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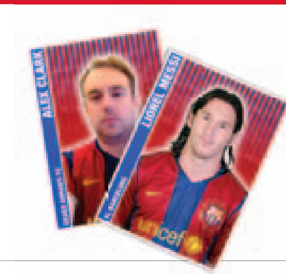

Football studies outcomes more closely than healthcare researchers, p 25

Mortality in former Olympic athletes: retrospective cohort analysis

R Zwiers, F W A Zantvoord, F M Engelaer, D van Bodegom, F J G van der Ouderaa, R G J Westendorp

Objective To assess the mortality risk in subsequent years (adjusted for year of birth, nationality, and sex) of former Olympic athletes from disciplines with different levels of exercise intensity.

Design Retrospective cohort study.

Setting Former Olympic athletes.

Participants 9889 athletes (with a known age at death) who participated in the Olympic Games between 1896 and 1936, representing 43 types of disciplines with different levels of cardiovascular, static, and dynamic intensity exercise; high or low risk of bodily collision; and different levels of physical contact.

Main outcome measure All cause mortality.

Results Hazard ratios for mortality among athletes from disciplines with moderate cardiovascular intensity (1.01, 95% confidence interval 0.96 to 1.07) or high cardiovascular intensity (0.98, 0.92 to 1.04) were similar to those in athletes from disciplines with low cardiovascular intensity. The underlying static and dynamic components in exercise intensity showed similar non-significant results. Increased mortality was seen among athletes from disciplines with a high risk of bodily collision (hazard ratio 1.11, 1.06 to 1.15) and with high levels of physical contact (1.16, 1.11 to 1.22). In a multivariate analysis, the effect of high cardiovascular intensity remained similar (hazard ratio 1.05, 0.89 to 1.25); the increased mortality associated with high physical contact persisted (hazard ratio 1.13, 1.06 to 1.21), but that for bodily collision became non-significant (1.03, 0.98 to 1.09) as a consequence of its close relation with physical contact.

Conclusions Among former Olympic athletes, engagement in disciplines with high intensity exercise did not bring a survival benefit compared with disciplines with low intensity exercise. Those who engaged in disciplines with high levels of physical contact had higher mortality than other Olympians later in life

Public health associations recommend physical exercise because it is associated with lower mortality risks, better mood and cognition, and lower prevalence of cardiovascular disease.[1-7] However, when Pheidippides ran from Marathon to Athens in 490 BC to announce the Greek victory over the Persians, he died on arrival. As his case illustrates, exercise of high intensity can also place great strain on the body and can cause serious injuries and damage.[8] The question is whether regular high intensity exercise is associated with a lower or higher mortality risk. When the first modern Olympic Games were held in Athens in 1896, including a marathon run to Athens, the organisers decided to shorten the distance, with the death of Pheidippides in mind. The current distance of 42.195 km was determined only later during the third Olympics in London, when the royal family requested the race to be from the start at Windsor Castle to the royal stage in the White City Stadium. This year, the Olympic Games were back in London, but whether high intensity exercise is beneficial for reducing mortality risk is still debated.[9 10]

The effect of high intensity exercise on mortality later in life has mostly been studied among professional athletes, using the general population as a control group. The outcomes from these studies differ; some did not find a survival benefit, whereas others showed lower mortality in athletes than in their non-athletic counterparts from the general population.[11-24] The lower mortality risk of professional athletes compared with the general population could be due to specific social and psychometric characteristics, and whether high intensity exercise brings a survival benefit or an increased mortality risk for athletes remains to be elucidated. We analysed mortality patterns in a large historic cohort of athletes

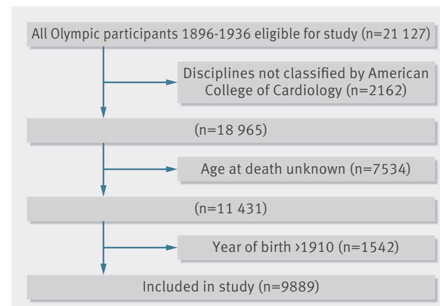

Fig 1 | Flow diagram showing inclusion of former Olympic athletes in study

WHAT IS ALREADY KNOWN ON THIS TOPIC

Modern athletes who perform high intensity exercise have a survival benefit when compared with the general population

Intensive exercise places great strain on the human body and can cause serious injuries and damage

WHAT THIS STUDY ADDS

Former Olympic athletes who engaged in disciplines with high cardiovascular intensity had similar mortality risks to those from disciplines with low cardiovascular intensity

Engaging in disciplines with risk of bodily collision or physical contact was associated with a higher mortality risk compared with other disciplines

ALL IMAGES OF ATHLETES: PA

Table 1 | Hazard ratios of mortality for athletes in disciplines with different intensities of exercise

Intensity	Univariate analysis* Hazard ratio (95% CI)	P value	Multivariate analysis† Hazard ratio (95% CI)	P value
Cardiovascular:				
Low	Reference		Reference	
Moderate	1.01 (0.96 to 1.07)	0.71	1.04 (0.95 to 1.15)	0.40
High	0.98 (0.92 to 1.04)	0.46	1.05 (0.89 to 1.25)	0.58
Static:				
Low	Reference		Reference	
Moderate	0.94 (0.89 to 0.99)	0.02	0.93 (0.85 to 1.01)	0.09
High	0.99 (0.94 to 1.04)	0.62	0.95 (0.85 to 1.07)	0.40
Dynamic:				
Low	Reference		Reference	
Moderate	0.94 (0.89 to 0.99)	0.03	0.94 (0.87 to 1.01)	0.09
High	0.97 (0.92 to 1.02)	0.19	0.94 (0.83 to 1.06)	0.34

*Adjusted for sex, year of birth, and nationality.
†Additionally includes all types of exercise intensity (cardiovascular, static, and dynamic) in model.

