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Review

Mortality and longevity of elite athletes

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Abstract

The health benefits of leisure-time physical activity are well known, however the effects of engaging in competitive sports on health are uncertain. This literature review examines mortality and longevity of elite athletes and attempts to understand the association between long-term vigorous exercise training and survival rates. Fourteen articles of epidemiological studies were identified and classified by type of sport. Life expectancy, standardised mortality ratio, standardised proportionate mortality ratio, mortality rate, and mortality odds ratio for all causes of death were used to analyse mortality and longevity of elite athletes. It appears that elite endurance (aerobic) athletes and mixed-sports (aerobic and anaerobic) athletes survive longer than the general population, as indicated by lower mortality and higher longevity. Lower cardiovascular disease mortality is likely the primary reason for their better survival rates. On the other hand, there are inconsistent results among studies of power (anaerobic) athletes. When elite athletes engaging in various sports are analysed together, their mortality is lower than that of the general population. In conclusion, long-term vigorous exercise training is associated with increased survival rates of specific groups of athletes.

Keywords: Epidemiology; Death; Exercise training; Endurance; Power

Contents

1. Introduction

Physical activity performed at moderate intensity during leisure time is associated with the reduced risk of all-cause mortality in the general population.[1] Specifically, moderate-intensity physical activity helps to prevent cardiovascular disease, hypertension and some types of cancers (e.g., colon, breast, and lung cancers).[1] In addition, engaging in regular physical activity reduces the risk of overweight and obesity and promotes maintaining a healthy body weight,[1] whereas excess body fat could cause various diseases, including hypertension, high blood cholesterol, type 2 diabetes mellitus and coronary heart disease.[2] Moderate-intensity physical activity is generally defined as activity completed at an intensity of 3.0–5.9 metabolic equivalents (METs), such as brisk walking (i.e., walking at 3.0 mph [80.4 m/min] or faster).[3] According to the 2008 Physical Activity Guidelines for Americans,[3] adults in the general population should accumulate at least 150 min of moderate-intensity physical

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activity per week to gain substantial health benefits. Despite this recommendation, Healthy People 2010[4] reported that 40% of adults aged 18 years and older engage in no leisure-time physical activity.

Although the health benefits of leisure-time physical activity are well documented, the association between vigorous exercise training and mortality/longevity of elite athletes is not fully understood. Longitudinal observations showed that vigorous exercise and sports play had an additional benefit on lowering mortality among former Harvard College students and athletes.[5] On the other hand, Wannamethee and Shaper[6] suggest that moderate physical activity is sufficient to reduce the risk of cardiovascular disease and all-cause mortality, whereas engaging in vigorous physical activity and competitive sports may increase the risk of heart attack.[7,8] According to the American College of Sports Medicine and the American Heart Association, vigorous exercise can transiently increase the risk of sudden cardiac death and acute myocardial infarction, particularly among those with structural cardiac disease (e.g., hereditary or congenital cardiovascular abnormalities, atherosclerotic disease).[9] Because of the lack of understandings, we believed that a comprehensive analysis was necessary on this topic. In particular, the following questions were formulated: (1) do elite athletes live longer than the general population and (2) are survival rates of elite athletes related to specific types of sports? The purpose of this literature review is to examine mortality and longevity of elite athletes who participated in different types of sports and to determine whether long-term vigorous exercise training is associated with higher survival rates.

2. Methods

The inclusion criteria for this review were: (1) the study examined athletes who had experience of competing nationally, internationally, or professionally and (2) the study measured mortality and/or longevity of athletes by comparing them with the general population. If studies followed athletes other than described above (e.g., college athletes, master athletes, and recreational athletes) or did not compare mortality or longevity of athletes with general population controls, they were excluded from this review.

A preliminary literature search was performed using scholastic databases, PubMed (1950–) and Scopus (1960–). Key words, including mortality, longevity, life expectancy, death and (elite/professional) athletes and players, were used to locate research articles for this review paper. Reference lists in the articles identified above were also used to locate additional articles on this topic. An abstract of each article identified by the preliminary literature search was examined for the inclusion and exclusion criteria. Through the abstract review, 17 articles were selected as the studies potentially suited for the current review paper. In addition, 10 more articles for which abstracts were not available on the databases were included, because the above key words (e.g., longevity and athletes) were found in the titles of these articles. Then, full texts of all 27 articles were obtained and examined for further analyses.

