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Changing more than a name

The longevity of sporting legends

Note on the author

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Acknowledgements

ILC UK is grateful to the Business school (formerly Cass) for supporting this research and for the many useful conversations the author has had with like-minded sports enthusiasts.

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Executive summary

Playing sport may be good for your health, but is it also good for longevity? That is to say, will you live longer if you play sports? This research looks at the lifespan of different groups of sporting legends who've reached the pinnacle of their profession in seven hugely popular sports.

The sports included here – football, cricket, rugby union, tennis, golf, boxing and horse racing – all have rich histories and huge followings, making it possible to identify and find lifespan data for elite players throughout the years: our 'sporting legends'. While the sample sizes are not huge the methodology is robust on finding statistically significant differences between them.

We already know that participation in sport has many advantages. Aside from health benefits, it can have a positive influence on younger participants, encouraging leadership qualities; it can even be a route out of poverty if played to an elite level. However, we do not yet have the evidence base to link sporting prowess to longevity in the wider population.

Existing research tends to focus on the current health of active participants, not on longevity, which requires a much longer historical record to draw valid conclusions. If playing sport generally increases longevity it would strengthen the case for participation throughout our lives, and for promoting the health benefits of all types of physical exercise.

But how do you compare the life of someone born in the 19th century with someone from the 20th or 21st centuries, given advances in health and wellbeing and the overall rise in life expectancy? The expected age of death for a 20-year-old man born in 1880 was 65, compared with a death age of 82 for a 20-year-old born in 1960, so this should be adjusted for.

To ensure we're comparing like with like, we compare the lifespan of our sporting legends with those of the general population of people born in the same year. Our findings show that across the seven sports we studied, our sporting legends can live up to 13% longer than the general male population of England and Wales but one or two are lower.

We also consider whether the total population of sporting legends alive in any given year is older or younger than the general population for that year, and whether these figures appear to be changing over time. For instance, in 2020 we find that an incredible 50% of all the Wimbledon Gentlemen's Singles finalists that have ever lived were still alive in 2020.

A closer look at the differences between sports shows that there are 36% more Wimbledon finalists alive today than would be expected if they had the same mortality as the average male. This compares with 16% more England rugby captains, 14% cricket captains, 9% British Open Champions, 3% Derby winners, 2% football captains but 7% fewer heavyweight boxing champions.

Additionally, professionals in cricket, rugby, tennis, golf, and horse racing are more likely to live longer now than they were between 1900 and 1960 – reflecting a number of factors ranging from improvements in safety, life styles, and post career welfare. Socio-economic factors, like class, education and leadership qualities also appear to give a longevity boost but are harder to quantify – the comparison between rugby and football backgrounds being a classic example.

As ever, there are some limitations to our research. Successful sporting careers tend to be relatively short, with an increased risk of injury or death compared to the general population. This risk has decreased for horse racing as time goes by, but stayed broadly the same for football and boxing. And it's not uncommon to continue playing tennis or golf well into old age, albeit at a less competitive level, with injury rates reducing over time.

Our research was unable to cover women or additional sports, because the historical record is much thinner. Other sports, like snooker, downhill skiing or F1 racing, took off much later than those on our list; while it would still be possible to investigate survivorship for participants, it's harder to analyse completed lives. In future work we intend working closely with sporting associations and others to fill these gaps.

Introduction

We can safely say that playing sport is good for your health, but is it also good for longevity? That is to say, will you live longer if you play sports? This research investigates longevity in sporting legends, who have reached the pinnacle of their profession in seven popular sports. Our timeframe covers the period from 1841 to 2020, which covers the inception and initial record-keeping of the sports under investigation, as well their subsequent development. This period also matches the demographic record: official mortality records began in 1841, allowing us to compare the longevity of these individuals with that of the wider population.

Our sport selections

Sport is a global business in its own right. It can have a positive influence on younger participants, encouraging leadership qualities; it can even be a route out of poverty if played to an elite level. Sport is a huge part of people's lives whether they are spectators, club members, or participants. Encouraging people to participate in sport regardless of whether they can play competitively could have huge health benefits – but not all sports are equal in this regard.

The sports included here – football, cricket, rugby union, tennis, golf, boxing and horse racing – all have rich histories and huge followings. Our goal is to find out whether they extend lives as well as improve health. If playing sport increases our longevity, this would strengthen the case for participation throughout our lives, and for promoting the health benefits of all types of physical exercise. However, we do not yet have the evidence base to link sporting prowess – on the playing field, in the ring or on the race track – to longevity in the wider population. This research is intended to fill that gap.

This report is intended for four different audiences:

- Those interested in the health benefits of sport for its own sake, as well as those looking at how an interest in sport activates participation, offers enjoyment and a sense of national pride to spectators, and provides role models for adoring fans
- Those interested in the public health benefits of sport, and whether it can be shown to increase both lifespan and quality of life
- Sports scientists and qualified trainers who are concerned with optimising sporting performance on the field of play or in the sports arena
- Regulators of specific sports, who might be interested in identifying and making small adjustments to increase safety, participation and enjoyment and secure the long-term viability of their sports

All the sports covered in this research are well established in the UK, with each having originally been founded or codified there; their continuing popularity and the celebrity culture around the participants makes for good reading. One of the oldest, horse racing, dates back to ancient times, with classic races that are still run today, such as the Epsom Derby, dating from the 18th century.

An important distinction is that football, rugby union and cricket are team sports, whereas the others are 'individual' sports – in the latter, individuals are in control but in the former, team captains have the extra responsibility of setting an example to the rest of the team. This is reflected in the results of our analysis.

Our player selections

Our selection criteria are based on entirely on the sporting success of our 'legends', for two reasons. The first is that readers will find it easy to identify with many of the famous names; but also the historical record is astonishingly complete for them, at least in terms of years of birth and death. Precise dates of birth and death may be missing in individual cases, which mean we can't calculate exact ages of death. However, we can calculate the years lived by subtracting individual years of birth from years of death, which will be accurate in around 75% of cases.

As women have not always been welcome to participate in sports, the historical sporting record for women is patchier and more recent. For this reason, we have been forced to focus on men in sports. Similarly, the prevalence of black athletes in sports is relatively new for our purposes, making the historical record too short to draw separate conclusions based on ethnicity.

However, this still leaves us with a large field. If we take captaincy of a national team as one of our inclusion criteria, sample sizes are still quite large but manageable. The situation differs from sport to sport – for example, there may be multiple winners of a particular event like the Epsom Derby. To boost our sample, we have extended our inclusion criteria in two ways. For boxing, we have included winners of the British Championship in all heavyweight divisions; for tennis we include all Wimbledon Gentlemen's Singles finalists who played in the annual championships, both winners and runners-up.

Sports like cricket, football and rugby usually include nationality as part of the eligibility criteria to play in the national team. However, this isn't the case for all of the sports in this study. As other nationalities may (and do) participate in tournaments such as Wimbledon, sporting legends from these activities aren't the exact equivalent of the general population we're comparing them to: men from England and Wales. We have been very interested to see whether or how this affects longevity figures. The post-war dominance of Wimbledon by players from the USA, Australia, Sweden and Germany is a case in point.

Our research doesn't require our sporting legends to have died to be included. If it did, we would exclude many who are alive today, in their 70s or older. For example, 50% of all male Wimbledon finalists were, remarkably, still alive in 2020. In such cases, we base our estimate of their longevity on their current age and their year of birth, to see whether their longevity has exceeded expectation. We can apply this test to previous years too.

In doing so we can predict whether each sport is likely to lead to a life that's longer than expected, long after our legends' sporting careers are over. Since such careers are relatively short, how sportsmen spend the rest of their lives is likely to be influenced by their sporting experience, but not necessarily determined by it.

Why longevity differs by sport

Our selection criteria will inevitably have other in-built biases. There are various reasons why longevity might be greater for players of one sport rather than another. For example, it seems obvious to say that boxing is riskier to long-term health than cricket. But is football more dangerous than rugby? There's an ongoing debate about the risk of concussion in football, boxing and rugby (from heading the ball in football, and from accidental collisions in rugby). However, there's little information on the long-term effects of concussion in contact sports, apart from individual cases which manifest in the form of dementia and cognitive decline.

It's hard to know from mortality data alone whether such injuries are unusual or how they might affect longevity – although it's a reasonable assumption that continued exposure will be deleterious. The anecdotal evidence of the long term health effects of concussion is growing, but must be tempered by the fact that people are living longer, as well as the impact of differences in how these sports are played today, compared to in the past. Our use of lifespan as a comparator is imperfect but provides a useful yardstick, making this research indicative rather than conclusive proof of longer-term health effects.

As for other factors affecting longevity, the evidence points in different directions. We find that shorter life-spans are associated with less wealthy backgrounds; these are traditionally more typical of sports like football, boxing or horse racing (for unrelated reasons). However, affluence does not have to mean longer lives. Educational background is also linked to longevity and may be an important factor differentiating sports like boxing and football from rugby and cricket.

Sporting careers are relatively short, so adverse health behaviours outside the field of play are another differentiating factor. For example, some high-level players find it hard to cope with life after their sporting careers are over. Conversely, some top athletes go on to have successful non-sporting careers, for instance in senior management or ambassadorial positions. But this could apply to a range of athletes rather than focusing on sporting legends.

Of the following sections, Section 1 describes our methodology, while we set out the results for each sport in Section 2. This includes some highlights of key events and personalities that have shaped the individual sports and compares longevity both within and between sports. Section 3 provides a short commentary on the overall rankings and a final section provides the conclusions. Technical details are given in Annexes A and B.

A summary of the data sets used is shown in Box 1.