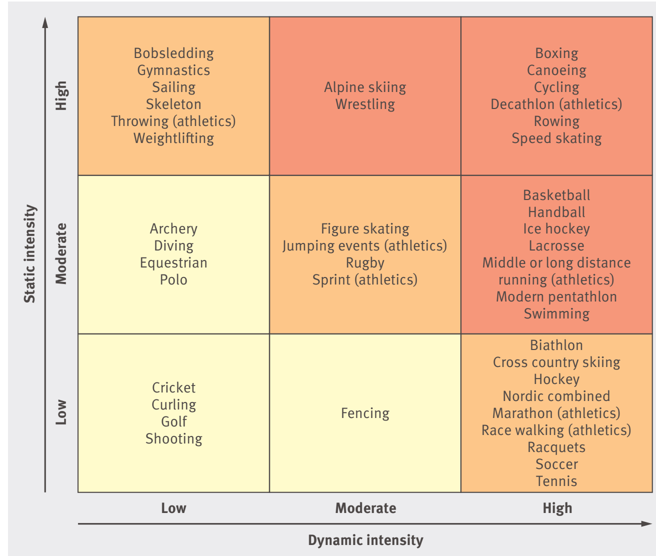

Fig 2 | 43 Olympic disciplines classified in categories of static and dynamic intensity, as well as three categories of low, moderate, and high cardiovascular intensity (from yellow to red).[26]

who had all participated in the Olympic Games between 1896 and 1936 but performed at different levels of cardiovascular, static, and dynamic intensity exercise.

Methods

Study population

In May 2011 we retrieved a cohort of 21 127 former Olympic athletes from the continuously updated Sports Reference database, the largest online database of Olympic athletes.[25] Figure 1 summarises the inclusion process. We included 9889 former Olympic athletes, born between 1830 and 1910, with a known age at death, who participated in at least one of the Summer Olympic Games between 1896 and 1936. We excluded 2162 athletes from nine disciplines that were not mentioned in the classification of the American College of Cardiology.[26] We classified skeleton as bobsledding and polo as equestrian, because of the very similar types of exercise. For 7534 athletes, the age at death was unknown owing to an unknown date of birth, date of death, or both. Finally, we excluded 1542 participants born after 1910, as they could possibly be still alive.

Classification of Olympic disciplines

We classified the 43 Olympic disciplines according to the classification system of the 8th Task Force on the Classification of Sports by the American College of Cardiology.[26] The classification of cardiovascular intensity sums a static component reflecting maximal voluntary muscle contraction and a dynamic component reflecting maximal oxygen uptake; both were categorised at three levels of intensity—low, moderate, and high. The system also defines three levels of static and dynamic intensity—low, moderate, and high. When an athlete had participated in multiple disciplines, we categorised him/her in the discipline with the highest cardiovascular score. The risk of bodily collision was also classified by the American College of Cardiology.[26] Finally, we classified the various disciplines as low (non-contact), moderate (limited contact), and high (full contact), according to the classification of contact sports of the American Academy of Pediatrics.[27] The levels of exercise intensity were similar in athletes who were included in and excluded from this analysis (data not shown).

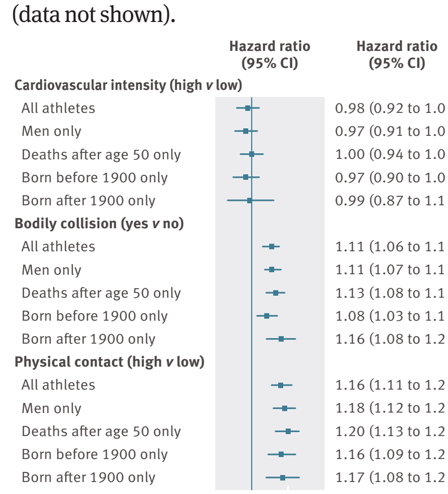

Fig 3 | Hazard ratios of mortality (95% CIs) in former Olympic athletes according to cardiovascular intensity, bodily collision, and physical contact. Analyses were adjusted for sex, year of birth, and nationality

Statistical analysis

We calculated hazard ratios for all cause mortality by using a left truncated Cox proportional hazards model, entering participants at the age of first participation in the Olympic Games. All analyses were adjusted for sex, year of birth, and nationality. We used Stata 11 for all calculations.

Results

We included 9889 athletes from 43 different Olympic disciplines that were classified in various categories of intensity of exercise, risk of bodily collision, and the level of physical contact. The supplementary table summarises the characteristics of these 43 disciplines. Figure 2 shows all 43 disciplines stratified for the level of static, dynamic, and cardiovascular intensity, classified according the American College of Cardiology.[26]

We firstly calculated hazard ratios for mortality dependent on different levels of exercise intensity. As the participants came from different birth cohorts, we adjusted all our analyses for year of birth, which, as expected, was correlated with mortality. Next, we adjusted for sex and nationality, which were also correlated with mortality (data not shown). Table 1 shows hazard ratios for mortality for different levels of cardiovascular, static, and dynamic intensity in both univariate and multivariate analyses. Engagement in disciplines with increasing cardiovascular intensity was not associated with a significantly higher mortality risk; the hazard ratio for moderate intensity was 1.01 (95% confidence interval 0.96 to 1.07; P=0.71), and that for high intensity was 0.98 (0.92 to 1.40; P=0.46). Multivariate analysis showed similar results (table 1). Analysis of the static and dynamic components separately showed similar non-significant results. Univariate analysis showed a small beneficial effect of moderate static exercise, but this was not reflected in a lower hazard ratio in athletes engaged in disciplines with high intensity static exercise.