Of these 27 studies, 13 studies were excluded for the following reasons: 5 studies did not compare mortality or longevity of athletes with general population controls, 4 studies were not original investigations but review articles, 3 studies were duplicate reports from original investigations and were published in a letter format, and 1 study was not published in English. The remaining 14 studies met the inclusion criteria, were published as journal articles, and were either cohort or case–control studies that are appropriate study designs for investigating the relationship between exposure (i.e., long-term vigorous exercise training) and outcome (i.e., mortality and longevity).

Each of the 14 studies selected for this paper was classified by type of sport: endurance sports (mainly aerobic exercise), mixed-sports (combination of aerobic and anaerobic exercise), and power sports (mainly anaerobic exercise), as done by Sarna et al.[10] This classification was made based on the average maximal oxygen uptake (VO_2max) of athletes in Swedish national teams.[11] Athletes not measured by the Swedish researchers, such as baseball, American football, and rugby players, were ranked according to the average VO_2max obtained from other sources.[12–14] If the study combined athletes engaging in different types of sports and only analysed their overall mortality or longevity, it was categorised into "all-sports." The following measures of mortality and longevity were examined in the selected studies: life expectancy (LE), standardised mortality ratio (SMR), standardised proportionate mortality ratio (SPMR), mortality rate (MR), and mortality odds ratio (OR) for all causes of death.

3. Results

Among the 14 articles reviewed, Sarna et al.[10] examined endurance, mixed-sports and power athletes separately. Consequently, we identified 2 studies for endurance athletes, 3 studies for mixed-sports athletes, 8 studies for power athletes, and 3 studies for all-sports athletes. The main findings of the studies are presented in Table 1. A majority of the studies examined male athletes, whereas two studies included both male and female athletes.

Both studies in Table 1 indicated that long-distance runners and cross-country skiers lived significantly longer than the general population or reference cohorts (LE = 2.8–5.7 years longer; OR = 0.59).[10,15] In particular, the observed deaths among endurance athletes were less than two-thirds of the expected deaths estimated from the general population.[10] Lower numbers of deaths from cardiovascular disease contributed to the better survival rates of these athletes.[10]

Researchers who followed soccer, ice-hockey and basketball players, as well as track and field jumpers, short- and middle-distance runners, and hurdlers, observed that these athletes survived longer than the general population or ref-

Table 1
Studies on mortality and longevity of elite athletes engaging in different types of sports.

