Occurrence of Chronic Disease in Former Top-Level Athletes
Predominance of Benefits, Risks or Selection Effects?

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Abstract

Former elite athletes from most sports disciplines have lower overall morbidity risk and enjoy better self-rated health in later years compared with the general population and matched controls who were healthy at young age. This is seen particularly among former endurance athletes who have a lower incidence of coronary heart disease and type 2 diabetes mellitus. Most often data are available only for men. Based on the available data, participation in elite sports cannot be regarded as an overall health hazard. However, aside from a high risk of acute injury in specific sports, possible negative effects of long-standing athletic activity on the development of osteoarthritis should not be neglected. It should also be remembered that elite athletes are a biologically and genetically select group who are not representative of the population at large. Given the nature of the available data, the possible health consequences of recent changes in different characteristics of sports, such as training practices, professionalism and use of doping, cannot be properly predicted.

The available, mostly observational, data indicate that physical activity is associated with numerous health benefits, such as lower incidence of cardiovascular disease,1 and type 2 diabetes mellitus.2 The amount of exercise necessary for acquiring health benefits through positive effects on factors such as plasma lipid levels3 is widely studied; however, there is no overall consensus on whether there are individual specific threshold levels for the intensity in the lower and higher limits of beneficial exercise levels.4 In addition, acute complications tend to increase with increasing vigour of the activity.

Health benefits and risks of very vigorous activity are still to be studied and are currently under intensive discussion. Public discussions on the health benefits of participation in sports often start from casual and casuistic observations in well known sports stars and ignore available evidence of the physiological effects of different types of sports. Often the focus is on observations based on potential health hazards of top-level athletes using doping or on participation in especially dangerous sports, such as motor racing. Regarding the overall health effects of long-lasting athletic activity, a comprehensive synthesis of all its aspects is currently lacking.
One important issue is that the prospective studies on population samples do not involve useful numbers of very active men and women to study the health effects of very vigorous activity and do not justify conclusions on the most active individuals, such as elite athletes. One exception is the cohort study of the Finnish former elite athletes,[5] which has documented lower lifetime risks for many diseases but also significant health hazards. Based on this cohort, and supplementing the results with other data available, we try to critically evaluate the balance of these different health effects for former elite athletes, keeping in mind the potential role of genetic and other selection effects.

Special emphasis has to be placed on correct interpretation of the sport-health relationship. Many health habits, such as smoking and diet, are differently distributed between athletes and non-athletes and this makes it extremely difficult to establish cause-effect relationships between vigorous activity and future disease based on observational studies alone. Also, genetic selection may play an until now underestimated role because top level athletes are a selected group regarding both physical fitness, many other risk factors and morbidity.

This article summarises the currently available evidence on the occurrence (incidence or prevalence) of chronic disease among former elite athletes, discusses the limitations of present findings and offers some speculations on future health issues of elite athleticism. When analysing the occurrence of disease among former elite athletes we have to keep in mind that the life expectancy of former male athletes in particular that of endurance athletes, has usually been documented to be higher than that of non-athletes; however, this has not been seen in cohorts of individuals who only have participated in collegiate sports at university.[6,7]

1. Data Sources

This article summarises data on the occurrence of disease among former elite athletes, differentiating athletes participating in different types of sports. Another paper focuses on permanent disabilities caused by acute injuries during elite athletic careers.[8] The main body of evidence for this article is based on the Finnish male former elite athlete cohort. To complete the findings with data available from the scientific literature on other studies on former elite athletes, we have performed extensive literature searches using Medline database among others, and using the terms ‘sports’ and ‘athlete’ as well as terms for different diseases. Data on collegiate athletes are only included if the sports activity of students was shown to be comparable to the level of national team members.