We also studied the effect of bodily collision and physical contact on mortality (table 2). Athletes engaged in disciplines with a high risk of bodily collision had an 11% higher mortality risk compared with those who were not exposed (hazard ratio 1.11, 1.06 to 1.15; P<0.001). When comparing athletes who had performed in disciplines with various levels of physical contact, we found that those who participated in sports with only moderate contact did not have a higher mortality risk. However, athletes who were exposed to high levels of physical contact had a 16% higher mortality risk compared with those with low physical contact (hazard ratio 1.16, 1.11 to 1.22; P<0.001). These higher mortality risks remained similar in the multivariate analysis, whereas the hazard ratio for bodily collision became non-significant.

We additionally did similar analyses in various subgroups—men only, deaths after age 50, born before 1900, and born after 1900 (fig 3). In none of the subgroups was exercise at high cardiovascular intensity associated with a reduction in mortality risk. However, we found a significant higher mortality risk in all these subgroups for risk of bodily collision and high physical contact.

Discussion

Our results show that former Olympic athletes who engaged in disciplines with high cardiovascular intensity had similar mortality risks to athletes from disciplines with low cardiovascular intensity. This would indicate that engaging in cycling and rowing (high cardiovascular intensity) had no added survival benefit compared with playing golf or cricket (low cardiovascular intensity).

Although comparing modern sporting activity with that during the first series of the games is a daunting task, this analysis is sobering for all those athletes who trained so hard to qualify for the London Olympics in 2012. Moreover, our analyses point to a potential risk for those engaged in disciplines with a high risk of bodily collision or high levels of physical contact. As the higher mortality risk persisted for death after age 50, this increased risk could not be explained by the death of young athletes due to trauma. We consider it more likely that the higher mortality risk reflects the effect of a gradual accumulation of multiple bodily injuries during sporting activities. Previous studies have shown that bodily collisions or fierce physical contacts are responsible for a large proportion of the total burden of injuries.[8 28] These injuries may have longlasting detrimental effects, in line with the generalised theory of ageing. For instance, repetitive blows to the head, especially in boxers, are associated with cognitive impairment, early onset dementia, and reduced life expectancy.[29 30]

Our findings stand in contrast to several other studies showing a benefit to late life mortality risk in very well trained athletes.[31-34] A possible explanation could be that these studies included only exercise of moderate intensity. Other studies, however, described a late life survival advantage for endurance athletes who had trained at high physical intensity.[22-24 35] All previous observations may be subject to bias, however, as trained athletes differ from the general population in more ways than just physical fitness. We consider our comparison of former Olympic athletes who performed their sports at different physical intensity to be more robust than a comparison between trained athletes and people from the population at large. This interpretation is strengthened by the fact that outcomes were congruent in all domains of physical intensity (for example, cardiovascular, static, and dynamic intensity).

In this study, we used data from athletes who participated in the Olympic Games between

Table 2 | Hazard ratios of mortality for athletes in disciplines with different risk of bodily collision and physical contact

Sport type	Univariate analysis* Hazard ratio (95% CI)	P value	Multivariate analysis† Hazard ratio (95% CI)	P value
Bodily collision:				
No	Reference		Reference	
Yes	1.11 (1.06 to 1.15)	<0.001	1.03 (0.98 to 1.09)	0.25
Physical contact:				
Low	Reference		Reference	
Moderate	0.97 (0.93 to 1.02)	0.25	0.96 (0.92 to 1.01)	0.16
High	1.16 (1.11 to 1.22)	<0.001	1.13 (1.06 to 1.21)	<0.001

*Adjusted for sex, year of birth, and nationality.
†Additionally includes both bodily collision and physical contact in model.

1896 and 1936, so outcomes reflect late life consequences of intensive exercise programmes that were in vogue 70 to 110 years ago. Since then, training programmes, especially on a (semi) professional level, have changed substantially. Top athletes now not only train more often and more intensely, but training has also become more individualised and specifically focused. Moreover, medical care to prevent permanent damage is undoubtedly better and could explain why in the past the potential benefits of intensive physical training were overwhelmed by trade-offs later in life.

Regarding the negative effect of bodily collision and fierce physical contact, current sporting activities are much more extreme with regard to velocity, *g* force, and other mechanical strains. Collisions and physical injuries could therefore have more effect nowadays, despite better protective aids and medical treatment. Our findings could well underestimate the late life effects of the gradual accumulation of permanent damage due to repeated collisions and injuries to which top athletes are exposed.

Although we did not find evidence that former Olympic athletes from disciplines involving high intensity exercise have a higher mortality risk than other former Olympians, people should think for a moment before engaging in disciplines with risk of bodily collision or fierce physical contact. This notion may help to explain a historical fact. Before Pheidippides exclaimed "νικωμεν" (we have won) and collapsed, he had not only run from Marathon to Athens but had fought in the battle of Marathon before that. It is tempting to speculate that it was not the run from Marathon to Athens but the effect of armed force that led to his tragic death.

