Elite Athletes Live Longer Than the General Population: A Meta-Analysis

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Abstract

**Objective:** To perform a meta-analysis of cohort studies aimed at providing an accurate overview of mortality in elite athletes.

**Patients and Methods:** We reviewed English-language scientific articles available in Medline and Web of Science databases following the recommendations of the Meta-analyses Of Observational Studies in Epidemiology group. We searched for publications on longevity and professional or elite athletes (with no restriction on the starting date and up to March 31, 2014).

**Results:** Ten studies, including data from a total of 42,807 athletes (707 women), met all inclusion criteria. The all-cause pooled standard mortality ratio (SMR) was 0.67 (95% CI, 0.55-0.81; \(P<.001\)) with no evidence of publication bias (\(P=.24\)) but with significant heterogeneity among studies (\(I^2=96\%\); \(Q=224.46\); \(P<.001\)). Six studies provided data on cardiovascular disease (CVD) and 5 on cancer (in a total of 35,920 and 12,119 athletes, respectively). When only CVD was considered as a cause of mortality, the pooled SMR was 0.73 (95% CI, 0.65-0.82; \(P<.001\)) with no evidence of bias (\(P=.68\)) or heterogeneity among studies (\(I^2=38\%\); \(Q=8.07\); \(P=.15\)). The SMR for cancer was 0.60 (95% CI, 0.38-0.94; \(P=.03\)) with no evidence of bias (\(P=.20\)) despite a significant heterogeneity (\(I^2=91\%\); \(Q=44.21\); \(P<.001\)).

**Conclusion:** The evidence available indicates that top-level athletes live longer than the general population and have a lower risk of 2 major causes of mortality, namely, CVD and cancer.

There is strong epidemiological evidence that regular physical activity (eg, brisk walking and jogging) has great potential in the management and rehabilitation of various diseases and is associated with lower risk of all-cause mortality, cardiovascular disease (CVD), hypertension, stroke, metabolic syndrome, type 2 diabetes, breast and colon cancer, depression, and falling. However, whether the repeated exposure to the highest exercise levels, such as those required in professional sports participation, affects human longevity and disease risk remains an open question. There is growing evidence on the potential arrhythmogenic effects of intense endurance exercise, such as marathon running, in previously healthy people. The debate is fueled by news media reports of sudden death in young athletes and by recent provocative murine research establishing a cause-effect relationship between long-term forced treadmill training and the development of cardiac fibrosis and ventricular arrhythmia. Accordingly, a certain tolerance “threshold” has been proposed after which exercise would no longer be beneficial and might be even harmful to the heart. Some authors recently postulated that strenuous endurance exercise (eg, running) for more than approximately 1 h/d might induce deleterious effects on the human heart.

To determine whether the health benefits of exercise are actually confined (or not) to noncompetitive, moderate (or recreational) practice is of broad medical interest and might help clinicians have more evidence-based data on exercise benefits. Thus, we conducted a meta-analysis of cohort studies comparing mortality in elite athletes with mortality in the general population. We hypothesized that the overall health benefits of competitive exercise would counteract any potential detrimental effect, resulting in higher longevity and lower disease risk in elite athletes than in the general population.
PATIENTS AND METHODS

Data Sources and Searches
We followed the recommendations of the Meta-analyses Of Observational Studies in Epidemiology group9 [see the checklist in Supplemental Appendix 1 (available online at http://www.mayoclinicproceedings.org)]. We searched for publications on longevity and professional or elite athletes (with no restriction on the starting date and up to March 31, 2014). The search terms longevity or survival and professional, elite, or Olympic athletes were used, or combinations of 1 or more of these terms, with restrictions to English-language scientific articles (excluding congress abstracts) indexed in the Medline and Web of Science databases. We also extended the search spectrum to the “related articles” and the bibliographies of all retrieved studies. Once potentially relevant articles were identified, their reference lists and abstracts were retrieved. Two authors independently assessed the records obtained by the search results.

Study Selection
The criteria for including a study in the meta-analysis were as follows: (1) available information on the evaluation of the longevity or survival; (2) athletic cohort composed solely of professional athletes or elite athletes (with the latter implying having experience in international competitions, eg, Olympic Games11); (3) using a cohort study design; and (4) providing standard mortality ratio (SMR) with 95% CI or, alternatively, providing sufficient observed and expected death data to allow this variable to be calculated.