Box 1: Data sets

Football: England football captains
(121, born between 1842 and 1994, with 47 alive in 2020)

Cricket: England cricket captains
(80, born between 1842 and 1990, with 26 alive in 2020)

Rugby union: England rugby captains
(130, born between 1847 and 1993, with 51 alive in 2020)

Tennis: Wimbledon Gentlemen's Singles finalists
(110, born between 1849 and 1990, with 55 alive in 2020)

Golf: Winners of the British Open Golf Championship
(82, born between 1842 and 1993, with 35 alive in 2020)

Boxing: British heavyweight champions in the light, middle and heavyweight divisions (140, born between 1879 and 1997, with 72 alive in 2020)

Horse racing: All winning jockeys of the Epsom Derby
(89, born between 1841 and 1993 with 26 alive in 2020)

1. Methodology

Comparing longevity is not a simple matter of averaging out different ages of death. We must adjust any direct comparison with the general male population: the longevity 'goal posts' keep shifting as life expectancy goes up for all. We must also include those sporting legends who are alive today and determine if their longevity is exceptional – for instance, is the fact that there are seven Wimbledon Gentlemen's Singles finalists still living in their 90s statistically unusual?

To provide us with a firm basis for comparison, we have based our analysis on Office for National Statistics (ONS) cohort life tables from 1841 onwards for males born in England and Wales. These give the probabilities for a person born in a given year surviving to any given age. We take 20 as our starting age rather than zero, to allow us to select individuals who have reached the relevant measure of sporting success.

It's important to note that cohort life tables use mortality trends by age and year of birth. The alternative would be to use period life tables, which are based on current rather than prospective mortality rates. We consider a cohort-based approach to be more accurate, because it predicts the probability of someone born in 1900 being alive in 1980, for example. If we were to calculate life expectancy using mortality rates from 1900, our calculations would soon underestimate true life expectancy.

To give an example of the difference this makes, the cohort life expectancy of a 20-year-old man born in 1880 was 45 years, compared with 62 years for a 20-year-old man born in 1960. This would make the expected age of death for the former 65 (45+20) and 82 (62+20) for the latter. Using period-based tables would have given us equivalent figures of 60 and 71. The difference is much greater in the latter case because of rapid improvements in life expectancy during the 20th century.

This distinction is also important when comparing people alive today based on their mortality prospects in their birth year; we therefore choose to use forward-looking mortality rates rather than the mortality rates that applied in the years of their births. Sporting success obviously doesn't begin at birth but during adulthood; this is why we've taken a starting age of 20 as our benchmark.

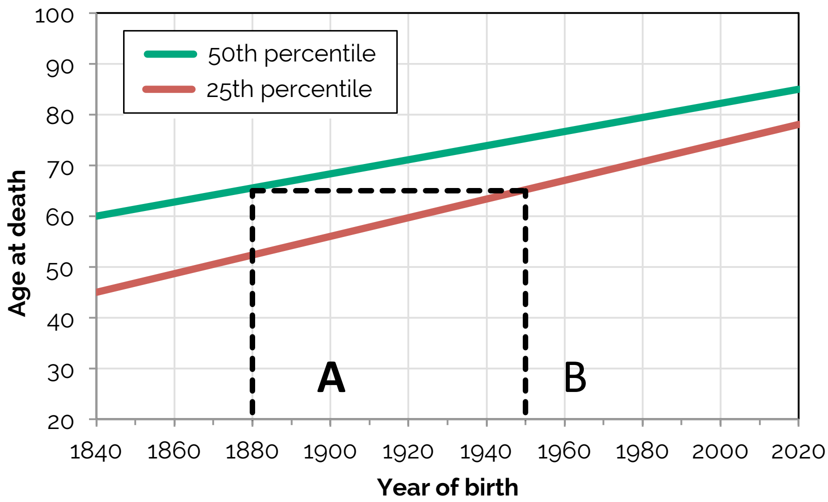
Given that events such as the Epsom Derby or the Wimbledon Championships tend to be annual, sample sizes tend to reflect annual and seasonal cycles and are sufficient for statistical purposes; in this case for determining if champions live longer. One exception is where there can be repeat winners of the same trophy, such as in the Wimbledon Championships. To boost this particular sample we have extended it to include finalists and winners.

A. Deceased sportsmen

Age of death is no longer an absolute measure of longevity, as longevity in the general population has been increasing for decades. (A person dying at 65 in the 19th century might be considered old when compared with someone dying at the same age in 1950.) There were also greater inequalities in age of death in the 19th century: today, ages of death tend to bunch more closely together. For all these reasons, we use a relative measure of age, achieved by comparing the percentile of the general population that lives to a given age, to the percentile of individuals in this study who live to the same age and were born in the same year. Figure 1 explains how this works.

The vertical axis represents age of death and the horizontal axis year of birth. Consider two individuals A and B: the first born in 1880 and the second in 1950. Both die at 65, as indicated by the horizontal hatched line. For person A, dying at the age of 65 would have been considered 'normal', since 50% of the population born in that year would also be dead by that age. For person B, 65 would have been considered a relatively young age to die, since only 25% of the corresponding population would have died by that age (half as many as for the 1880 cohort). Note that the 25th and 50th percentiles tend to converge over time: this is termed the 'compression of mortality'. It occurs because ages of death have bunched more closely together and applies to all percentile ranges.

Figure 1: Measuring the comparative longevity of individuals with respect to the general population



Our test of longevity is whether the number of deaths is higher or lower than expected within given probability ranges. For example, if deaths bunch in the 95-99 percentile bracket it means they're long lived compared with the general population.

We test for five different percentile categories: 0-10, 10-25, 50-75, 75-95, 95-99 and 99+. In words, we would expect 10 of every 100 deaths to occur in the 0-10 bracket, 15 in the 10-25 bracket and so on. Where the actual number of deaths is higher or lower than expected, we can test whether this is statistically significant or not. Given our sample size, our decision rule is based on the probability of such an occurrence being 0.05 or less, i.e. a very low probability that this is the result of chance.

As a final step we aggregate the results to produce one single overall measure of longevity, which we then express as an index. For example, if our aggregate measure of mortality for men in a particular sport is equal to 1.2, this would equate to a 20% longevity advantage over the general population; if it is 1.3, it would be a 30% advantage, and so on. A simple way to think about this is as follows: if 50% of the general population had died within a certain age interval while only 40% of our sporting sample had died, leading sportsmen would have a longevity advantage of (100-40)/50 = 1.2 or 20%. This also enables us to rank the sports in this study against each other based on ages of death.

B. Living sportsmen

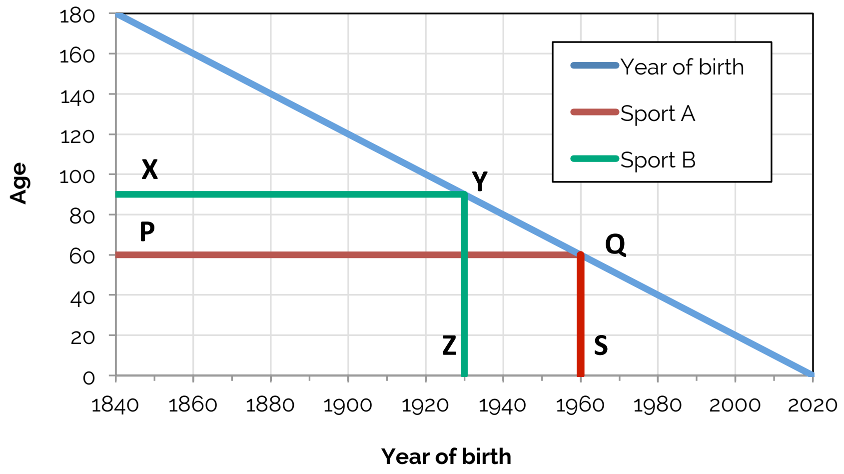
Mortality is always backward looking; a sportsman will not appear on charts such as Figure 1 if they're still alive. This means that we're studying people who for the most part would have been born 70+ years ago: the peak of their prowess might have been while in their 20s or 30s. But the numbers of sportsmen still alive long after their sporting careers have finished is also probability dependent. Their average lifespan will be determined by their health, birth year and the time frame – in this case from 1840 to 2020. There's a simple way to represent this process.

Figure 2 illustrates the case of a sport A, in which all subjects live to the same age in this case 60 years. Assume that a different winner of a given event is born each year from 1840 to 2020; the horizontal line PQ shows their age of death by birth year. QS is the dividing year denoting whether they would be dead or alive in 2020. Since they all live to the age of 60, any born on or before

1960 would be dead in 2020 and any born after 1960 would be alive.

Over the entire period from 1840 to 2020 we would expect 66.6% to be dead and 33.3% to be alive [(2020-1960)/ (2020-1849) 100 =33.3%]. In sport B if they each lived to 90 (XY), we would expect 50% to be alive in 2020 and 50% to be dead where YZ denotes the dividing line. In the real world the actual age of death has been increasing and so the horizontal line must be replaced by an upward sloping line. A worked example based on the Wimbledon Gentlemen's Singles finalists is given in Annex B.

Figure 2: Simplified illustration of survivorship



Because people live to different ages, the test to determine if their age is exceptional is more complicated. We base it on the number alive in any given year, their current age, and the year in which they were born. We then consider if this number is higher than expected by applying cohort life tables to extract the probability of each individual subject being alive. This probability is then summed over all birth years and expressed as an index figure of the actual number alive in any given year. If the index is greater than 1, more are alive than would be expected; if it's less then 1, fewer are alive.

There are many reasons why this figure might fluctuate over time. This could include improvements in safety, e.g. new rules and regulations that have the gradual effect of extending lives. Boxing, horse racing, rugby and football are all sports in which safety issues are important considerations. Trends in the index might indicate that greater survivorship is intrinsic to the sport, that there have been safety improvements, or that there are other factors, including external ones.

As with age of death, this index is a random variable; we need to know if the probability of it deviating from 1 is statistically significant, using the same decision rule as for age of death. Index values consistently higher than 1 indicates long-term differences – in other words, survival advantage. The opposite applies in cases where the index is generally less than 1. Where the index is exactly 1, survivorship is the same as for the general population.

As our data is from 1841, for the first part of the period (to 1900) most of our subjects were still alive. It means that comparing survivorship rates with the general population isn't very revealing, because everyone is still relatively young. This starts to alter as subjects reach the age of 60, approximately, as more start to die. We therefore confine our figures to the time period 1900 to 2020, which provides sufficient time for patterns to emerge and settle down.