Type of sport	Study	Athletes/players	Gender	*N*	Mortality/longevity
Endurance (aerobic)	Karvonen et al. (1974)	Finnish champion skiers born 1845–1910	Male	396	LE: 2.8–4.3 years longer than the calendar period-adjusted general male population in Finland
	Sarna et al. (1993)	Finnish long-distance runners and cross-country skiers competing internationally 1920–1965	Male	303	LE: 5.7 years longer than age- and area of residence-matched reference male cohorts in Finland OR: 0.59 compared with age- and area of residence-matched reference male cohorts in Finland
Mixed-sports (aerobic + anaerobic)	Belli and Vanacore (2005)	Italian soccer players active in the three top leagues 1960–1996	Male	350	SPMR: 1.0 compared with the national death rates specific for sex, age, cause and calendar period
	Sarna et al. (1993)	Finnish soccer, ice hockey, and basketball players, track and field jumpers, short- and middle-distance runners, and hurdlers competing internationally 1920–1965	Male	1,185	LE: 4.0 years longer than age- and area of residence-matched reference male cohorts in Finland OR: 0.90 compared with age- and area of residence-matched reference male cohorts in Finland
	Taioli (2007)	Professional soccer players enrolled in Italian A and B leagues 1975–2003	Male	5,389	SMR: 0.68 compared with age- and calendar period-stratified mortality from the general male population in Italy
Power (anaerobic)	Abel and Kruger (2005)	U.S. major league baseball players debuting 1900–1950	Male	2,604	LE: 4 years longer than age-adjusted controls from the general public
	Abel and Kruger (2006)	U.S. major league baseball players debuting 1900–1939	Male	4,492	LE: 4.8 years longer than age-adjusted controls from the general public
	Abel and Kruger (2006)	U.S. professional American football players debuting prior to 1940	Male	1,512	LE: 6.1 years longer than age-adjusted controls from the general public
	Beaglehole and Stewart (1983)	New Zealand international rugby players since 1884	Male	822	LE: the same survival curve as the general male population in New Zealand
	Metropolitan Life Insurance Company (1975)	U.S. major league baseball players debuting 1876–1973	Male	10,079	SMR: 0.97 for players debuting 1876–1900, 0.64 for players debuting 1901–1930, and 0.55 for players debuting 1931–1973 compared with the general male cohorts in the U.S.
	Parssinen et al. (2000)	Finnish powerlifters placed 1st–5th in weight series 82.5–125 kg in national champions 1977–1982	Male	62	MR: 12.9% compared to 3.1% among the age-matched general male population in Finland during a 12-year follow-up (4.6-fold higher risk of death)
	Sarna et al. (1993)	Finnish weightlifters, wrestlers, boxers, and track and field throwers competing internationally 1920–1965	Male	909	LE: 1.6 years longer than age- and area of residence-matched reference male cohorts in Finland OR: 1.02 compared with age- and area of residence-matched reference male cohorts in Finland
	Waterbor et al. (1988)	U.S. major league baseball players beginning careers 1911–1915	Male	985	SMR: 0.94 compared with the general male population in the U.S.
All-sports	Gajewski and Poznanska (2008)	Polish athletes participating in the twentieth century Olympics since 1924	Male	1,689	SMR: 0.50 compared with the age-specific urban male population in Poland
			Female	424	SMR: 0.73 compared with the age-specific urban female population in Poland
	Menotti et al. (1990)	Italian track and field athletes competing internationally as members of the national team since 1940	Male	700	SMR: 0.73 compared with age-matched general male controls in Italy
			Female	283	SMR: 0.48 compared with age-matched general female controls in Italy
	Schnohr (1971)	Danish athletic champions, record-holders, and members of national teams from 19 different sports born 1880–1910	Male	297	SMR: 0.61 in the life period of 25–49 years, 1.08 in 50–64 years, and 1.02 in 65–80 years compared with the age-matched general male population in Denmark

Notes: LE, life expectancy; MR, mortality rate for all causes of death; OR, mortality odds ratio for all causes of death; SMR, standardised mortality ratio for all causes of death; SPMR, standardised proportionate mortality ratio for all causes of death.

erence cohorts (LE = 4.0 years longer; SMR = 0.68).[10,16] On the other hand, Belli and Vanacore[17] found that Italian professional soccer players had the same death rates as the national averages (SPMR = 1.0). The investigators pointed out that the soccer players had considerably high death rates for diseases of the nervous system mainly from amyotrophic lateral sclerosis (ALS).[17] Dietary supplements or drugs taken by these soccer players to enhance performance were the potential causes of ALS.[17] Similar to endurance athletes, mixed-sports athletes had lower cardiovascular disease mortality than nonathlete counterparts.[10]

In contrast to the better survival rates observed among endurance and mixed-sports athletes, mortality and longevity of power athletes reported across the studies were not consistent. Abel and Kruger in their two studies[18,19] showed that professional baseball players lived about 4–5 years longer than controls from the general public, whereas other studies did not find significant differences in mortality (SMR = 0.94–0.97) between professional baseball players who began their careers prior to 1915 and people from the general population.[20,21] The nonsignificant differences in mortality between the two groups may derive from the birth cohort of the players. During the late 1800s and early 1900s, infectious diseases (e.g., pneumonia, tuberculosis) were the major causes of death,[22] and the protective health effect of playing baseball during those years was probably minimal. On the other hand, baseball players who debuted from 1901 to 1930 and from 1931 to 1973 had lower SMRs (0.64 and 0.55).[20] By this time, chronic diseases (e.g., coronary heart disease and stroke) were more prevalent as the causes of death,[23] and the health benefits of physical activity (i.e., playing baseball) became evident. With regard to athletes other than baseball players, professional American football players were shown to live an average of 6.1 years longer than controls from the general public,[24] whereas New Zealand rugby players had the same LE as the general population.[25] Beaglehole and Stewart[25] hypothesised that the rugby players did not live longer than expected, because they did not maintain high fitness levels after retirement and/or playing rugby itself deteriorated their health. Sarna et al.[10] reported similar mortality and longevity between power athletes (weightlifters, wrestlers, boxers, track and field throwers) and reference cohorts (LE = 1.6 years longer; OR = 1.02). Parssinen et al.[26] observed that 12.9% of Finnish powerlifters died prematurely (mean age of death = 43 years) compared to 3.1% of the age-matched general population during a 12-year follow-up.