Data Extraction
When the SMR and its 95% CI were not provided directly, they were calculated from the reported observed and expected deaths as SMR = observed death/expected death and its 95% CI = SMR ± 1.96 (observed death/expected death)1/2. We also calculated the inverse variance weighted pooled summary estimates of SMRs (meta-SMRs). The meta-SMR (or “pooled SMR”) represents a summary estimate of the increased risk of death in elite athletes than in the general population, weighted by the inverse of the log variance of SMRs of each study. We used the Newcastle-Ottawa Quality Assessment Scale12 to assess the quality of each study included in the meta-analysis.

Statistical Analyses
All analyses were performed with the Stata statistical software package (version 13, StataCorp, 2010). The meta-SMR was computed using a random effects model, and heterogeneity was tested using the Q and F statistics. Calculations were performed on the log of SMRs from the individual studies, and the resulting pooled values were then transformed back to the SMR scale. Separate meta-SMRs were calculated for CVD and cancer. Because heterogeneity is expected to exist in meta-analyses of observational studies, meta-regression analysis was performed to account for sources of heterogeneity on the basis of causes of mortality. Egger’s tests were used to assess evidence of publication bias. The significance level was set at P<.05.

RESULTS
From an initial identification of 88,192 studies, 88,138 were excluded (ie, not potentially relevant studies, congress abstracts, and duplicated material). From the remaining 54 potentially relevant studies, 44 studies were excluded with reasons, namely, not written in English (n=3), SMR not reported (n=38), and duplicated or nonelite athletic population (n=3).

Ten studies,13-22 including a total of 42,807 athletes (707 women), met all the inclusion criteria (Table). Of a maximum 9-point score, 2 studies had a quality score of 7, 6 had a quality score of 8, and 2 had a quality score of 9. Thus, this meta-analysis included data on (1) professional team sport athletes (85.2% of the total), for example, North American and African American football and baseball players and Italian professional soccer players; (2) Finnish and Polish Olympic athletes of various disciplines (9.6%), namely, power, “mixed,” and endurance events; (3) track and field athletes from Italy (2.7%); (4) European road cyclists, that is, participants in the Tour de France (1.8%); and (5) Olympic (international) level athletes from Denmark participating in heterogeneous disciplines, including team, power, and endurance sports (0.7%).

The all-cause pooled SMR was 0.67 (95% CI, 0.55-0.81; P<.001) with no evidence of publication bias (P=.23) but with significant heterogeneity among studies (I²=96%: Q=224.46; P<.001; Figure 1). Six studies provided data...
on CVD\textsuperscript{13,14,17,18,20,21} and 5 on cancer (in a total of 35,920 and 12,119 athletes, respectively).\textsuperscript{13,17,20-22} The pooled SMR for CVD was only 0.73 (95% CI, 0.65-0.82; \textit{P} < .001) with no evidence of bias (\textit{P} = .68) or heterogeneity among studies (\textit{I}^2 = 38%; \textit{Q} = 8.07; \textit{P} = .15; Figure 2). The SMR for cancer was 0.60 (95% CI, 0.38-0.94; \textit{P} = .03) with no evidence of bias (\textit{P} = .20) but with significant heterogeneity among studies (\textit{I}^2 = 91%; \textit{Q} = 44.21; \textit{P} < .001; Figure 3).

**DISCUSSION**

The results of this meta-analysis indicate that elite athletes live longer than the general population. Such a powerful effect on human longevity is comparable, if not higher, to that reported for vigorous but less competitive exercise. For instance, the all-cause SMR of well-trained recreational athletes (Dutch endurance ice-skaters) was 0.76 (95% CI, 0.68-0.85).\textsuperscript{23}

Growing evidence indicates that intense endurance exercise might produce cardiac alterations (mainly increased risk of atrial fibrillation),\textsuperscript{5-7} and a “safety threshold” has been postulated to exist in competitive sports, especially in endurance events.\textsuperscript{5,6} However, the studies analyzed here as well as other published articles do not support that such type of exercise is overall harmful to the human heart. Recent data indicated 58% lower overall mortality and 57% lower CVD risk in a large cohort of participants in a 90-km cross-country ski race,\textsuperscript{24} which was accompanied