Finally, we also observe that trends in the data are simpler to understand if we use a five-year moving average rather than a spot figure for each year. We have divided the results into two equal-sized periods: 1900 to 1960 and 1960 to 2020. As with our deceased sportsmen, we've aggregated the results over time to produce a single overall measure of survivorship for each sport.

2. Analysis

A. Football

Football is regarded as the UK's premier national sport – one that's played all over the world. The laws of football date back to 1863, when they were formally adopted by the newly formed Football Association. In Britain, football is traditionally regarded as a working class sport; most players in the national team traditionally come from working class backgrounds. Football became a professional sport in the summer of 1885, with the very first league contested in 1888 by just 12 clubs. In the first-ever international match, England played against Scotland in 1872. An incredible 120 years later, 11 of those 12 teams are still up and running in football's top flight.

There have been 121 England football captains born since 1840, of whom 74 have died and 47 were still alive in 2020. Overall, a new captain has been appointed on average once every two years, but more recently captaincy has changed hands much more often. The most skilful players don't necessarily become captains; endurance and motivational skills are arguably equally important. We also found that, unlike in cricket or rugby, the direction of play today is dictated by trainers on the touchline, rather than by captains on the pitch, which could indicate they are more replaceable.

There are many famous names that could be recounted: of the deceased, Charles W. Alcock was the first England captain; he was born in 1842 and died, aged 65, in 1907. Reginald "Tip" Foster (1878 –1914), commonly designated R.E. Foster in sporting literature, was the only man to have captained England at both football and cricket. Bobby Moore (1941-1993) was the only England football captain to win the FIFA World Cup, in 1966. The oldest captain still alive in 2020 is Ron Flowers (aged 86). The best-known is probably David Beckham (b. 1975), who captained England from 2000 to 2006. He will always be remembered for scoring a wonder goal with a last-gasp free kick against Greece in a 2001 World Cup eliminator.

Figure 3 shows the ages of death of 76 England football captains, in order of birth. The 1970 horizontal axis cut off reflects that fact that there are no deaths for captains born after this year. The longest lived, Henry Wace, was born in 1853 and died age 94, but this is unusually old for football. The sloping lines from left to right show survivorship in the general male population by year of birth; the six divisions range from the 10th to the 99th percentile. The upwards slope reflects how survival is improving over time, with the inequality gap between upper and lower percentiles narrowing.

Figure 4 shows the cumulative percentage of deaths as compared with those in the general male population, based on the data pattern in Figure 3. Although the percentages are lower than the comparator group in the 10-25 percentile range, we find no statistically significant difference in the overall mortality. We use similar charts to illustrate mortality patterns in each of our other sports.

Figure 5 is the chart we use to measure survivorship. It shows index figures for those still alive in any given year compared to the number expected to be alive: the pattern suggests that our sporting legends lived longer during the period 1900 to 1960 compared to the general population. This is borne out by analysis: the index is significantly greater than 1 in the first period but not in the second. This decline could be due to several factors, such as professionalisation of the game, and a greater physical toll from playing more matches with heavier balls in previous years.

Figure 3: Ages of death of England football captains compared with the general male population based on year of birth and probability of survivorship

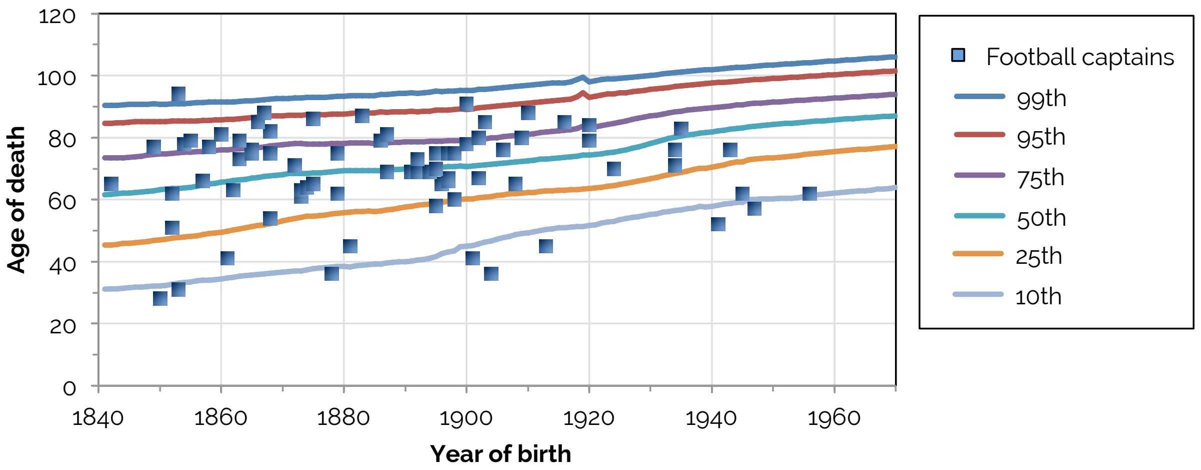


Figure 4: Cumulative % of deaths compared with the general male population

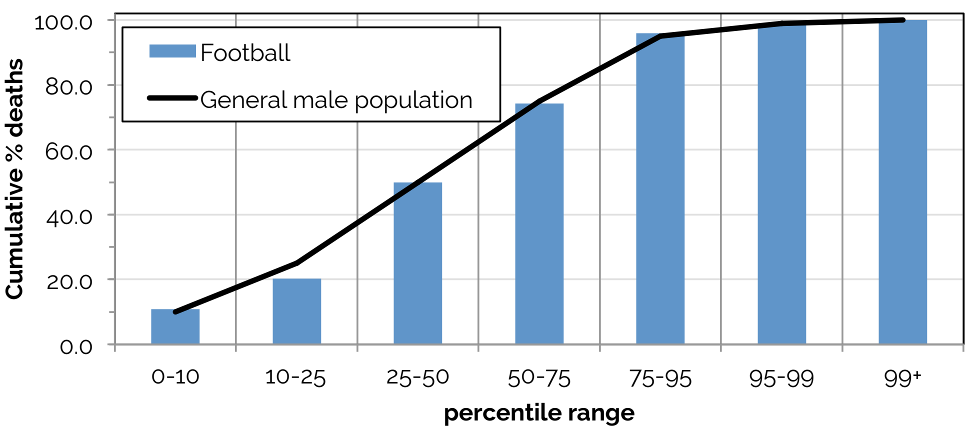
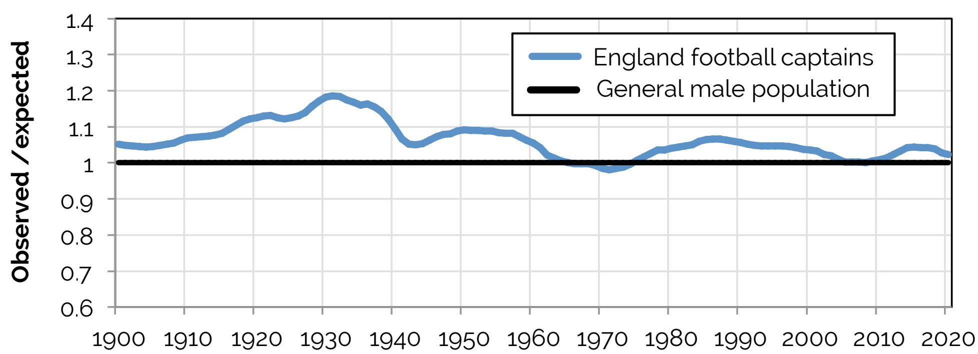


Figure 5: Index for observed versus expected number alive by year (5-year moving average)



B. Cricket

Cricket is the UK's national summer sport; today it's played in many different formats. Some, like 20-over cricket, last less than a day, while international test cricket matches can last up to five days. The earliest known cricket code was drafted in 1744; since 1788 the current code has been owned and maintained by its custodian, the Marylebone Cricket Club (MCC) in London. The first international test was played between England and Australia in 1877, in a competition that became known as the Ashes. Today cricket is televised globally and is especially popular in south Asian countries, including India. The shorter formats of the game in particular attract huge audiences today.

Whilst cricket is a physical game, exposure to injury is different from that of contact sports. When played in hotter climates there's danger from extreme heat and fatigue but we don't have evidence as to whether this has a negative effect on longevity. Cricket is a highly tactical game, with those tactics dictated on the field of play by the captain, chosen primarily for leadership, tactical and team selection skills. On average a new captain is appointed every 21 months, but because the game is now played in different formats there may be more than one captain at a time.

There have been 80 England cricket captains born since 1840, of whom 54 have died and 26 are living today. James Lilywhite, who was born in 1842 and died aged 87, was the earliest England captain and Bob Willis died most recently in 2019, aged 70.

England cricket captains tend to be younger as we move forward in time; the oldest was the renowned W.G. Grace, who captained England against Australia in 1899 at the lofty age of 51. Sir George "Gubby" Allen captained England against the West Indies in 1947 at 45, while Walter Hammond was captain against Australia in 1948 at 43.

Our analysis of the mortality data in Figure 6 shows a sprinkling of players above the 95th percentile. Further analysis shows that that unlike in football, cricket captains generally outlive the general male population. This difference is statistically significant ($p<0.05$) in the 0-10 and 50-75 percentile ranges (Figure 7). The longest living captain was Bob Wyatt, who died aged 94 in 1995, while several other pre-war captains lived to the age of 90, including Sir Pelham "Plum" Warner (d. 1963), Ken Cranston (d. 2007) and Donald Carr (d. 2016).

Turning to Figure 8 we see that the index for the ratio of the number still alive compared with the general population fluctuates but is generally higher than 1 in all but six years, the first occasion being either side of 1915 and the second in 1965. Overall the ratio is slightly more favourable post-1960, but the index is generally significantly different from 1 ($p<0.05$). Among the former captains alive in 2020 are Ray Illingworth, aged 88; Mike Smith, aged 87; and Ted Dexter, aged 85.

However, cricket isn't danger-free. Probably the most fearless captain was Brian Close who died in 2015, aged 84. Among his feats of bravery was being famously bruised and battered by the intimidating fast bowling of Wes Hall and Charlie Griffith in the Second Test against the West Indies in 1963. Today protective gear, including helmets, is commonplace – but even so in 2014 Australian cricketer Phillip Hughes died two days after receiving serious head injuries during a domestic match in Sydney.