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EDITORIAL, p 3

Survival of the fittest: retrospective cohort study of the longevity of Olympic medallists

Philip M Clarke, Simon J Walter, Andrew Hayen, William J Mallon, and David M Studdert

Objective To determine whether Olympic medallists live longer than the general population.

Design Retrospective cohort study, with passive follow-up and conditional survival analysis to account for unidentified loss to follow-up.

Setting and participants 15 174 Olympic athletes from nine country groups (United States, Germany, Nordic countries, Russia, United Kingdom, France, Italy, Canada, and Australia and New Zealand) who won medals in the Olympic Games held in 1896-2010. Medallists were compared with matched cohorts in the general population (by country, age, sex, and year of birth).

Main outcome measures Relative conditional survival.

Results More medallists than matched controls in the general population were alive 30 years after winning (relative conditional survival 1.08, 95% confidence interval 1.07 to 1.10). Medallists lived an average of 2.8 years longer than controls. Medallists in eight of the nine country groups had a significant survival advantage compared with controls. Gold, silver, and bronze medallists each enjoyed similar sized survival advantages. Medallists in endurance sports and mixed sports had a larger survival advantage over controls at 30 years (1.13, 1.09 to 1.17; 1.11, 1.09 to 1.13) than that of medallists in power sports (1.05, 1.01 to 1.08).

Conclusions Olympic medallists live longer than the general population, irrespective of country, medal, or sport. This study was not designed to explain this effect, but possible explanations include genetic factors, physical activity, healthy lifestyle, and the wealth and status that come with international sporting glory.

Pierre de Coubertin, founder of the modern Olympics, introduced the Olympic motto "citius, altius, fortius" (swifter, higher, stronger) to describe the sporting aspirations of athletes.[1] It is also an apt description of Olympians, who represent the pinnacle of human fitness and physical achievement. Do Olympians enjoy longer life?

There are no large scale published studies of the longevity of Olympians, and the evidence on whether elite athletes live longer is mixed.[2] German international soccer players were recently shown to have a shorter life expectancy than matched men from the general population.[3] Studies of Danish athletic champions,[4] New Zealand international rugby players,[5] and US major league baseball players[6] have found no differences, and an early review of the literature reached the same conclusion.[7] By contrast, analyses of Polish Olympians,[8] the Italian national track and field team,[9] major league baseball players,[10] and selected tennis champions and Olympic medallists in several sports and years[11] have identified survival advantages compared with the general population. Studies of Finnish athletes in various sports found lower standardised mortality ratios among competitors in endurance, team, and "mixed" sports, but not among competitors in "power" sports.[12 13] Most research has focused on

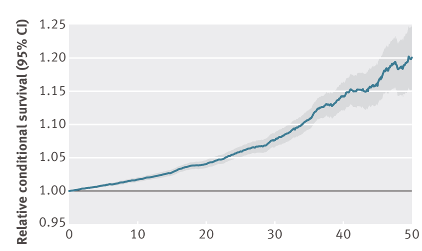


Fig 1 | Survival of Olympic medallists from selected countries relative to the general population, 1896-2012

WHAT IS ALREADY KNOWN ON THIS TOPIC

Evidence on whether elite athletes live longer is mixed and whether Olympic medallists do so is not known

WHAT THIS STUDY ADDS

Olympic medallists live longer than the general population, irrespective of country, medal, or sport

Possible explanations include genetic factors, physical activity, healthy lifestyle, and the wealth and status that come with international sporting glory

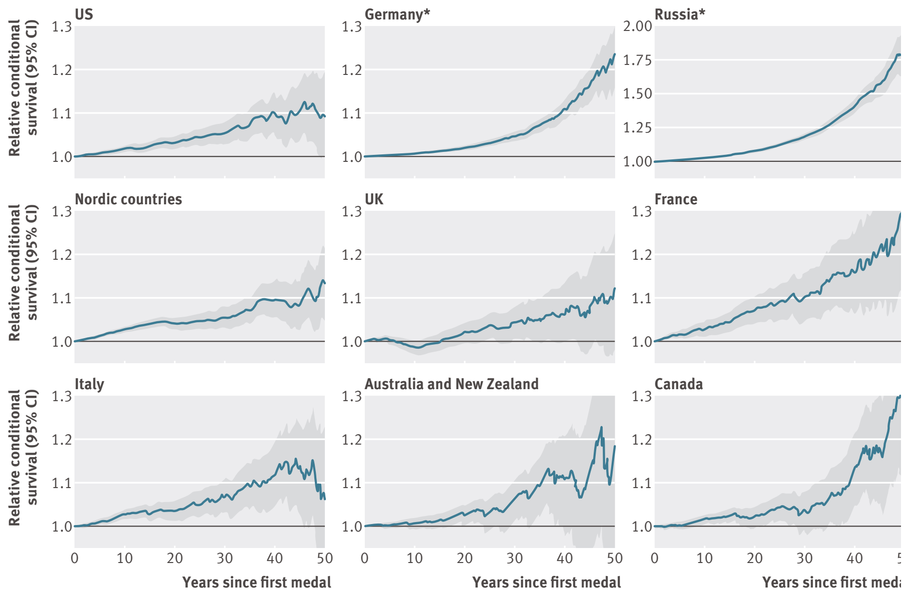


Fig 2 | Survival of Olympic medallists, by country group. *Excludes medallists from Olympic Games before 1950