**TABLE. Main Characteristics of the Studies Entered in the Meta-Analysis**

<table>
<thead>
<tr>
<th>Reference, year</th>
<th>Cases</th>
<th>All-cause SMR (95% CI)</th>
<th>SMR due to CVD only (95% CI)</th>
<th>SMR due to cancer only (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baron et al,\textsuperscript{13} 2012</td>
<td>n=3439</td>
<td>National Football League players with &gt;5 pension-credited playing seasons from 1959 to 1988</td>
<td>0.53 (0.48-0.59)</td>
<td>0.68 (0.56-0.81)</td>
</tr>
<tr>
<td>Belli et al,\textsuperscript{14} 2005</td>
<td>n=24,000</td>
<td>Italian professional soccer players active during 1960-1996 in the 3 top leagues (A, B, and C)</td>
<td>1.00 (0.90-1.10)</td>
<td>0.83 (0.69-1.00)</td>
</tr>
<tr>
<td>Gajewski et al,\textsuperscript{15} 2008</td>
<td>n=2113 (424 women)</td>
<td>All Polish participants in all Olympic Games held in the 20th century</td>
<td>0.51 (0.45-0.57)</td>
<td>NA</td>
</tr>
<tr>
<td>Kalist and Peng,\textsuperscript{16} 2007</td>
<td>n=2641</td>
<td>Major US league baseball players who were born between 1945 and 1964</td>
<td>0.31 (0.23-0.39)</td>
<td>NA</td>
</tr>
<tr>
<td>Kujala et al,\textsuperscript{17} 2001</td>
<td>n=2009</td>
<td>Athletes who had represented Finland in international competitions during 1920-1965 and were alive in January 1971</td>
<td>0.74 (0.69-0.79)</td>
<td>0.72 (0.64-0.82)</td>
</tr>
<tr>
<td>Marjon et al,\textsuperscript{18} 2013</td>
<td>n=786</td>
<td>French cyclists who competed in 1 or more editions of the Tour de France during 1947-2012</td>
<td>0.59 (0.51-0.68)</td>
<td>0.67 (0.50-0.88)</td>
</tr>
<tr>
<td>Menotti et al,\textsuperscript{19} 1990</td>
<td>n=1148 (283 women)</td>
<td>Track and field athletes who had participated in international events as members of the Italian national team from 1940 until now</td>
<td>0.70 (0.47-0.93)</td>
<td>NA</td>
</tr>
<tr>
<td>Taioli,\textsuperscript{20} 2007</td>
<td>n=5389</td>
<td>Soccer players who were enrolled in the Italian professional leagues A and B for at least 1 season between 1975 and 2003</td>
<td>0.68 (0.52-0.86)</td>
<td>0.41 (0.20-0.73)</td>
</tr>
<tr>
<td>Waterbor et al,\textsuperscript{21} 1988</td>
<td>n=985</td>
<td>All baseball players who played their first games for a professional major league baseball team in the United States between 1911 and 1915 and who survived until 1925</td>
<td>0.94 (0.88-1.00)</td>
<td>NA</td>
</tr>
<tr>
<td>Schnohr,\textsuperscript{22} 1971</td>
<td>n=297</td>
<td>Athletic champions (world record holders; medalists at Olympic Games and World, European, or Nordic championships; members of Olympic teams; Danish champions, record holders, and members of national teams) born in Denmark between 1880 and 1910</td>
<td>1.00 (0.80-1.20)</td>
<td>0.95 (0.63-1.26)</td>
</tr>
</tbody>
</table>

CVD = cardiovascular disease; NA = not available; SMR = standard mortality ratio.
Results of the meta-analysis when only cardiovascular disease was considered as the cause of mortality. SMR = standard mortality ratio.

The main findings of the meta-analysis, SMR:

**FIGURE 1.** Main results of the meta-analysis. SMR = standard mortality ratio.

by a rather mild increase in atrial fibrillation risk (hazard ratio, 1.2). Veteran athletes with arrhythmias have higher heart rate variability, which has a cardioprotective effect. Some evidence also starts to accumulate against the notion that exercise benefits are confined to “moderate” doses, at least in terms of total exercise time, with higher moderate-to-vigorous physical exercise (e.g., brisk walking and running) levels (≥450 min/wk), which are clearly above the minimum international recommendations of 150 min/wk, being associated with longer life expectancy. On the other hand, caution is needed when extrapolating provocative data from animal studies to humans. Benito et al. reported a cause-effect relationship between long-term forced treadmill training and the development of right ventricular remodeling in rats. The authors trained rats at approximately 90% of maximum heart rate, 1 h/d, 5 d/wk for 16 weeks; when translated to the human life span, this time period would be equal to approximately 10 years. Such continuous intense exercise loads are unrealistic for most athletes, including those participating in the Tour de France. Former participants in the Tour de France live longer than the general population as indicated by a study included in our meta-analysis as well as by a previous report. Particularly strong epidemiological evidence supporting the benefits of strenuous endurance exercise on life expectancy and health comes from Finnish male population-based cohort studies with elite athletes of various disciplines who were Olympians between 1920 and 1965. Athletes, especially endurance athletes, had higher mean life expectancies than did controls; in addition, they had lower mortality rates owing to CVD than did controls. Consequently, former elite athletes had a lower risk of medication for chronic diseases.