In brief, for the Finnish former athlete cohort, male athletes who had represented Finland at least once at the Olympic games, world or European championships, or other international competitions between 1920 and 1965 in selected sports were identified.[5] Controls were selected from Finnish men who at about 20 years of age had been classified as completely healthy (military class AI, fully fit for ordinary military service) at the medical examination preceding their conscription. The original cohort of athletes included 2401 men and the control group of 1712 men. For many of the studies, the selected sports were grouped based on their ranking in terms of average maximal oxygen uptake (VO2max) as follows: endurance sports (highest VO2max: long-distance runners and cross-country skiers), mixed sports (medium VO2max: soccer, ice hockey, basketball, track and field jumpers, and short-distance runners), and power sports (lowest VO2max: weight lifters, wrestlers, boxers and track and field throwers). In 1985, 1995 and 2002, questionnaires on health-related outcomes and disease risk factors were sent to the surviving cohort members. In addition to repeated questionnaire studies, the long-term follow-up of occurrence of disease manifestations among the Finnish athlete cohort has been accomplished by record linkage to the hospital discharge registry, reimbursable medication registry, cancer registry and death certificates covering all residents of Finland (for details of the registries, see specific reports on different diseases[5,10-12]).
Chronic Disease in Former Top-Level Athletes

Table I. Relative risk (95% confidence interval) of different diseases and use of hospital care in the cohort of Finnish male former elite athletes compared with controls a

<table>
<thead>
<tr>
<th>Disease</th>
<th>Endurance sports (long-distance running, cross-country skiing)</th>
<th>Mixed sports (soccer, ice hockey, basketball, track and field short distance and jumping events)</th>
<th>Power sports (boxing, wrestling, weight lifting, track and field throwers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary heart disease b</td>
<td>0.33 (0.18–0.61)</td>
<td>0.64 (0.45–0.90)</td>
<td>0.73 (0.51–1.03)</td>
</tr>
<tr>
<td>Diabetes b</td>
<td>0.24 (0.07–0.81)</td>
<td>0.52 (0.29–0.92)</td>
<td>1.21 (0.75–1.95)</td>
</tr>
<tr>
<td>Hypertension b</td>
<td>0.70 (0.45–1.09)</td>
<td>0.86 (0.65–1.13)</td>
<td>0.70 (0.52–0.94)</td>
</tr>
<tr>
<td>Cardiac insufficiency c</td>
<td>0.49 (0.34–0.71)</td>
<td>0.47 (0.36–0.61)</td>
<td>0.83 (0.66–1.04)</td>
</tr>
<tr>
<td>Asthma d</td>
<td>0.64 (0.21–1.10)</td>
<td>0.68 (0.32–1.41)</td>
<td>0.68 (0.31–1.50)</td>
</tr>
<tr>
<td>Chronic bronchitis d</td>
<td>0.48 (0.21–1.10)</td>
<td>1.07 (0.70–1.64)</td>
<td>0.94 (0.59–1.50)</td>
</tr>
<tr>
<td>Emphysema e</td>
<td>0.73 (0.31–1.72)</td>
<td>0.46 (0.23–0.92)</td>
<td>0.49 (0.29–0.83)</td>
</tr>
<tr>
<td>Osteoarthritis of hip, knee or ankle e</td>
<td>2.42 (1.26–4.68)</td>
<td>2.37 (1.32–4.24)</td>
<td>2.68 (1.51–4.15)</td>
</tr>
<tr>
<td>All-cause use of hospital f</td>
<td>0.71 (0.70–0.73)</td>
<td>0.86 (0.85–0.87)</td>
<td>0.95 (0.94–0.96)</td>
</tr>
</tbody>
</table>

a The original cohort included 2401 male athletes who represented Finland between 1920–1965 in selected sports, and 1712 matched controls who were healthy at the age of 20 years.[5]

b Odds ratios adjusted for age, occupational group, body mass index and smoking.[10]
c Hazard ratios for need of reimbursable medication due to chronic cardiac insufficiency.[14]
d Odds ratios adjusted for age, occupational group, smoking and exposure to chemicals.[15]
e Hazard ratios for admissions to hospital due to lower-limb joint osteoarthritis adjusted for age, occupational group and body mass index.[16]
f Rate ratios adjusted for age and occupational group.[11]