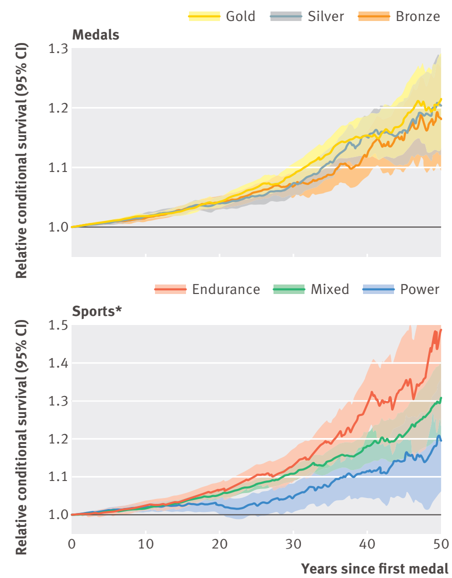


Fig 3 | Survival of Olympic medallists by medal and sport. *Analysis based on subsample (30%) of all medallists from the nine country groups

athletes from one country in a particular sport.

Since the modern Olympic era began in 1896, nearly 25 000 athletes competing under 136 different flags have won medals. Most medallists come from a small number of countries, including the United States, Germany, Russia, and the United Kingdom. We compared the longevity of these medallists to a matched cohort of their compatriots from the general population.

For details of ascertainment of date of death, calculation of longevity of matched general populations, and statistical analysis, see bmj.com.

Study variables and sample

The OlyMADMen database contains information on 118 442 athletes who participated in the 27 summer and 21 winter games held from the first modern Olympics in Athens in 1896 to Vancouver in 2010. (At the time of data extraction for our study, the OlyMADMen database did not include information on medallists from the 2012 Games in London.) Variables in the database included Olympians' sex, birth date, and death date; the year, sports, and events competed; event placings; and countries represented.

One or more medals were won by 24 785 athletes competing for 136 different countries and geopolitical entities. However, nine countries or country groups (each with >850 medallists) accounted for most Olympic medallists in the modern era (n=15 820; 63.8%). These groups are: the US, Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden), Russia (the Russian Empire, Soviet Union, and Russia), Germany (the German Empire, Interbellum Germany, East Germany, West Germany, and reunified Germany), UK, France, Italy, Canada, and Australia and New Zealand. We focused the analysis on medallists from these countries.

For Germany and Russia, we restricted the sample to medallists from Olympics after 1950. This was because life table coverage for German medallists was poor during the first and second world wars, which undermined construction of comparator cohorts in the general population. Russia had only a small number of medallists before 1950.

Medallists who represented more than one country group or competed in more than one sport or games were classified on their status when they won their first medal. After excluding 214 medallists with missing birthdates, the final study sample consisted of 15 174 medallists. Although other variables of interest had

trivial numbers of missing values, death dates posed an analytical challenge.

Results

Medallists were mostly men and had a mean age of 26 years (table). The nine country groups that produced the most medallists accounted for 64% of all medallists. By 15 March 2012, 5095 (34%) medallists had died.

Figure 1 reports the survival of medallists from the nine country groups relative to the general population. At 10 years, 2% more of the medallist cohort were alive; at 30 years, 8% more of the medallist cohort were alive (relative conditional survival 1.02, 95% confidence interval 1.01 to 1.02; 1.08, 1.07 to 1.09). On average, medallists lived 2.8 years longer.

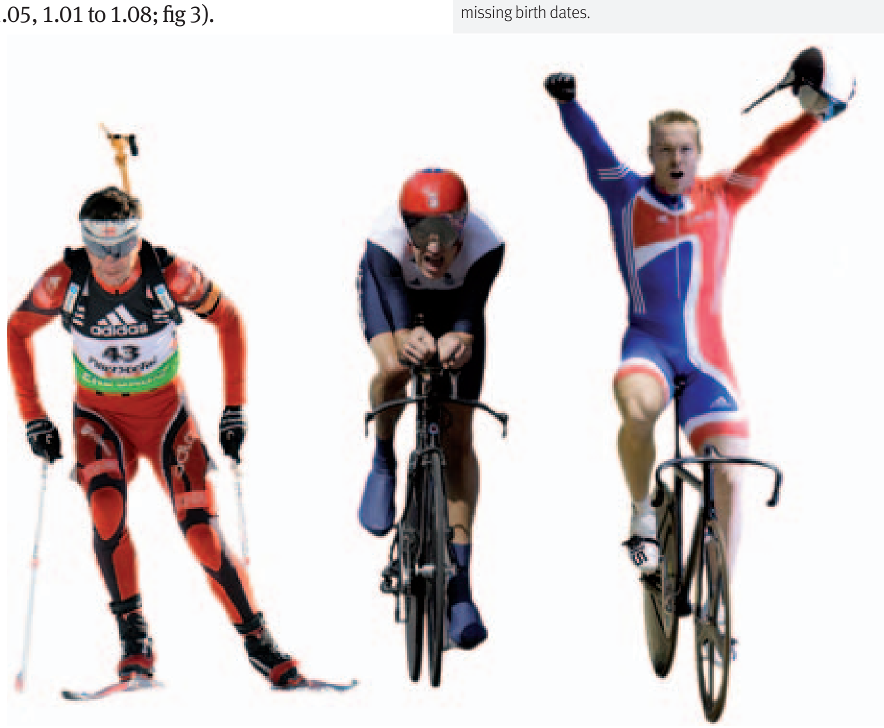
This survival advantage occurred in eight country groups, although the size of the advantage varied (fig 2). At 30 years, medallists from Russia (relative conditional survival 1.18, 95% confidence interval 1.16 to 1.20), France (1.10, 1.05 to 1.15), Italy (1.07, 1.03 to 1.11), Australia and New Zealand (1.06, 1.01 to 1.11), Germany (1.05, 1.03 to 1.06), Nordic countries (1.05, 1.03 to 1.08), and the UK (1.04, 1.00 to 1.08) had a survival advantage over their matched compatriots. The survival advantage of Canadian medallists at 30 years over the general population was not significant (1.04, 0.99 to 1.08).