Figure 6: Ages of death of England cricket captains compared with the general male population based on year of birth and probability of survivorship

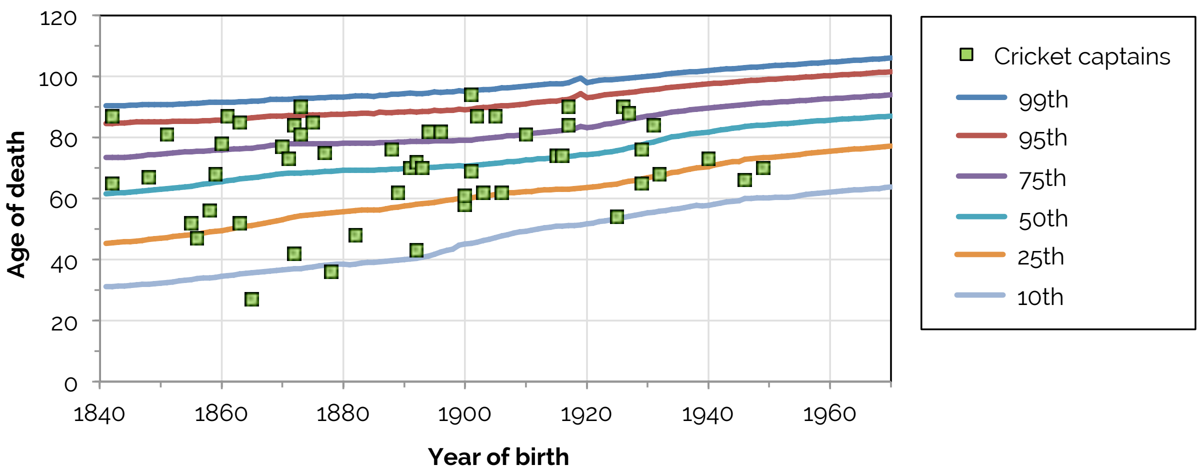


Figure 7: Cumulative % of deaths compared with the general male population

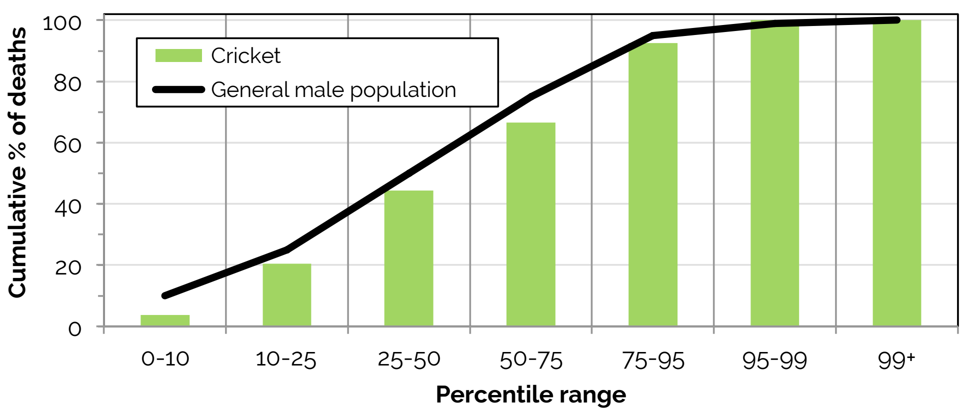
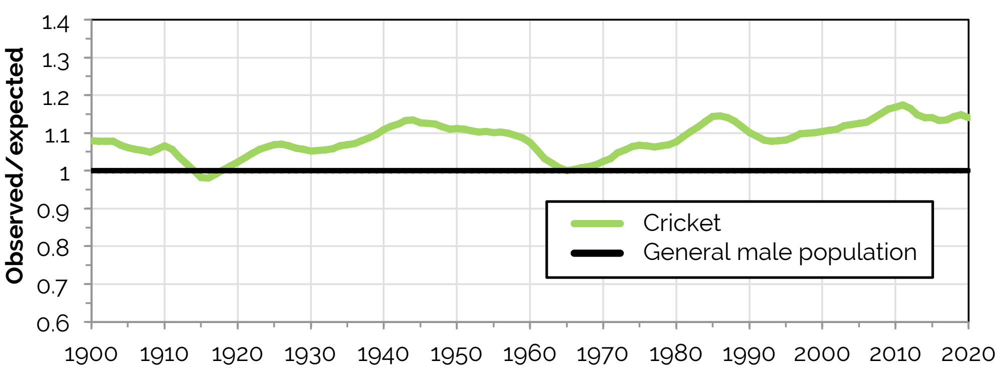


Figure 8: Index for observed versus expected number alive by year (5-year moving average)



C. Rugby

Rugby is said to have originated in 1823, at Rugby School in Warwickshire, when during a game of football, William Webb Ellis decided to pick up a ball and run with it. Although there's very little evidence to support this story, the Rugby World Cup Trophy is still named in his honour. The first set of rules for any type of football was written down in 1845; Blackheath Club decided to leave the Football Association in 1863, and the Rugby Football Union was formed in 1871. The first international match was between England and Scotland in 1871 (narrowly won by Scotland). Rugby League, which is mainly played in the north of England with different rules, broke away in 1895, after a row over payments to its players.

A long-standing perception that Rugby Union is mainly played in English public schools is reflected in the saying, "Football is a gentleman's game played by hooligans, and rugby is a hooligans' game played by gentlemen." But this ignores the huge following around the world, where rugby is played by people of many different backgrounds.

There have been 130 England rugby union captains, of whom 79 have died and 51 were alive in 2020. On average a new captain is appointed every 14 months. Albert Hornby, who was born in 1847 and died aged 78, was the earliest born captain. David Perry, who was born 1937 and died aged 80 in 2017, is the captain who has died most recently. Andrew Stoddart, born in 1863, has the distinction of having captained England at both rugby and cricket.

Rugby is a tough contact sport which George Orwell once described as "war without bullets". Both English and Welsh rugby players show remarkable longevity, suggesting that socio economic background isn't a factor, with longevity more likely associated with educational factors or rugby culture. In fact, this longevity would be even more pronounced had five England captains not been killed in action during the First World War: they were Perry Kendall, Harry Alexander, Edgar Mobbs, Ronald Poulton-Palmer and Lancelot Slocock.

Figure 9 shows that many deaths are bunched in the 75th to 95th percentiles. The cluster of data points below the 10th percentile occurring at the end of the 1800s represents those killed in action. Figure 10 shows the cumulative percentage of deaths, compared with those in the general male population based on the pattern in Figure 11. Mortality is much lower compared with football, being in the 75th percentile, which equates to being aged over 80 in today's terms. The pattern seen is also significantly lower than that for the general population up to this point ($p<0.05$); it's slightly better than for cricket captains.

Figure 11 shows that the index figure representing the index of those alive to those expected to be alive is consistently above 1 for the whole period; there is a significant difference ($p<0.05$), averaging around 1.1 or 10% higher. The only time it dips below 1 is during the nine years of the 1930s: this reflects the combined effect of those born in the 1800s dying away and the premature deaths of those killed during the First World War. Consequently we see a much improved index after 1960: by 2020 it has climbed to around 1.16, based on 51 surviving captains from a grand total of 130. These survivors include John Willcox (b.1937) and Richard Sharp (b.1938), who scored one of the most memorable tries ever seen at Twickenham, against Scotland in 1963.

Figure 9: Ages of death of England rugby captains compared with the general male population based on year of birth and probability of survivorship