2. Findings on the Occurrence of Chronic Diseases Among Former Elite Athletes

2.1 Coronary Heart Disease

After adjustments for age, body mass index, smoking status and occupational group, the odds ratio for coronary heart disease was 0.33 (95% confidence interval [CI] 0.18–0.61) in Finnish male former endurance athletes compared with matched controls who were healthy at the age of 20 years (table I).[10] In former athletes from mixed sports, the odds ratio was 0.64 and in power athletes 0.73 (table I). In a further follow-up, both a previous aptitude for endurance athletic events and continuity of vigorous physical activity was associated with protection against coronary heart disease.[13]

2.2 Cardiac Insufficiency

Based on the need of reimbursable medication at middle- and old-age, the occurrence of chronic cardiac insufficiency was about 50% lower among former Finnish athletes compared with controls (table 1).[14] More studies are needed to document which types of cardiac insufficiency can be prevented by physical activity.

2.3 Diabetes Mellitus

After adjustments for age, body mass index, smoking status and occupational group, the odds ratio for diabetes mellitus was 0.24 (95% CI 0.07–0.81) in Finnish male former endurance athletes compared with matched controls who were healthy at the age of 20 years (table I).[10] In former athletes from mixed sports, the odds ratio was 0.52, but the odds ratio of power athletes did not differ from controls (table I).

2.4 Hypertension

Among the Finnish former elite athlete cohort, in 1985 there were no statistically significant differences between the athlete groups and controls in the prevalence of hypertension (table I).[10] The cumulative 10-year incidence of hypertension between 1986 and 1995 was significantly lower in the endurance and mixed sports group (23.6%) compared with the power sports group (33.3%) and the control
group (32.0%). This trend remained after adjustment for age, later physical activity, body mass index and use of alcohol, but was statistically non-significant after these adjustments.

Earlier studies on the blood pressure levels among athletes during their athletic career have usually not shown significant differences compared with control groups. However, Lange-Andersen and Elvik reported low levels among soccer players compared with controls, and Lehmann and Keul reported lower levels among all male athletes compared with population values. Also, in the study of Lehman and Keul, weight lifters had higher prevalence of increased blood pressure values compared with ball games and endurance athletes, which is in accordance with the data on former Finnish elite athletes. In accordance, Pyörälä et al. have earlier shown that former endurance athletes have low blood pressure levels.

2.5 Pulmonary Diseases

The prevalence of pulmonary diseases (asthma, chronic bronchitis and emphysema) among former Finnish athletes was low in 1985 compared with controls who were healthy at the age of 20 years (table I). However, during the last decade, the prevalence of asthma and/or exercise-induced asthma has been reported to be higher in elite athletes than in the general population. Follow-ups of athletes with asthma-like symptoms are needed to study whether the symptoms persist after the athletic career.

2.6 Cancer

Compared with the Finnish population, male former elite athletes had less cancers (standardised incidence ratio [SIR] 0.82, 95% CI 0.73–0.91), which was mainly explained by smoking-related cancers being less common in athletes who smoke less. There was a decreased risk of lung cancer (SIR 0.35, 95% CI 0.25–0.48). Also, the risk for kidney cancer was reduced.

2.7 Osteoarthritis and Related Disability at Old Age

Based on many studies on male and female former athletes, the development of premature osteoarthritis in weight-bearing lower-limb joints is a common clinically-significant adverse effect of vigorous physical activity. The risk of developing premature osteoarthritis is associated with the occurrence of joint injuries and the mode of activity. Among endurance athletes, the prevalence of osteoarthritis was not increased at middle age but after the age of 65 years an increased prevalence was seen (table I). However, osteoarthritis did not cause an increase in disability during old age except for knee osteoarthritis-related disability among former team games athletes. The topic of long-term consequences of sports career on the musculoskeletal system is discussed in more detail in a related review.