Two studies showed that Olympic and national team athletes (males and females) in various sports survived longer than the general population (SMR = 0.48–0.73).[27,28] Schnohr[29] reported that Danish national-level athletes during the life period from 25 to 49 years had the SMR of 0.61 compared with the age-matched general population. Conversely, the SMRs of these athletes from 50 to 64 years old and 65 to 80 years old were 1.08 and 1.02, respectively.[29] The study concluded that the Danish elite athletes survived longer than the general population under the age of 50 years, whereas there were no significant differences in survival rates between the groups after 50 years old.[29] The reason for these inconsistent results was unclear.[29]

4. Discussion

The purpose of this review is to examine the role of long-term vigorous exercise training on mortality and longevity of elite athletes. The findings across the epidemiological studies indicate that long-term vigorous exercise training can positively impact mortality and longevity. Specifically, endurance and mixed-sports athletes tend to survive longer than the general population. Lower cardiovascular disease mortality among these athletes seems to play a major role in their better survival rates. All-sports athletes also have lower mortality than nonathlete counterparts. On the other hand, due to the inconsistent results, it is not possible to determine the effect of exercise training for power athletes on mortality and longevity.

There are possible explanations of increased survival rates among elite athletes. First, elite athletes engage in high volumes of vigorous exercise training. It has been suggested that a higher dose of physical activity has an additional benefit on reducing all-cause mortality (i.e., dose–response relation).[30] Second, high physical fitness levels achieved by elite athletes may explain their better survival rates, as studies have shown an inverse relationship between physical fitness levels and all-cause mortality.[31,32] Research also suggests that physical (cardiorespiratory) fitness and physical activity are independently related to the risks of coronary heart disease or cardiovascular disease.[33] Third, elite athletes are a select group because only the healthiest and fittest individuals are likely to be able to compete at elite levels.[10] The selection of elite athletes may be explained by genetic factors, as current evidence indicates a moderate to substantial genetic influence on physical fitness parameters related to human performance, such as VO_2max and muscular strength/endurance.[34,35] Therefore, it is likely that individuals become elite athletes because of their genetic components associated with high physical fitness, which may provide them with survival advantages.[31,32] Finally, former elite athletes, especially endurance athletes, tend to maintain active and healthy lifestyles later in life, by engaging in more physical activity and smoking less than people in the general population.[36,37] Sarna et al.[10] found that athletes, regardless of sport type, engaged in more leisure-time physical activity or competitive sports (60% or more vs. 17%) and less smoking (47–59% vs. 27%) than reference cohorts during their adult lives. We cannot conclude what factors are responsible for the better survival rates of elite athletes, however all of the factors listed above could improve mortality and longevity.

It is interesting to note the differences in mortality and longevity among athletes engaging in different types of sports. As mentioned previously, endurance and mixed-sports athletes are likely to survive longer than the general population, but that trend is not obvious among power athletes. One possible explanation for this discrepancy is that endurance activities or aerobic exercise may be more effective in lowering mortality, especially from cardiovascular diseases, than power activities or resistance exercise.[38,39] Cardiorespiratory fitness improved by aerobic exercise has been shown to be associated with the reduced risk of chronic diseases (e.g., hypertension, coronary heart disease and type 2 diabetes), whereas the role of resistance exercise, the main component of training for power athletes, on preventing chronic diseases is not well understood.[40] Another potential explanation for lower survival rates of power athletes when compared with endurance or mixed-sports athletes is that former power athletes are at greater risk of being obese and diabetic later in life.[41] Miller et al.[42] also found that the prevalence of metabolic syndrome (e.g., obesity and raised fasting glucose) among professional American football linemen who train similar to power athletes was significantly higher than that among nonlinemen counterparts (59.8% vs. 30.1%) whose activity consists of a combination of aerobic and anaerobic exercise. Evidence shows that obesity, when combined with diabetes, can substantially increase disease-specific mortality.[43,44] In addition, the differences in mortality or longevity between power athletes and other groups of athletes may partly be a result of anabolic steroid use that is frequently reported among weightlifters and powerlifters.[45,46] Parssinen et al.[26] indicated that powerlifters in their study, whose mortality rate was 4.6 times higher than that of the comparison group, were highly suspected to have used anabolic steroids. It has been documented that long-term steroid use causes adverse health consequences (e.g., cardiovascular disease and liver dysfunction) and could result in premature death.[47] This may be why the studies in Table 1 that included weightlifters and powerlifters did not find favorable mortality and longevity.[10,26] More studies will be necessary to understand whether exercise training for power athletes is linked with their mortality and longevity while accounting for steroid use.