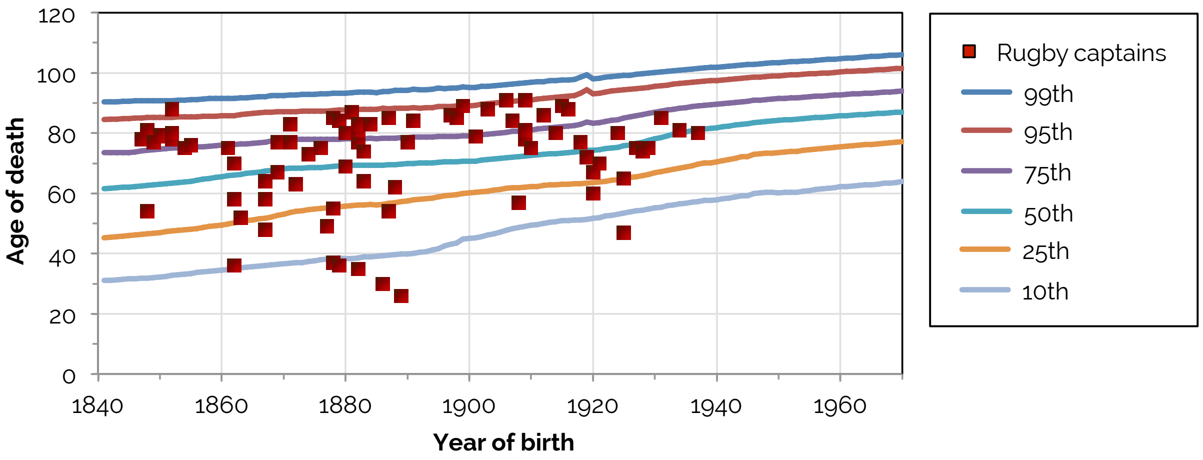


Figure 10: Cumulative % of deaths compared with the general male population

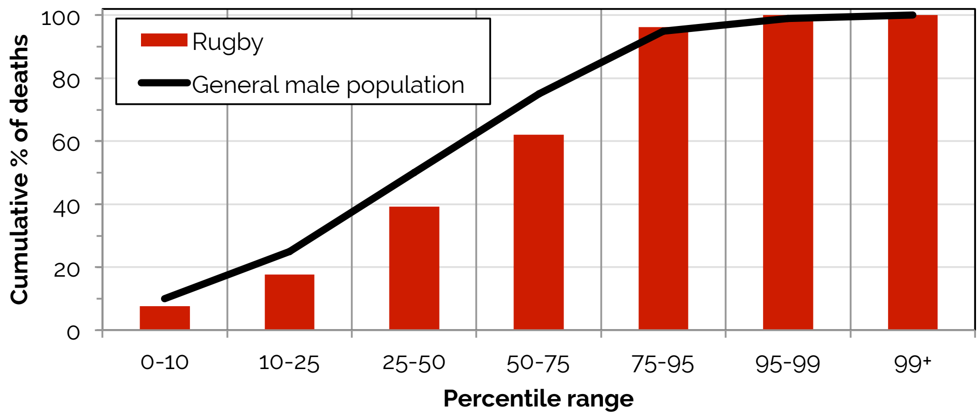
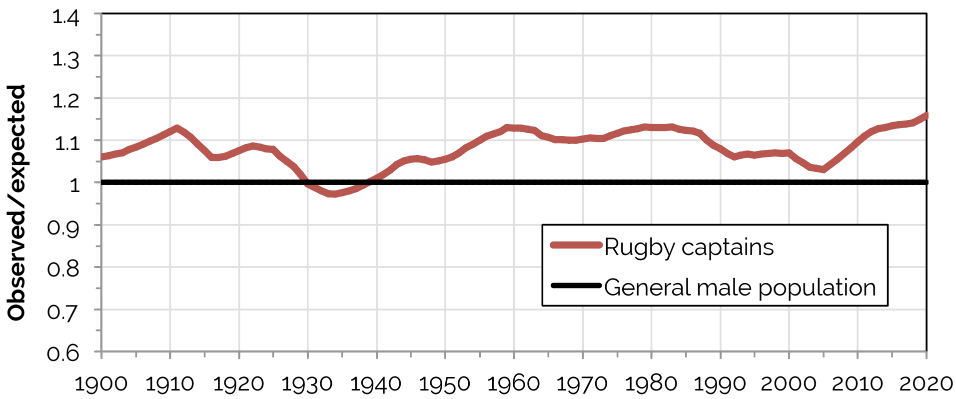


Figure 11: Index for observed versus expected number alive by year (5-year moving average)



D. Tennis

Tennis is a competitive racket sport played by men and women all over the world. It's usually played by individuals (singles) or in pairs (doubles) on various flat surfaces, including grass (known as lawn tennis). Tennis began in medieval France, as an indoor game called jeu de paume ("palm game"). From France, it spread across Europe, taking firm hold in England in the 16th and 17th centuries. Legend tells that the Dauphin sent Henry V three tennis balls to remind Henry of his reputation for being a careless pleasure-seeker rather than a serious threat to France.

The rules of tennis as played today were codified by Major Walter Wingfield in 1874. The first Wimbledon Championships were held three years later in 1877. Tennis soon became so popular that the All England Croquet Club changed its name to the All England Lawn Tennis and Croquet Club! Wimbledon is one of the foremost tennis tournaments in the world, entered by top players of all nationalities. Wimbledon was originally an amateur-only competition, but 1968 ushered in the 'open era,' when professional players were also admitted.

The winner that year was the Australian Rod Laver, who won the gentlemen's singles title four times altogether, including twice as an amateur. Several other players have also won the title multiple times, including Roger Federer (Swiss, eight-time winner), Pete Sampras (US, seven times) and Bjorn Borg (Swedish, five times). Fred Perry, who was British, won three times between 1934 and 1936. The only Briton to win since is Andy Murray, who won in 2013 and 2016.

If we include finalists as well as winners, there are a total of 110 players and ex-players in the sample, 55 of whom were still alive in 2020. Figure 12 is particularly interesting because it shows more players dying above the 95th percentile of the general male population than in any other sport in our study. Notable inclusions are Sydney Wood (US, who died aged 98), Jean Borotra (French, who died aged 96), Henry "Bunny" Austin (British, died aged 94) and Rene Lacoste (French, died aged 94). In contrast, two notable US players from the open era died at relatively young ages: Chuck McKinley (who died aged 45) and Arthur Ashe (who died aged 49) – but this was highly unusual in tennis terms. The longevity of tennis players is confirmed by our mortality analysis in Figure 13, which finds that Wimbledon finalists outlive the general male population up to and including the 95th to 99th percentile ($p<0.05$).

There is clearly some truth in the observation that many of the longest lived were not British but French, US and Australian. This is strongly supported by Figure 14, which shows the ratio of players still alive by year. For 96 out of 121 years since 1900, the index has been above 1, but the most rapid and continuous period of improvement occurs after 1950. In 2020 the index stands at 1.36, which is higher than for any other sport at this stage. The data show remarkable numbers of ex-finalists well into their 90s today, either American or Australian. They include players such as Vic Seixas (US, aged 97), Geoff Brown (Australia, aged 97), Budge Patty (US, aged 97), Bob Falkenburg (US, aged 95), Dick Savitt (US, aged 94), and Frank Sedgman (Australia, aged 93). The lack of Britons in the list reflects the fact that Andy Murray is the only British male to reach the final since Bunny Austin in 1938.

Figure 12: Ages of death of Wimbledon finalists compared with the general male population based on year of birth and probability of survivorship

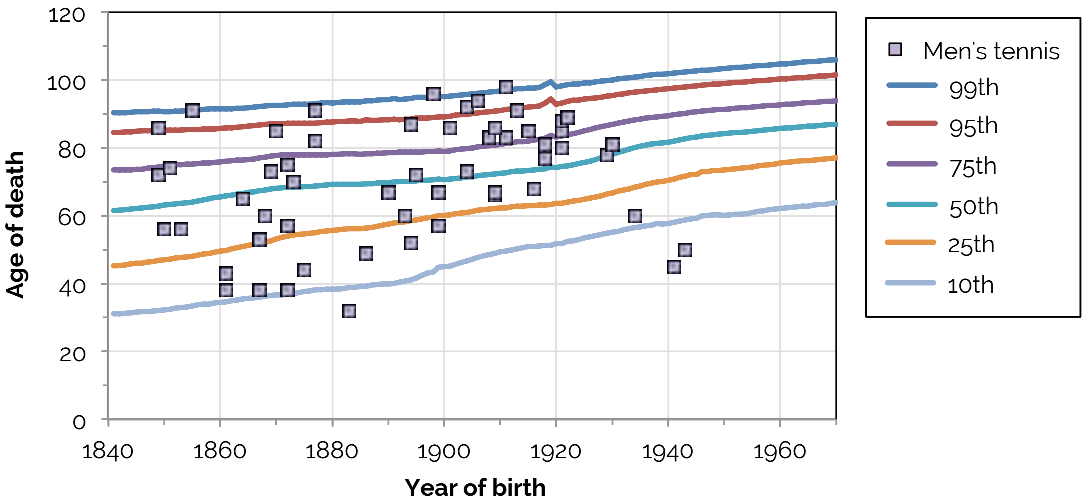


Figure 13: Cumulative % of deaths compared with the general male population

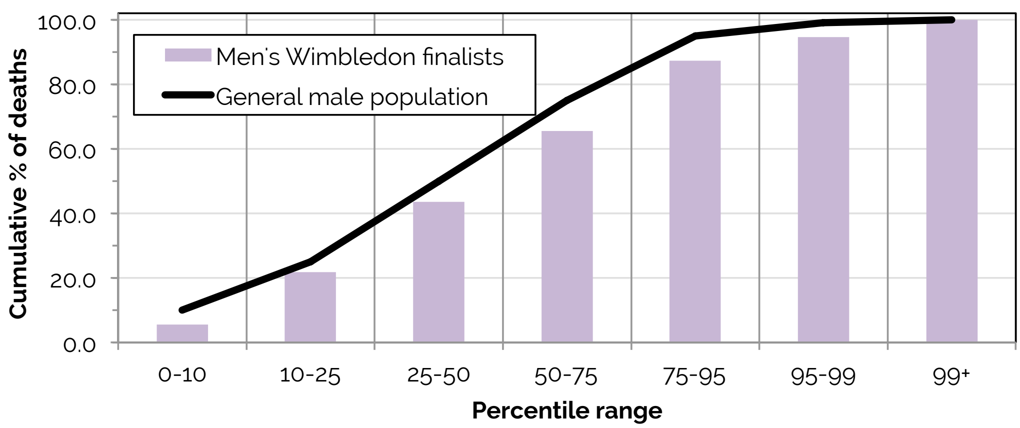
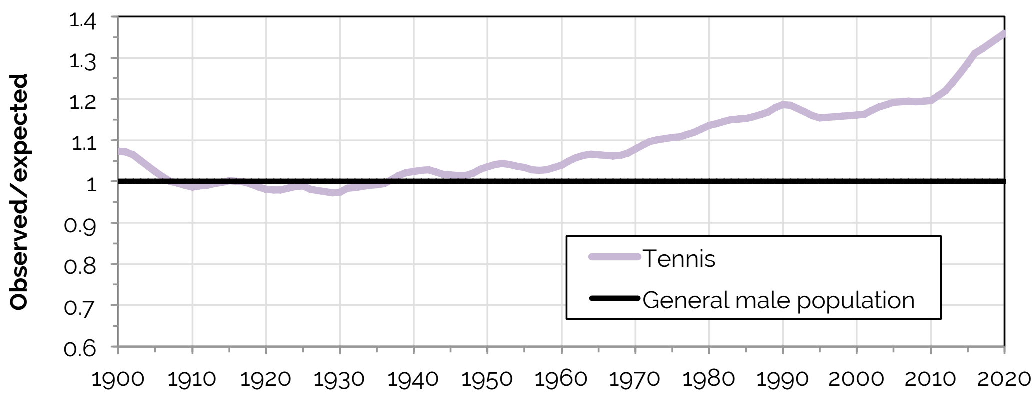


Figure 14: Index for observed versus expected number alive by year (5-year moving average)



E. Golf

Golf is a centuries-old sport. Versions of the game have been played in many countries, but its modern origins can be traced to Scotland in the 18th century, with the publication of the Articles and Laws in Playing at Golf in 1744. Although played by both men and women, competitive golf is usually segregated. We have drawn our sample from the British Open Championship (often referred to as 'the Open'), the oldest golf tournament in the world, which is open to all comers who reach the required standard. The first Open took place in 1860 at Prestwick in Scotland, and was won by Willie Park Senior, who went on to win on three further occasions. Willie was born in 1833, just outside of our time frame. There was no championship during the two world wars.