2.8 Osteoporotic Fractures

Although physical activity increases bone density, no difference in the occurrence of osteoporotic hip fractures was seen among the Finnish male athletes compared with controls (unpublished data). This may be due to the fact that former athletes having higher life expectancy are more physically active at a very old age and, as a consequence of this, have higher exposure to situations that may cause fractures. According to a study on Swedish former soccer players and controls, there was no group difference in the number of fractures occurring after the age of 50 years. The statistical power of these studies on osteoporotic fractures is low.

2.9 Other Health-Related Outcomes

The vigorously physically active lifestyle usually continues among former elite athletes in later years. The athletes have a higher performance capacity than that of the sedentary population, and physically active individuals also have a decreased age-specific need for hospital care during later years. The athletes also have decreased risk
of occupational disability.[32] During later years, based on the Finnish cohort, controls were more depressed than endurance sport and team sport athletes.[33]

2.10 Former Athletes’ Self-Assessment of Current Health at Old Age

Based on a questionnaire to the Finnish former athletes and controls in 2002 when all the cohort members were aged over 50 years, 15% (95% CI 12–17) of athletes and 7% (95% CI 5–10) of controls rated their general health to be very good (unpublished data). Respectively, 67% (95% CI 64–70) of former athletes and 45% (95% CI 40–50) of controls rated their general health to be at least rather good. Also, a higher proportion (80%) of Swedish former track and field champions than controls (61%) estimated their general health to be good at the age of 50–80 years.[34]

3. Risk of Sudden Death Due to Cardiac Causes During Sports

A physically active lifestyle is associated with lower mortality; however, the relative risk of myocardial infarction and sudden death has been reported to be increased during and after vigorous physical activity.[35,36] Among athletes, the increased risk of death is short-lived. Among the general population, the increase is small in regularly physically active individuals and higher in habitually sedentary individuals.[35,36] Apparently, healthy master endurance athletes participating continuously in competitive sports have a reduced risk of heart attacks compared with healthy non-athletic controls.[37] Accordingly, in later years, the mortality of former endurance athletes who usually continue vigorous physical activity is reduced compared with controls who were healthy at the age of 20 years,[5] as well as compared with the Finnish population.[38]

So far, the specific issue of sudden cardiac death occurring in former elite athletes has not been studied epidemiologically. Based on different case series studies, we know that the causes of sudden death associated with very vigorous activity vary with respect to age. In individuals over 35 years of age, coronary artery disease is the predominant cause of sudden death. In younger individuals, the most common causes include hypertrophic cardiomyopathy, anomalous coronary arteries and arrhythmogenic right ventricular dysplasias, the most common causes possibly being population specific.[39,40] Maron et al.[41] have reported that a blunt impact to the chest can also lead to sudden death from cardiac arrest during sports activities. Even though there are difficulties in doing scientific studies on the misuse of anabolic steroids, an association between the use of anabolic agents and sudden death has been shown among power lifters.[42] The most common reasons for death among athletes abusing high doses of anabolic steroids are heart attacks and suicides.[42] However, it is not exactly known to what extent the misuse of anabolic agents is an underlying cause of hypertrophic cardiomyopathy, a condition linked with increased risk for both arrhythmias and sudden death.[43]

4. Risk-Benefit Balance

The available data show that the prevalence of many chronic diseases are lower among former athletes than controls, but there are also health hazards that cannot be completely neglected. Top-level endurance athletes seem to carry the highest health benefits concerning many chronic diseases. These benefits are clearly higher than among power athletes and also clearly higher than what has been reported for moderately physically active individuals. However, there is probably no level of activity where the benefits are maximal in the absence of any risks. This observation even applies when considering different organ systems. Regarding heart attacks, the lifelong risk cannot be minimised without some exposure to risk of sudden cardiac death or increase in risk of developing atrial fibrillation in later years.[44]