There are limitations associated with the current literature review. This paper focuses on the association between long-term vigorous exercise training and survival rates. However, factors other than exercise or physical activity that we did not examine, such as smoking and diet/nutrition, could affect mortality and longevity.[48,49] Besides, a paucity of existing studies on mortality and longevity of elite athletes makes it difficult to develop better understandings on this topic. For instance, we were able to locate only two articles that followed elite endurance athletes, and both studies examined Finnish athletes. In addition, the athletes and players examined in the selected studies were playing/competing mostly in the late 1800s to early/mid-1900s. Thus, the mortality and longevity data from more recent athletes may not be similar to those found in the selected studies. Moreover, only two studies included female athletes, hence it is not known whether the influence of long-term vigorous exercise training on mortality and longevity is the same between male and female athletes. Furthermore, the current review does not take into consideration the training experience (i.e., years) of athletes that may also affect mortality and longevity. Lastly, we do not know if the athletes in the selected studies continued to engage in regular physical activity after their competitive careers, even though former athletes tend to be physically active later in life.[10,36,37] Therefore, it is not known whether elite athletes survive longer because they maintain active lifestyles or because regular physical activity done during youth and young adulthood (i.e., vigorous exercise training during the competitive period) is "banked" and results in enhanced mortality/longevity.

It should also be mentioned that this review paper is "narrative" rather than "systematic." As the first step to understand the association between long-term vigorous exercise training and mortality/longevity, we believed that it would be important to examine various studies and to obtain a broad perspective on the current topic. Therefore, we included studies with different research designs (i.e., case–control and cohort studies) that used different measures of mortality and longevity (i.e., LE, MR, OR, SMR and SPMR). These factors, along with the limited number of existing studies, made it difficult to generate quantitative answers for the current topic, as quantitatively combining the results of studies is an essential feature of a systematic review.[50] As a result, we were only able to develop a qualitative summary of relevant evidence.

In conclusion, elite endurance and mixed-sports athletes appear to survive longer than the general population because of their lower cardiovascular disease mortality. Therefore, long-term vigorous exercise training is associated with increased survival rates of these athletes. The possible factors for the better survival rates of elite athletes are: the dose–response relation between physical activity and mortality, higher physical fitness levels achieved by elite athletes, the natural selection of elite athletes, and active and healthy lifestyles maintained by former athletes. Lower mortality of all-sports athletes suggest that elite athletes, in general, live longer than nonathletes. On the other hand, little consensus exists regarding the benefit of vigorous exercise training on mortality and longevity of power athletes. This may be due to the superiority of aerobic exercise over resistance exercise for lowering mortality, a higher prevalence of obesity and diabetes in former power athletes, and/or anabolic steroid use being prevalent among power athletes. Further studies will be necessary to examine elite athletes from a wide variety of sports. Future research should also be devoted to studying female athletes to determine whether gender has any influence on mortality and longevity of elite athletes.

Practical implications

- Similar to leisure-time physical activity, engaging in competitive sports and vigorous exercise training is generally beneficial to improving mortality and longevity.

- Elite endurance athletes (e.g., distance runners and cross-country skiers) tend to survive longer than people in the general population.
- Elite mixed-sports athletes who perform both endurance and power activities (e.g., soccer, ice hockey, basketball and short- to moderate-term events in track and field) are also likely to live longer than the general population.
- Elite power athletes may survive longer, similar to, or shorter than the general population depending on type of sport and substance use.

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