Entry to the Open is based on merit rather than nationality. Our sample includes 82 winners, of whom 47 have died and 35 are alive. ('Old') Tom Morris Sr is the oldest winner, having won at age 46 in 1867, while his son ('Young') Tom Morris Jr is the youngest, winning at age 17 in 1868, then again in 1869, 1870 and 1872. In 1869 Young Tom Morris scored the first ever Open hole-in-one at the 166-yard, par-3, eighth hole at Prestwick Golf Club, Scotland. The longest-lived winner was Gene Sarazen from the US in 1932, who won the open in 1933 and died in 1999, aged 97. He also made a hole-in-one at the Open in 1973 at the age of 71 in Troon, Scotland. This made him the oldest player ever to do so, exactly 50 years after his 1933 victory. Two others who lived well into their 90s were Ken Nagle (from Australia, who died in 2015 aged 95) and Roberto de Vicenzo (from Argentina, who died in 2017 aged 94).

Figure 15 shows the distribution of deaths by year of birth and percentile range. Only four golfers died within the 0-10 percentile, while several have survived above the 95th percentile, as compared with the general male population. Figure 16 shows the cumulative percentage of deaths within each percentile range. Further analysis finds that these champions have greater longevity than the general male population in the 25-50, 50-75 and 75-95 percentile ranges ($p<0.05$), which positions them roughly between rugby and tennis legends. Greater survivorship is also apparent in Figure 17, which shows an index representing the ratio of the observed number of golfers alive compared with expectation by year. The value is above 1 (parity) in 110 years and below 1 in only 10, all which occurred in 1900. The index is slightly higher before 1960 than afterwards, but in either case the difference is statistically significant ($p<0.05$).

The steep drop in value from 1960 to 1975 is due to the unconnected deaths of several former winners. Of those alive in 2020, the oldest are Bob Charles (84), Lee Trevino (81) and Jack Nicklaus (80). Charles is a New Zealander and the first left-hander to win the Open. Trevino won in 1971 and 1972, while Nicklaus won three times in 1966, 1970 and 1978. The most prolific winner ever was Harry Vardon, who won on six occasions between 1896 and 1914. Since 1945, both Peter Thomson (Australia) and Tom Watson (USA) each achieved the feat on five occasions, Thomson between 1954 and 1965, and Watson between 1975 and 1983. Seve Ballesteros (Spain) also won on three occasions between 1979 and 1988, but sadly he died at the young age of 54. Nick Faldo (England) also won three times between 1987 and 1993.

Figure 15: Ages of death of British Open winners compared with the general male population based on year of birth and probability of survivorship

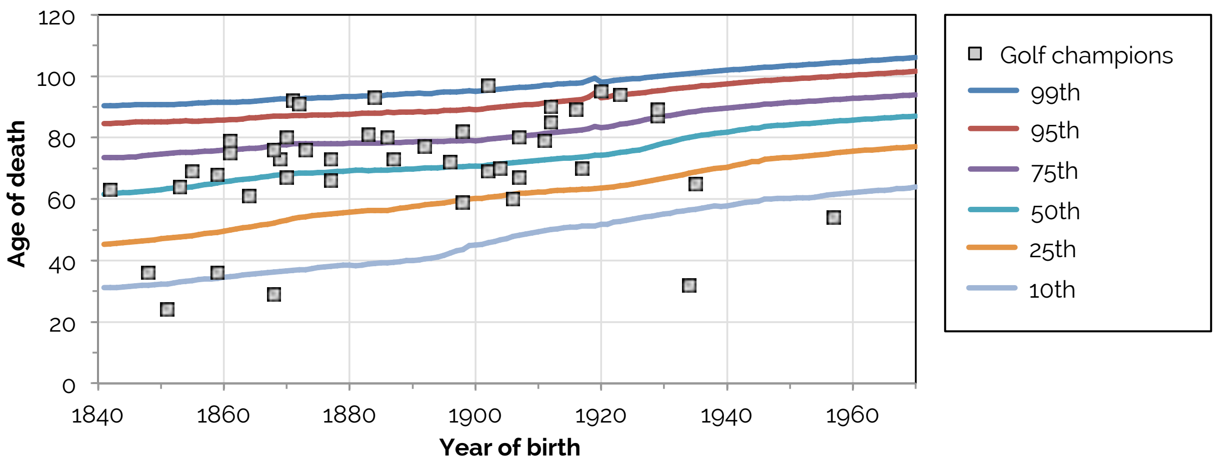


Figure 16: Cumulative % of deaths compared with the general male population

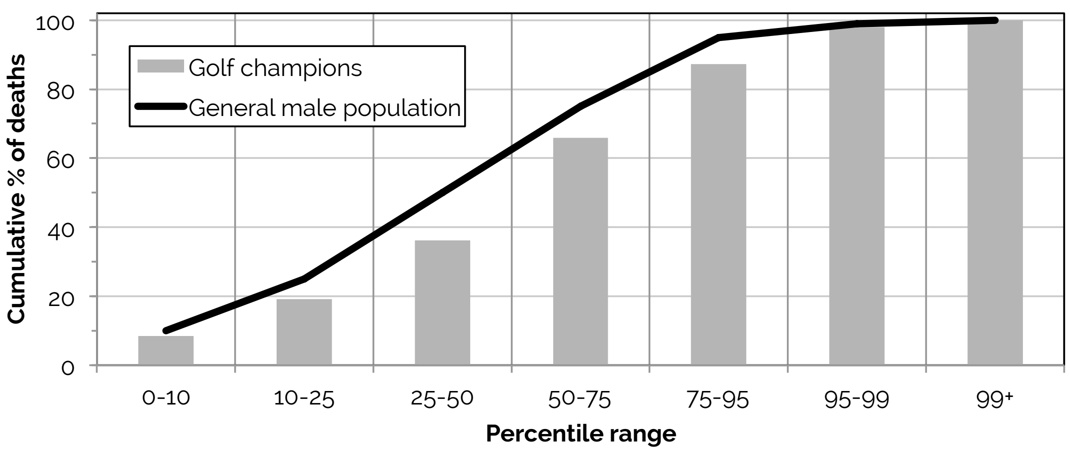
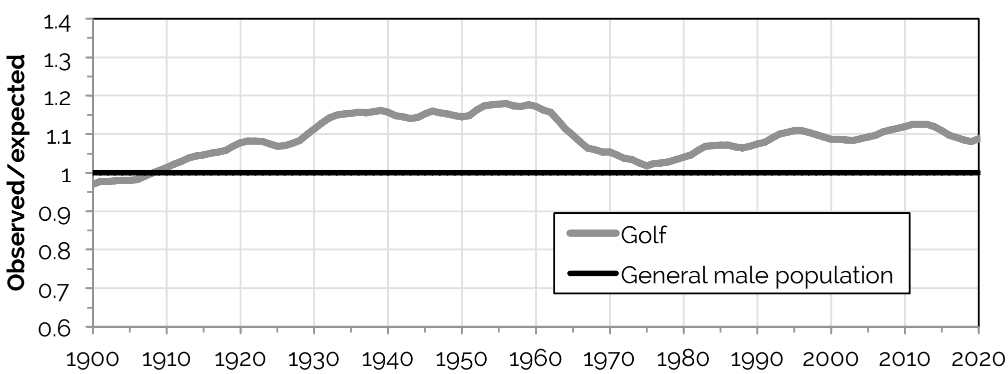


Figure 17: Index for observed versus expected number alive by year (5-year moving average)



F. Boxing

Boxing, like horse racing, dates back to ancient times. It resurfaced in England during the early 16th century in the form of bare-knuckle boxing (sometimes referred to as prize fighting). The modern rules of boxing, known as the Queensbury rules, are attributed to the Marquess of Queensbury in 1867. A professional boxing match consists of up to 12 three-minute rounds, with one minute intervals for boxers to receive advice and attention from their coaches. Amateur ones typically only last for three rounds, though four-round professional fights are common for less experienced boxers. Although boxers must wear gloves, headgear is not permitted in professional bouts, and professionals are allowed to take much more damage than amateurs before a fight is halted.

Referees work in the ring to judge and control the fight, and rule on safety issues. The Lonsdale Belt, originated in 1909 by Lord Lonsdale, was originally given to the champion in each division, being passed on as the title changed hands. From 1929 the belts were awarded by the British Boxing Board of Control, becoming the property of a champion who won three title fights in a division (not necessarily in succession). Boxers traditionally come from impoverished backgrounds. The sport is often regarded as a route out of poverty, as well as a means of instilling self confidence and purpose for economically vulnerable young men.

Boxing has a huge following around the world. The majority of talent today comes from poverty-stricken areas in countries that include Mexico, South America, and Eastern Europe – but Britain still produces its fair share. Our research focuses on British champions from heavyweight divisions. Since the number is quite small, we've expanded the sample to include the middleweight and light heavyweight divisions. We also include cruiser weight, a relatively new category between light heavyweight and heavyweight.

There are 140 British boxers in our sample, of whom 68 have died and 72 were alive in 2020. The first British heavyweight champion to be crowned was Jack Palmer in 1905, who was born in 1879 and died aged 49. The first light heavyweight champion was Dick Smith, crowned in 1914, and the first middleweight was Welshman Tom Thomas in 1906. The first British boxer to be crowned world heavyweight champion was Bob Fitzsimmons in 1897 – a feat not repeated until Lennox Lewis won in 1993, followed by Tyson Fury and Anthony Joshua more recently. The most celebrated British champion, with eight defences of his title, was Henry Cooper who died in 2011 aged 77. He is remembered for knocking Mohammed Ali to the floor in a world title fight in 1963, when Ali was still known as Cassius Clay.

Figure 18 shows that boxing is not conducive to extended longevity. Over 20% of our sample died before the 10th percentile compared to the general male population; all of them died before the 95th percentile. The oldest at their deaths were Tom Gummer, who died in 1982 aged 88 and was middleweight champion in the 1920s; Vince Hawkins, who died in 2008 aged 85, who was middleweight champion in 1946, and Eddie Phillips, who died in 1995 aged 84, who was light heavyweight champion in 1935.