Regarding the musculoskeletal system, high bone density and good muscle function will be maintained until old age in most former athletes; however, some of them will incur an increased risk of osteoarthritis and, especially in females, osteoporotic fractures. Self-rated health can be considered as

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an integrated measure of health benefits and risks. Both Finnish and Swedish former athletes aged over 50 years rated their health better compared with controls. This suggests that the overall impact of elite athleticism and later physically active lifestyle is positive for health. This is in agreement with the observations on lower rate of hospital admissions.[11]

5. Selection Issues

5.1 Vigorous Physical Activity Itself or Other Related Health Habits as Predictors of Disease

Many observational studies show associations between high physical activity and low future morbidity, but may be criticised for selection bias. Many health habits are differently distributed between physically active and sedentary individuals. These include smoking and dietary habits.[5] These health habits tend to be a part of the physically active lifestyle and the study designs do not allow precise conclusions on whether exercise itself or other lifestyle factors act as the ‘true’ biological protective mechanism in athletes. The socioeconomic status (SES) of physically active individuals usually differs from that of sedentary individuals and SES is a strong predictor of mortality.[45,46] All risk factors are not known and can never be measured without error. However, main known confounding factors are documented and statistically adjusted for in the more sophisticated studies, including the Finnish athlete cohort. Therefore, it is scientifically correct to conclude that both selection issues and vigorous physical activity during athletic career as well as high later physical activity level among former athletes contribute to the observed difference in the occurrence of disease between athletes and controls.

5.2 Genetic Selection Explaining High Physical Fitness and Low Morbidity?

It is commonly known that genes modify the risk for many diseases. It is also known that physical fitness has a genetic component.[47] When studying the associations between physical fitness, physical activity and disease we have to remember that physical activity also has a genetic component.[48,49] This is higher for vigorous activity than for low intensity daily physical activity.[49-51] Thus, when interpreting observational studies showing that high physical activity or high physical fitness is associated with lower future morbidity and mortality, we have to consider bias due to genetic selection.[13,51] Genetic selection may make it more easy for some individuals to achieve high levels of physical activity or fitness, as well as favouring them with lower morbidity and mortality. This means that effects observed in elite athletes may not always be generalisable to the population at large.

There may be numerous social, psychological and biological determinants of who is able to exercise vigorously or increase physical activity level in adulthood, and possibly of future disease and death risk, too. Biological characteristics of people who find it difficult to exercise should be compared in more detail to those of people participating in different types of vigorous activity. Today, the genes and their regulatory processes that determine high fitness or high physical activity are not known. For example, genetic factors contribute most to the high intra-individual variability in the proportion of slow-twitch muscle fibres,[52] and this proportion is one potential determinant of both physical activity level and morbidity. The proportion is not only associated with body build, but a high proportion of slow-twitch (oxidative type I) muscle fibres correlates positively with physical fitness, favourable lipid profile (high high-density lipoprotein-cholesterol and low triglyceride levels)[53,54] and with insulin action.[55] Compared with power athletes with a high proportion of fast-twitch (in particular glycolytic type IIb) muscle fibres, endurance athletes have a higher proportion of slow-twitch muscle fibres with high oxidative capacity.[56] Accordingly, men with natural ability in power sports are at higher risk of developing cardiovascular disorders than those with a natural ability in endurance sports.[13,38,57] Consequently, adhering to endurance versus power training may not solely be a matter of personal choice but is probably influenced by genetic factors that may
also be related to specific disease risk factors. This may contribute to at least some of the differences in the documented disease manifestations between power and endurance athletes. In turn, we cannot assume that power athletes would show the same health profile as endurance athletes if they had trained for endurance themselves.