Our meta-results have several limitations, particularly regarding the differences between studies in the duration of the selected time intervals used to calculate SMR. In addition, the apparent survival advantage conferred by elite sports participation during a period of an individual’s life might be inflated by potential confounders, including lifestyle habits (independent from intense exercise) during or after retirement from competition. For instance, former Finnish elite athletes were more physically active during leisure time, smoked less, consumed less alcohol, and had a healthier diet than their referents. Another important limitation arises from the absence of information on specific cause of death in 3 studies (accounting for ~14% of the total meta-analysis sample) and, especially, from the observed heterogeneity among studies for all-cause pooled SMR as well as for SMR due to cancer. A reason explaining such heterogeneity may be the large variability among studies in the sports phenotype of the cohorts, which included athletes participating in quite different sports specialties, that is, ranging from team sports with little aerobic component such as baseball to extreme endurance events such as Tour de France. In addition, the global term cancer includes numerous cancer types that differ in etiology (i.e., genetic vs lifestyle factors) whereas only 1 study reported subanalyses based on different cancer categories. In contrast, only 2 studies reported SMR for death due to musculoskeletal/connective tissue

<table>
<thead>
<tr>
<th>Reference, year</th>
<th>Measure (95% CI)</th>
<th>Weight</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baron et al. 2012</td>
<td>0.68 (0.57-0.82)</td>
<td>22%</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Belli et al. 2005</td>
<td>0.83 (0.69-1.00)</td>
<td>22%</td>
<td>.05</td>
</tr>
<tr>
<td>Kujala et al. 2001</td>
<td>0.72 (0.64-0.81)</td>
<td>31%</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Marjori et al. 2013</td>
<td>0.67 (0.51-0.89)</td>
<td>13%</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Tiao et al. 2007</td>
<td>0.41 (0.21-0.78)</td>
<td>3%</td>
<td>.01</td>
</tr>
<tr>
<td>Schnohr et al. 1971</td>
<td>0.95 (0.67-1.34)</td>
<td>9%</td>
<td>.75</td>
</tr>
<tr>
<td>Synthesis</td>
<td>0.73 (0.65-0.82)</td>
<td>100%</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**FIGURE 2.** Results of the meta-analysis when only cardiovascular disease was considered as the cause of mortality. SMR = standard mortality ratio.
diseases; that is, SMR=0.90 (95% CI, 0.02-5.02) in participants in the Tour de France vs SMR=3 (95% CI, 0.97-7) in football players. Whether this type of disease was specifically caused by sports participation and might negatively affect the mortality of former athletes remains to be determined in studies with high statistical power. In addition, there is a lack of information on fatal accidents during sports participation. Because female athletes accounted for less than 2% of the total athletes assessed in this meta-analysis, it is not possible to determine whether there is a sex effect on the association between elite sports participation and mortality. Finally, the comparatively high weightage of studies performed by Kujala et al in Finnish Olympic athletes and by Baron et al and Taïoli et al in football and soccer players, respectively, may have skewed the results toward a favorable effect on CVD. In fact, the combined weight of the 3 above-mentioned studies was approximately 68% (Figure 2) despite accounting for only approximately 25% of the total meta-analysis population.

CONCLUSION
Although more research is needed using more homogeneous cohorts and a more proportional representation of both sexes, the evidence available indicates that elite athletes (mostly men) live longer than the general population, which suggests that the beneficial health effects of exercise, particularly in decreasing CVD and cancer risk, are not necessarily confined to moderate doses. Future studies might elucidate whether the present high demands of professional sports participation also translate into an actual longevity and health benefit.

ACKNOWLEDGMENTS
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SUPPLEMENTAL ONLINE MATERIAL
Supplemental material can be found online at http://www.mayoclinicproceedings.org.

Abbreviations and Acronyms: CVD = cardiovascular disease; SMR = standard mortality rate

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