Figure 19 underlines the considerable differences in mortality between our sample and the general male population ($p<0.05$). Lower survivorship is also evident in Figure 20. The index hovers around 1 (parity) during the 51 years up to 1960 but drops below 1 for the 70 years to 2020; the maximum of 1.05 was in 1939, with two minima of 0.92, in 1972 and 2019.

Figure 18: Ages of death of British heavyweight boxing champions compared with the general male population based on year of birth and probability of survivorship

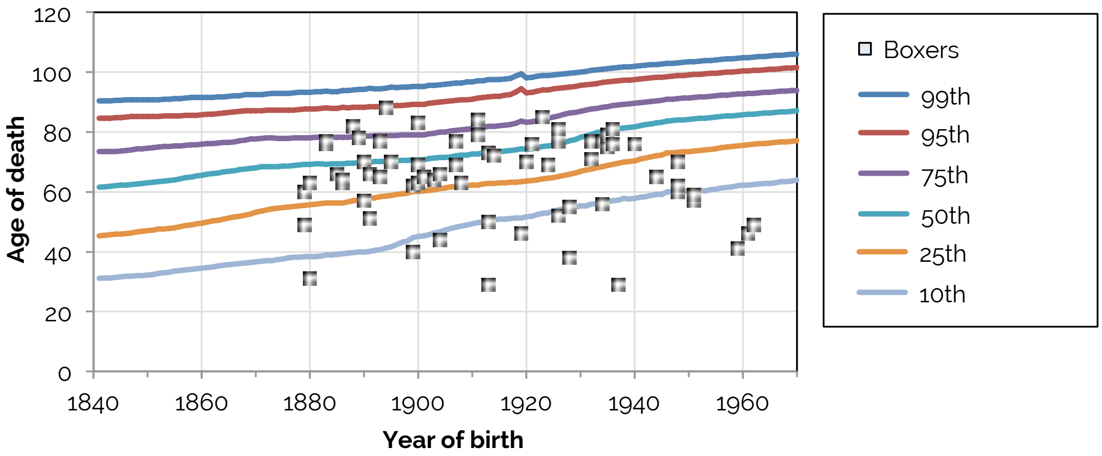


Figure 19: Cumulative % of deaths compared with the general male population

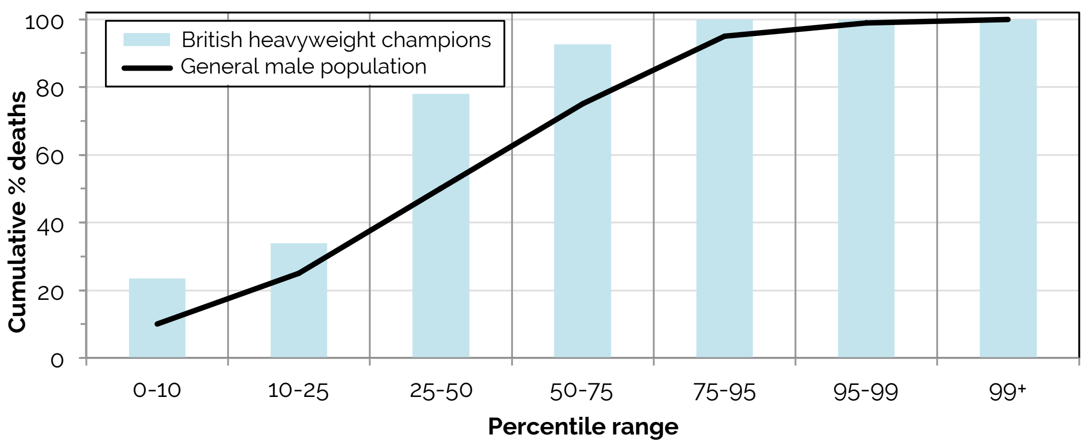
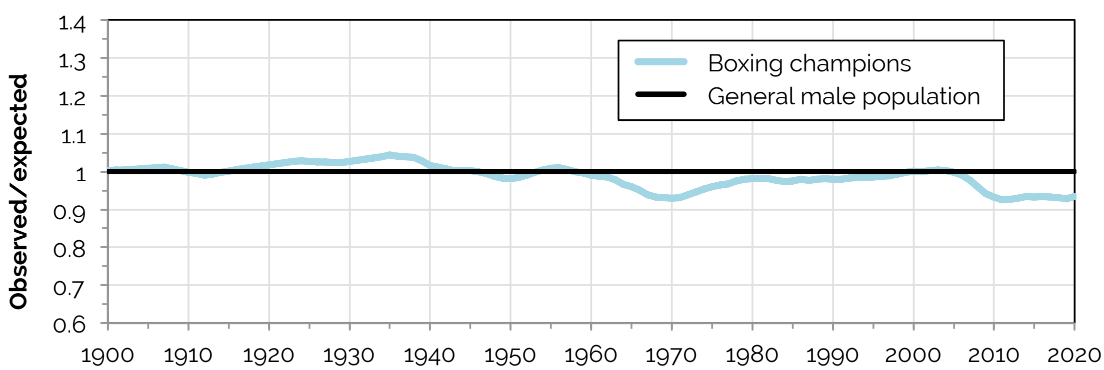


Figure 20: Index for observed versus expected number alive by year (5-year moving average)



G. Horse racing

Horse racing is the second largest spectator sport in the country, after football. It's overseen by the British Horse Racing Authority, which is responsible for both equine and human welfare. Our analysis of longevity is based on jockeys riding in the Epsom Derby, one of the most prestigious races in the British horse racing calendar. Like tennis, both men and women can compete against each other directly, but in practice, this sport is still largely male dominated. The first woman to ride in the Derby was Alex Greaves in 1996 – it was another 16 years before Haley Turner placed ninth on Cavalerio in 2012. However, in 2021, Rachael Blackmore won the Grand National, the other most prestigious event in the British racing calendar – an achievement which is ranked as a game-changer for women's participation in horse racing.

The inaugural running of the Derby was held in 1780. It was won by Diomed, a colt owned by Sir Charles Bunbury, who collected a prize of £1,065 and 15 shillings. Since then it has been run every year. John Forth was oldest man to win the Derby in 1829, aged 60; the youngest was John Parsons in 1862, aged 16. Possibly the most infamous running of the Epsom Derby took place in 1913. The winner was Edwin Piper riding Aboyeur, after the first horse ridden by John Reiff, Craganour, was disqualified. Emily Davidson, a member of the suffragette movement, was killed after running in front of the King's horse, Anmer. The rider of that horse, Herbert Jones, took his own life in 1951 aged 70; this is said to be related to that incident. By contrast John Reiff, the winning jockey, died of natural causes aged 89. In general, jockeys are physically capable of longer careers than participants of most other sports, some competing for decades. Lester Piggott, for example, won the Derby nine times between 1954 and 1983, finally retiring in 1995 aged 59.

Horse racing can be dangerous, with champion jockeys exposed to stress and physical danger throughout their careers. The welfare of both horses and jockeys is vitally important for the future of the sport and to ensure fair and free competition. Our analysis is based on 89 Derby winners born since 1840, of whom 26 were alive in 2020. This reflects the dangerous nature of the sport compared with the others in our list. Figure 21 shows a greater number of deaths at or below the 10th percentile compared with the general population, but also that a few lived into their 90s. Notable examples include Freddy Palmer, who died aged 98 in 2019, and Charles Wood who died in 1945 aged 91. Despite the longevity of some individuals, the cumulative percentage of deaths seen in Figure 22 puts mortality for jockeys higher than that of the general male population, at least up to and including the 25th percentile ($p<0.05$).

This pattern carries forward to the index representing the ratio of those alive in any given year compared with those expected to be alive. This may be seen clearly in Figure 23. This chart reveals that horse racing was more dangerous in the 19th century and the early 1900s, when the number of premature deaths was higher. Jockeys had to be licensed to ride on a Jockey Club racecourse in the 1800s, which probably led to gradual improvements in safety thereafter. For 74 years out of 121, the index has stayed slightly greater than 1, but it never exceeds 1.1 or has shown a statistically significant difference. While horseracing can be a dangerous sport, we conclude that the risk exposure today is broadly on a par with the general population.

Figure 21: Ages of death of Derby winners compared with the general male population based on year of birth and probability of survivorship