6. Unsettled Issues

6.1 Appropriateness of Data

Traditional epidemiological studies on the effects of very vigorous activity on health have been based on samples drawn from the general population, although usually only a minority of these individuals have in fact been exercising vigorously. The major strength of the Finnish data on former elite athletes is that it is by far the largest longitudinal study with a restrictive definition of elite athlete status, with long-lasting repeated follow-ups, with proper documentation of most disease endpoints relevant to athletic activity as well as potential confounding factors, and with an appropriately sized age-matched control group of men who were healthy at young age. A limitation is that the Finnish study does not include female athletes because during the period 1920–1965 there were not enough female elite athletes in Finland available for study, and no other corresponding studies on female athletes exist. Also, despite repeated documentation of current sports activity status, it is difficult to interpret the role of temporary versus life-long high performance physical activity on health outcomes. More research is needed on this issue, given that secular changes in exercise behaviour have taken place; athlete careers tend to extend into middle age and many recreational athletes engage in training levels that were typical for top athletes some decades ago. In recent years, leisure physical activities of great frequency and intensity have become much more common. We cannot be sure whether all of the findings obtained in the elite athletes who were active four or more decades ago apply in the same way to current elite or recreational athletes. Today, athletes start intensive training already at a younger age than previously, which may bring health benefits and hazards that are not documented in cohort studies starting to follow adult elite athletes.

6.2 Health of Female Athletes

Little can be said on the corresponding benefit-risk balance for female athletes. Physical activity can also provide health benefits among females; however, it is unlikely that very vigorous sports can cause, for example, a similar risk reduction in coronary heart disease due to its lower incidence among females. Recently, much attention has been paid to the ‘female athlete triad’, a condition where amenorrhea, osteoporosis and eating disorders may occur among adolescent and young adult female athletes. The bone-enhancing effect of exercise against osteoporosis is bound to sufficient oestrogen levels, but the risk of stress fractures and later osteoporotic fractures depends on many different factors. On the other hand, athletic activity prevents obesity, type 2 diabetes and disability at later life. More research is urgently needed.

6.3 Increasing Prevalence of Asthma-Like Symptoms

The reported high prevalence of asthma and/or exercise-induced asthma in active elite athletes may be partly due to the methods and/or the criteria used to identify asthma. In addition, many athletes report asthma-like bronchial symptoms, especially in endurance events. These bronchial symptoms may be more related to (irritant) bronchitis due to environmental factors than to asthma. Based on observations on former Finnish athletes it seems that participation in ‘asthmogenic’ sports such as running (high ventilation) and cross-country skiing (high ventilation with a cold dry environment) does not lead to excess prevalence of chronic asthma or other chronic pulmonary disease after the athletic career. Because most studies of asthma in athletes are cross-sectional, more follow-up studies are needed to clarify the importance of recent findings of increased prevalence of asthma and symptoms like asthma in elite athletes.
6.4 The Effect of Doping

The health consequences of doping cannot be estimated properly. The short-term use of many doping agents with low doses seems not to be detrimental to health, but first studies examining long-term consequences on doping use show an increased risk of specific disease and death among those who are using anabolic agents. The problem is that top-level athletes will not report their doping practices, which in addition may change very rapidly. This makes an accurate estimation of the health hazards virtually impossible. Also, it is unlikely that the possibly underlying doping abuse will be recognised as a reason if a severe health complication occurs in a top athlete. In case the disease profile of former athletes changes in the future, the use of doping should be considered as one contributing factor.

7. Conclusions

Former elite athletes from most sports disciplines seem to carry a lower overall morbidity risk and enjoy better subjective health in later years compared with matched controls and the general population. This is seen particularly among former endurance athletes. Based on the available data, elite sports cannot be regarded as an overall health hazard for athletes. However, aside from a very high risk of acute injury in specific sports, possible negative effects of long-standing athletic activity on the development of osteoarthritis should not be neglected. Future studies will show whether the health of today’s athletes remains consistently better compared with the general population as has been observed during the second half of the 20th century.

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