Grouping Olympians by the type of medal won showed similar survival advantages for gold, silver, and bronze medallists (fig 3). At 30 years, Olympic medallists in endurance sports (relative conditional survival 1.13, 95% confidence interval 1.09 to 1.17) and mixed sports (1.11, 1.09 to 1.13) had a larger survival advantage over the general population than did those in power sports (1.05, 1.01 to 1.08; fig 3).

Characteristics of Olympic medallists, 1896-2010*

	No (%) of medallists (n=15 174)
Demographics	
Male	11 619 (77)
Age at competition, mean (SD)	26 (6)
Deceased	5095 (34)
Medal type	
Gold	5180 (34)
Silver	4925 (32)
Bronze	5069 (33)
Country group	
US	3410 (22)
Nordic countries	2619 (17)
Russia/former Soviet Union†	2181 (14)
Germany†	1906 (13)
UK	1305 (9)
France	1048 (7)
Italy	957 (6)
Canada	879 (6)
Australia and New Zealand	869 (6)
Sports	
Athletics	1782 (12)
Rowing	1515 (10)
Swimming	1032 (7)
Ice hockey	915 (6)
Gymnastics	770 (5)
Sailing	709 (5)
Cycling	593 (4)
Fencing	530 (3)
Football	513 (3)
Other	6815 (45)
Olympic season	
Summer	12 660 (83)
Winter	2514 (17)
Olympic periods	
1896-1928 (9 summers, 2 winters)	3222 (21)
1932-60 (6 summers, 6 winters)	2781 (18)
1964-88 (7 summers, 7 winters)	4876 (32)
1992-2010 (5 summers, 6 winters)	4295 (28)

For medallists involved with multiple Olympics, sports, and medals, all characteristics pertain to the first medal won.
†Excludes medallists after 1950, and 214 medallists with missing birth dates.



Discussion

In this study of Olympic medallists from nine country groups that have won the most medals, medallists averaged longer lifespans, compared with matched cohorts in the general population. This advantage was significant in eight of the nine country groups examined, and across different types of medals and sports.

Comparison with other studies

Our findings broadly accord with other studies identifying survival advantages among elite athletes.[8-13] Although some studies have found longevity not to differ between athletes and the general population,[4-6] most of these studies are older and tracked athletes who competed in the first half of the 20th century, which may explain the discrepancy in findings.

A review by Teramoto and Bugnum[2] raises another possible explanation for conflicting results in studies of elite athletes' longevity. Athletes in some types of sport (such as endurance) have longer than average lifespans, while those in other sport types do not. Our sport subanalyses mimicked categories used in a 2001 study,[13] which found that elite Finnish athletes in endurance and mixed sports lived longer than the general population, but athletes in power sports did not. We found medallists in all three categories to have a survival advantage. Our study had a larger sample, included athletes from many countries, used a different analytical method, and focused on Olympic medallists only.

Interpretation of findings

Why do Olympic medallists live longer? Our study aimed to test whether medallists' had a survival advantage, not to identify reasons for this, so the following explanations are speculative. One explanation is that athletes are much healthier than the average person. Part of this advantage could be genetic, but environmental factors undoubtedly amplify genetic advantages. Young athletes who exhibit exceptional physical talents are often selected into national training squads to undergo intensive physical training over many years. Most Olympic medallists will have come through such programmes.

Strong evidence indicates that physical activity confers many health benefits, including improved functional health status and reduced risks of cardiovascular disease, coronary heart disease, stroke, depression, type 2 diabetes, and breast and colon cancer.[21 22] Studies of the relation between all cause mortality and physical activity generally show large reductions in mortality risk with low to moderate levels of activity, and small additional reductions at high activity levels.[21] The physical activity and fitness of elite athletes are usually at the extreme end of the spectrum. Thus, they should at least enjoy the survival advantages linked to vigorous exercise.

Nonetheless, for most elite athletes, the period spent training intensively and competing occupies a minority of their life. Surveys of retired Finnish athletes, including Olympians, have shown lower than average rates of smoking,[23-25] ischaemic heart disease and diabetes,[26] and depression and anxiety,[25] but possibly higher rates of musculoskeletal conditions such as osteoarthritis.[23 26] These former athletes also seemed to remain physically active.

Another explanation relates to the wealth and fame that international sporting success confers on many medallists. Evidence strongly indicates that higher socioeconomic status is associated with lower mortality.[27] Improved nutrition, education, and access to medical services all mediate this effect.[28] The influence of social status on mortality risk, independent of wealth, is more controversial, although many studies have identified such an effect.[29] Unlike other studies that have examined relative survival among celebrities of varying degrees of fame,[30] we observed no clear longevity differences by medallists' stature; similar survival advantages were observed among gold, silver, and bronze medallists.

Conclusion

The elite warrior Achilles in Greek mythology was forced to choose between a short glorious life and a long obscure one.[31] There is no such trade off for Olympic medallists.

