3	47.3	34.0
35-39	2.5	2.6	11.0	32.6	20.9
40-44	1.7	3.0	8.2	32.1	23.6
45-49	1.7	1.8	6.5	23.8	17.6
50-54	1.2	1.2	2.9	19.2	14.2
55-59	0.7	1.0	2.8	13.1	9.8
60-64	0.3	0.5	0.5	8.1	5.6
65-69	0.3	0.2	0.1	3.6	3.3
70-74	0.0	0.2	0.1	0.5	0.5
75-79	0.0	0.4	0.2	1.3	0.8
80-	0.0	0.0	0.0	0.5	0.7
Males					
20-24	19.0	28.3	36.0	78.9	68.4
25-29	12.7	21.3	34.5	64.5	57.3
30-34	8.3	16.7	28.5	68.0	57.3
35-39	5.8	9.2	17.7	56.6	50.9
40-44	6.0	10.0	10.3	46.7	41.2
45-49	5.0	6.1	8.5	39.4	35.7
50-54	3.9	4.1	7.0	24.2	20.3
55-59	2.2	3.0	3.9	18.3	15.0
60-64	1.8	1.1	2.3	15.5	12.8
65-69	2.2	2.3	1.9	10.9	10.1
70-74	0.7	0.6	1.1	5.2	4.4
75-79	0.0	0.5	0.9	3.6	2.6
80-	0.0	0.0	0.5	2.1	1.3
Total	14.199	12.682	9.983	6.123	6.124

Physical activity in leisure time - The Copenhagen City Heart Study 1976-2003. 1st examination (1976-1978), 2nd examination (1981-1983), 3rd examination (1991-1994), 4th examination (2001-03)

Examination	Inactive or light activity <2 h/week, %				Light activity 2-4 h/week, %				Light activity >4 h/week or heavy activity 2-4 h/week, %				Heavy activity >4 h/week, %			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Females																
20-24	7.1	8.9	4.9	3.2	55.1	34.1	45.9	38.9	36.2	50.4	44.3	41.1	1.6	6.5	4.9	16.8
25-29	7.5	7.7	9.0	6.9	64.5	55.6	40.7	31.6	26.5	33.1	42.7	51.7	1.5	3.5	7.5	9.8
30-34	14.0	2.3	6.0	6.3	63.2	56.1	51.2	34.7	21.6	38.2	40.0	51.6	1.2	3.5	2.8	7.4
35-39	13.1	11.5	8.0	10.9	60.9	52.6	57.7	49.6	24.7	35.3	31.0	37.2	1.3	0.6	3.3	2.3
40-44	18.5	13.4	10.7	9.6	59.1	54.8	56.7	49.2	20.9	30.0	31.1	39.1	1.4	1.8	1.5	2.0
45-49	21.6	16.4	9.6	7.4	56.4	58.7	54.5	54.1	21.2	24.0	34.1	35.8	0.7	0.9	1.9	2.7
50-54	18.6	17.1	10.1	8.0	62.4	56.9	57.9	50.5	18.3	24.8	30.0	38.9	0.7	1.2	2.1	2.7
55-59	20.0	19.6	11.6	5.0	58.4	51.7	62.3	61.2	21.0	28.0	24.7	32.0	0.5	0.6	1.4	1.8
60-64	20.0	15.9	12.8	6.3	59.5	54.2	57.8	58.3	20.0	28.8	27.9	32.1	0.5	1.1	1.6	3.3
65-69	24.5	20.3	12.5	7.8	55.3	51.7	59.9	56.2	19.8	26.9	25.1	32.9	0.4	1.1	2.4	3.1
70-74	30.4	26.3	14.8	9.3	50.3	44.7	63.9	59.8	19.2	28.0	20.0	29.1	0.0	1.0	1.3	1.8
75-79	30.7	34.9	19.8	13.8	53.4	40.3	62.2	62.3	15.9	22.7	17.6	22.5	0.0	2.1	0.4	1.3
80-	49.1	45.9	33.5	17.9	45.5	32.8	55.3	64.4	5.5	19.7	10.6	15.8	0.0	1.6	0.6	1.9
Males																
20-24	14.3	2.2	4.0	7.0	34.9	25.0	22.7	17.5	38.9	60.9	52.0	47.4	11.9	12.0	21.3	28.1
25-29	12.7	4.4	8.1	2.7	46.5	36.0	29.7	30.0	30.6	42.6	41.2	45.5	10.2	16.9	20.9	21.8
30-34	19.0	11.3	5.7	4.0	47.0	41.3	33.0	32.0	28.0	38.0	47.6	49.3	6.0	9.3	13.7	14.7
35-39	16.9	14.5	11.6	5.7	46.1	34.7	43.0	39.6	32.0	45.7	36.3	42.5	4.9	5.2	9.2	12.3
40-44	16.9	15.5	13.3	8.2	48.5	41.9	49.2	44.5	31.4	36.2	33.3	40.1	3.2	6.4	4.2	7.1
45-49	19.6	16.2	15.9	10.6	48.1	45.2	44.2	40.1	29.7	34.7	35.7	41.9	2.5	3.9	4.3	7.5
50-54	19.0	15.0	12.0	12.3	52.1	44.6	51.0	42.1	26.4	36.6	34.4	42.6	2.5	3.8	2.6	3.0
55-59	20.5	19.8	12.2	10.3	49.6	44.9	52.3	49.4	27.9	32.7	31.2	34.6	2.0	2.6	4.3	5.7
60-64	22.7	15.1	12.7	7.9	49.8	44.8	49.0	44.2	26.2	38.0	34.0	41.8	1.3	2.1	4.2	6.1
65-69	22.7	15.4	14.5	12.7	50.4	40.8	44.5	45.6	25.1	42.4	37.2	35.1	1.8	1.3	3.9	6.6
70-74	22.2	17.9	12.8	7.1	48.4	42.7	49.8	49.2	28.1	37.5	34.3	38.6	1.3	1.8	3.1	5.1
75-79	40.5	25.8	19.6	14.3	39.2	38.1	46.2	59.7	20.3	35.6	30.6	23.5	0.0	0.5	3.7	2.6
80-	43.8	40.9	24.7	15.1	38.4	31.8	50.2	57.7	17.8	27.3	23.3	25.5	0.0	0.0	1.8	1.7
Total	14.207	12.689	9.990	6.173												

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