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Contributors: PMC came up with the study idea; contributed to the study design, analyses, preparation, and design of exhibits; and cowrote the first draft of the manuscript with DMS. SJW and AH contributed to the study design, analyses, preparation of exhibits, and writing of methods and results. WJM and JH collected and assembled the study dataset, assisted in data interpretation, and contributed to the manuscript writing. DMS developed the study idea with PMC; contributed to the study design, data interpretation, and design of exhibits; conducted the literature review; and cowrote the first draft of the manuscript (with PMC).

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Data sharing: Data for Olympians used to construct the study sample are available from Bill Mallon of the OlyMADMen (bill1729@gmail.com).

References are in the version on bmj.com.

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EDITORIAL, p 3

What football teaches us about complex health interventions

Football and healthcare are both complex adaptive systems. **Alex Clark and colleagues** wonder why football scores more highly when it comes to introducing interventions

Who would you rather have as a player on your football team: Messi or Clark? Both players share numerous characteristics, such as they both have brown hair, have the same size feet, and are less than 6 ft (1.8 m) tall. Each has scored many goals, playing in the number 10 jersey.

However, focusing on these overt characteristics is not a good basis for decision making. Close observation, informed assessment, and knowing the context of previous successes (goals against whom and on what occasion) provide more useful insights into the determinants of success in football. Lionel Messi, the Argentinean international professional player, is infinitely preferable to Alex Clark, an amateur from the University of Alberta, Canada. Yet research into complex healthcare interventions still focuses on easily described components of interventions and risks overlooking what really matters.

Complex versus complicated

Interventions in football and healthcare systems are "complex" rather than "complicated."[1] Phenomena are complicated when intervention outcomes can be reliably predicted from past behaviour with the help of mathematical analysis. Sending a rocket to the moon is complicated.[2] However, phenomena are complex when too many factors are interacting. In such situations formulas have limited application and similar past experience is a poor predictor of future success.[2] Raising a child is complex—doing the same things at different times often results in quite different outcomes.[2] Accordingly, in football, formula driven approaches have consistently failed,[3] and a health intervention that succeeds in one setting may have very different results in another.

Complex interventions in football and healthcare have a range of shorter term and longer term outcomes (table 1) and are composed of many components that are made up of smaller subcomponents (table 2). Outcomes are generated by dynamic interactions between these components, not only with each other, but also with aspects of context and a wide range of other potentially influential laws, variations, and unpredictable factors (table 3, bmj.com).

Because of this complexity, outcomes in football and healthcare are not chaotic (random over time) or uniform (identical over time). Rather, outcomes are somewhat patterned. Some football players successfully complete passes more often than others, and identical medical interventions can result in very different outcomes in different doctors' hands. But unexpected outcomes still occur. Messi still misses chances he should score from, and an intervention to promote diabetes self care that was effective in one setting,[4] and is supported by meta-analyses,[5] may not have benefits in another setting. Given their shared complexity, we suggest some lessons that healthcare research can learn from football.

Lesson 1: Ontology—bring complexity in

Because football and healthcare are complex, describing interventions and explaining their effects requires attention to ontology: the underlying ways in which interventions are understood.[5] Football and its discourses reflect many aspects of complexity. Outcomes can be influenced by individual components (a manager), subcomponents (a single player's attitude), context (a muddy pitch), and a range of uncontrollable factors (injury to key player). Deeper still, interactions between these elements may occur and generate new effects—for example, the gifted player who underperforms in the context of the "big match" with a hostile crowd.

Spot the difference


DAVE THOMPSON/PA

In healthcare interventions, ontology seems to be thought of as irrelevant or a luxury when compared with the attention given to methods, measurements, and results.[5 6] Yet ontology shapes not only these aspects but also the questions that research should and can ask. Asking the question "Does this self-care intervention work?" risks adopting the flawed but common assumption that it is only the intervention that determines effectiveness, irrespective of time, place, and context.[7] This is akin to asking "Does this football team win?"—it assumes wrongly that a team can and will win every time.

More sophisticated methods are often incorrectly seen as an adequate substitute for ontology.[8] The failure of econometrics (arguably the most sophisticated quantitative discipline handling "big data"[9]) to predict the global recession illustrates this error.[8 9] Research into healthcare interventions should measure outcomes well and use appropriate methods, but it has to be based on ontologies that adequately reflect complexity.[5 6 10]

Lesson 2: Clarity—describe interventions well

Discussions about football tend to take account of many large parts of games (such as the presence or absence of particular players, teams, referees, and managers) as well as smaller parts (such as these people's skills, characteristics, experience, and tendencies). Conversely, comprehensive descriptions of the many components of healthcare interventions are mostly absent from publications.[10 11] Multifaceted interventions are often handled methodologically as single agents.[5] Components that are selected for more detailed description and incorporated into analysis tend to be those that are more easily quantifiable or physical in nature,[6] such as an intervention's duration or means of delivery. However, as with Messi, this risks missing the most powerful drivers of effectiveness—which may be less quantifiable but potentially more influential—such as the skills, experience, and values of those providing the intervention.[4]

The components of healthcare interventions should be described in research.[6] Taxonomies that describe interventions comprehensively and systematically are needed. Components that theory, observation, and other data suggest may contribute more to changes in outcomes should be included in these descriptions.

Lesson 3: Why?—don't just describe outcomes, explain them

Outcomes, on their own, tell little of what has generated them. Results are likely to be improved only when we understand what has contributed to past outcomes. Discussions in

Table 1 | Common outcomes in football and healthcare

Outcome	Football	Healthcare
Primary outcome(s)	Manager/team/player/fans: Goals scored versus goals conceded	Longer term: Mortality, morbidity
	Player: Tackle won, shot taken	Shorter term: Relevant health behaviours (such as smoking cessation), patient access, or quality of life
Secondary outcome(s)	Team: Shots on goal, corner kicks won	Patient satisfaction, risk factor change
	Player: Increased fitness, passes completed, avoidance of demobilising injury*	
Process outcome(s)	Team: Percentage of: possession, successful passes made, successful tackles made, higher confidence and team morale	Behavioural and psychological changes, programme factors or alterations in biological factors that contribute to or are likely to affect primary and secondary outcomes
	Players: Higher personal morale, self esteem, and confidence	
Reported outcomes	Manager: Employment sustained, sense of superiority over constantly doubting fans	Patient reported outcomes without interpretation by health professionals; often includes symptoms, tolerability, and function
	Players: Dignity intact with peers, fun had, revenge over opposition	
	Fans: Happier life disposition, spousal harmony	

*Particularly problematic for lay players in week before family holiday or wedding day.

Table 2 | Components of interventions in football and healthcare

Facet of complexity	Definition	Football examples	Healthcare examples
Main components	The main parts of the intervention	Relevant characteristics, skills, and behaviours of teams, managers, and players*	Important components of a disease management programme, including: personnel, setting, content, and theoretical basis
Subcomponents	The parts of the main components	The skills, talents, and values of particular players, the tactical nous and motivational powers of managers	The values, skills, and practices of the healthcare professionals providing the intervention
Generative effects	Outcomes are generated by components in combination	Substitutions, manager's tactical switches, and even the direction of a ricochet of the ball can all influence outcomes in combination with other factors in the game, such as a player's ability to predict where the ball will ricochet	Smoking cessation occurs only when patients feel the healthcare provider has listened to their past difficulties, has incorporated these difficulties into intervention content, and instigates telephone follow-up

*Fans of professional teams tend to see themselves as influential components when results are favourable but downplay their contributions to defeats.[20]

football consistently seek explanations for what has generated outcomes, such as the presence of a particular player in the team or the qualities of a particular player ("Clark can't run or shoot properly"). Suggestions abound as to what could or should be done to increase the probability of a more favourable outcome next time.

By contrast, attempts to explain outcomes of healthcare interventions by "opening the black box" are still relatively rare,[5 12] and they are dominated by an over-riding focus on results, especially when findings are favourable and statistically significant.[5] A randomised trial can show whether a patient counselling intervention worked but not why or how it worked.[4] A meta-analysis can aggregate the results of trials of sufficiently similar counselling interventions over a set period of time.[5] Sensitivity analysis or meta-regression can identify what components of these interventions contributed most to results, but this depends on underlying trials being well described, which is seldom the case.[11] As such, meta-analyses usually provide a measure of general trends in results but do not explain these trends. In football terms, this equates to simply aggregating all past results against sufficiently similar teams or the same team over a set period of time.

Explanation matters. Its ongoing relative absence from research into healthcare interventions reduces the capacity of research to improve outcomes. More research and theory are needed to identify which components of healthcare interventions have more influence on outcomes and why. Outcomes from interventions should be measured, but studies should also incorporate different qualitative and quantitative techniques to better explain these outcomes.[12]

Lesson 4: Opportunity—learn from failure and success

"Bad" results in healthcare and football usually negatively affect emotions, perceived status, reputation, power, and identity.

In football, bad results tend to lead to greater attempts to explain and improve outcomes.[13] Contributing factors are often seen to reside in components (manager's poor tactics) or subcomponents (fatigue of a skilful player), contextual interactions (such as negative effects on team morale of past bad results), or uncontrollable factors (notably seemingly "biased" referees).

Conversely, in healthcare research, failure is often presented as success: the results of 40% of studies with negative findings are "spun" into positive results,[14] or even turned into false "wins" through questionable adjustments, such as stopping data collection early or excluding outlying data.[15] But how will outcomes be improved if the opportunities gifted by failure are not harnessed more fully? It is important to learn both from what works and what does not work.[4] Failure to attain successful outcomes in healthcare interventions can generate especially useful lessons for intervention refinement.

Study designs should be used that harness these lessons for future interventions.

KEY MESSAGES

- Like football, healthcare is a complex adaptive system in which interventions are also complex
- Healthcare researchers can learn from football about describing the important components of interventions more comprehensively
- Approaches that take the complexity of interventions into account could help explain outcomes better so that more can be learnt from failure
- Taking complexity of healthcare research into account would improve the quality, usefulness, and translation of research into practice

What can we learn?

Football illustrates the folly of ignoring complexity. Healthcare researchers can learn from football by describing the important components of interventions more comprehensively and, irrespective of results, using research approaches that take the complexity of interventions into account and seek to explain outcomes better. Such an approach would not only improve the quality of research into healthcare interventions but also increase its uptake by practitioners and its ability to improve outcomes in clinical practice.[16]

That said, football can be criticised for being unscientific. Prejudices for and against players and teams can cloud judgment. Emotional over-involvement, anecdotal post hoc rationalisation, and centralism (the tendency to explain outcomes by a small number of individual factors) are common.[17] However, philosophers of science over the past 50 years have suggested that scientists—and their discussions, processes, and findings—are also prone to strikingly similar personal leanings, group tendencies, and vested interests.[18 19] Attempts to understand and improve outcomes in both healthcare and football are best strengthened not only by harnessing data, but also by reflexivity, transparency over conflicts of interests, and genuinely open minded and informed dialogue, particularly with those who hold different views.[20]

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