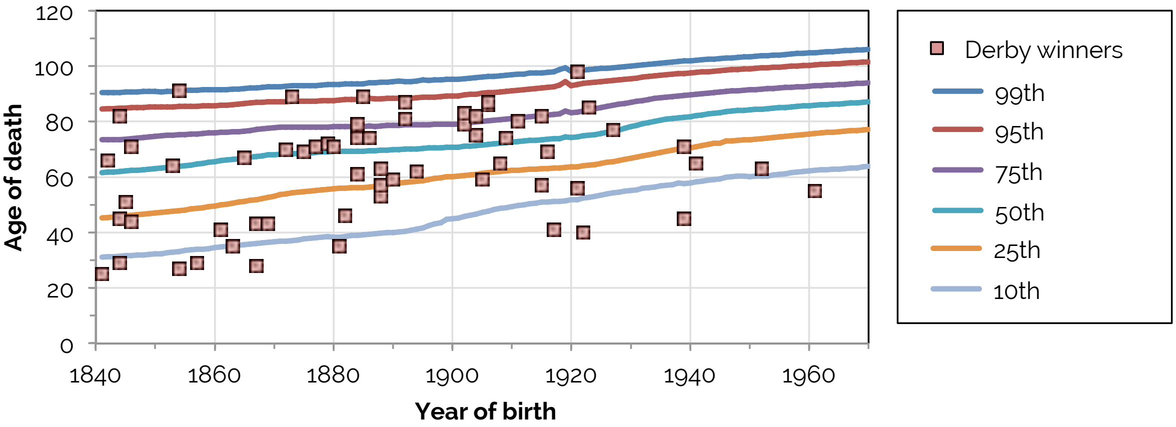


Figure 22: Cumulative % of deaths compared with the general male population

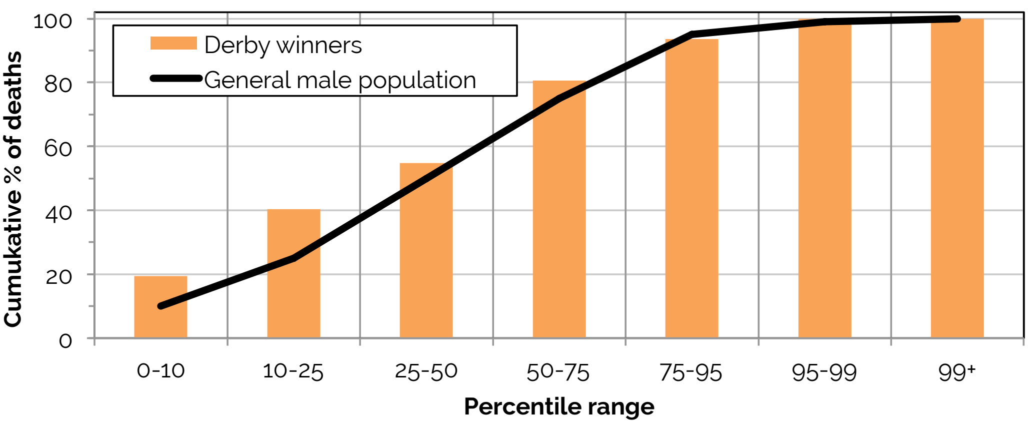
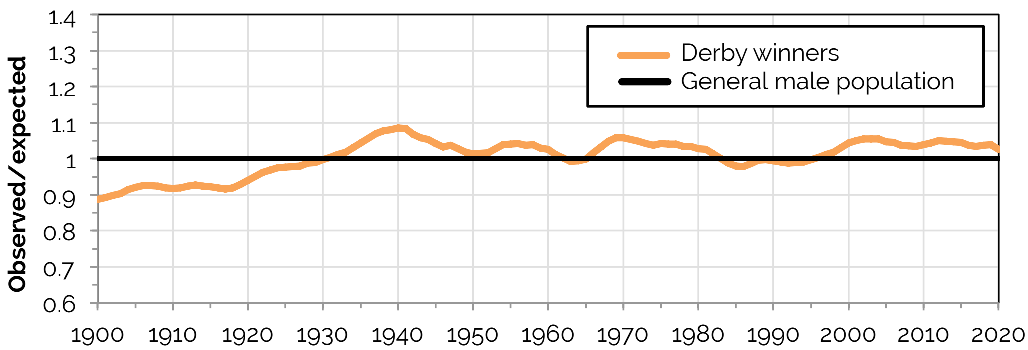


Figure 23: Ratio of observed versus expected number alive by year (5-year moving average)

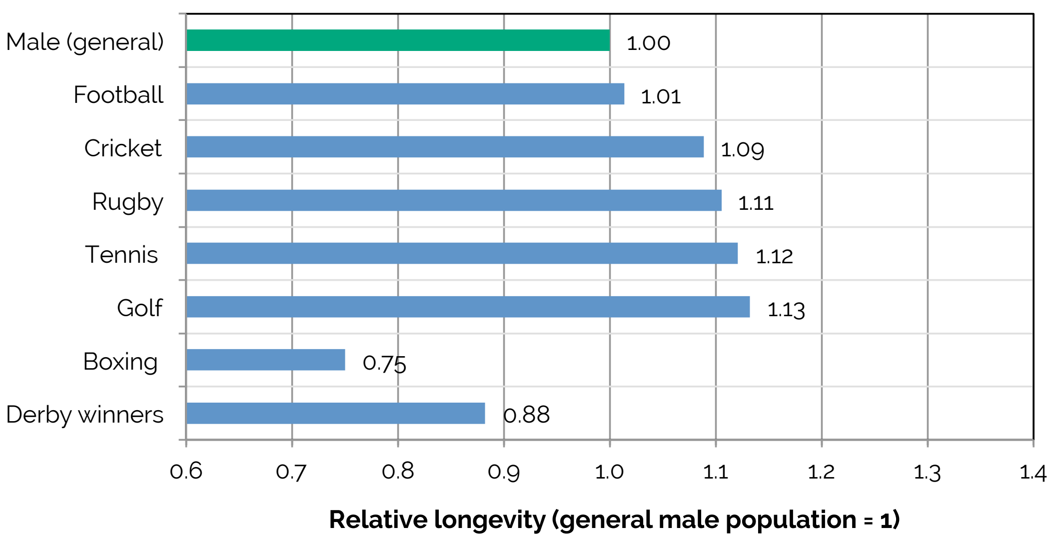


3. Which sport confers the greatest longevity?

We approach this question using two simple summary measures of longevity rather than tables with lots of numbers. The first measure is similar to the standard measure of life expectancy. The principal difference is that we aggregate the actual percentages of survivors to different levels compared with the percentages surviving in the general population, using the same percentile categories as in the analysis sections. This allows us to control for underlying changes in life expectancy over time, which would otherwise affect the results. If the index figure representing the comparison is 1, the sport in question demonstrates no advantage for its sporting legends compared to the general population; if the figure is lower the sport has a disadvantage, and if higher there's an advantage.

Figure 24 shows the results based on the first measure, which shows that four sports tend to boost longevity by between 9% and 13% ($p<0.05$). These are cricket, rugby, tennis and golf, rising in that order. With a ratio of 1.01, footballers are statistically no different from the general population, with no longevity advantage. Horse racing and boxing both do badly on this measure, with ratios of 0.88 and 0.75 respectively ($p<0.05$). Tennis and golf do better, but it may be relevant that both can be played to a high standard until relatively late ages (although not of course to championship standard). Worth also noting is that if five England rugby captains had not been killed in action, Rugby's advantage would increase to 16%.

Figure 24: Overall mortality by sport (general male population=1)

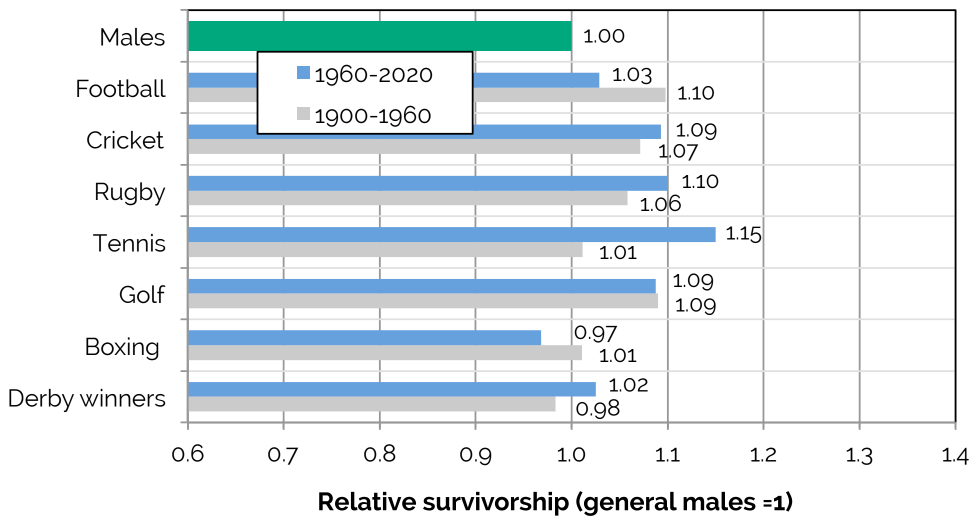


The second measure is based on comparing the ages of those still alive in any given year with the number we would expect to be alive based on cohort life tables at a given point in time, regardless of the individuals' ages. An index figure of 1 means there's no difference between the number actually alive and the number that would be alive if drawn from the general population; for less than 1, the sport gives a disadvantage and if greater than 1, it gives an advantage. Because we found evidence of change over time, we split this analysis into two periods: 1900 to 1960 and 1960 to 2020. This gives us greater opportunity to speculate which factors may be responsible for the differences.

Figure 25 shows the results based on the second measure. The ordering is quite similar to the first measure indicating consistency, but the differences between the two time periods are noteworthy. These could reflect a number of factors, including improvements in safety, life styles, and post-career welfare. Cricket and rugby have improved their relative positions over time, and compared with the general population. Cricket's advantage improved from 7% to 9%

and rugby from 6% to 10%. Golf is unchanged at 9%, putting it on a par with cricket and rugby, while horse racing and boxing remain at the bottom but with their positions reversed. The most spectacular improvement is in tennis: the advantage conferred on its sporting legends has increased from 1% before 1960 to 15% afterwards.

Figure 25: The relative survivorship of sporting legends (1900 – 1960 and 1960 – 2020)



These findings are averaged over each period. It can be argued the most recent year is more important as the figures seem to change with time. If we base our analysis only on those alive in 2020, we find that there are 36% more Wimbledon finalists alive today than would be expected if they had the same mortality as the average male. This compares with 16% more England rugby captains, 14% cricket captains, 9% British Open Champions, 3% Derby winners, 2% football captains but 7% fewer heavyweight boxing champions. Every year is slightly different; the issue becomes whether one sport shows a consistent advantage over time compared to another. It turns out that the results are reasonably similar to the average between 1960 and 2020, except that tennis was on a par with rugby at that time; of all the sports, its results have improved the most. It seems no accident that the meteoric rise in tennis is linked to the ushering in of the open era in 1968 when tennis professionals were admitted for the first time.

3.1 Other determinants of longevity

In our introduction we speculated that other factors could also be linked with longevity, although the direction of association may be hard to determine. For example, the prospect of increased financial rewards is a clear incentive to stay healthy and fit. This could be a factor in tennis, in which professionals were first admitted to major tournaments in 1968.. Another example is safety improvements, which might apply particularly to horseracing.

Table 1 is an attempt to review these factors in the light of our analysis and provide some general conclusions. It ranks the sports in order of survivorship, compared with the general population, from 1960 to 2020. We have used the results from the second of our time periods as they are more relevant to today's circumstances, providing a basis for further research.

Table 1: Survivorship in sporting rank order in 1960 to 2020 with influencing factors and showing direction of improvement

Ranking 1960-2020	Injury risk	Higher educational attainment	Higher socio-economic level	Leadership qualities	Selection	Change in influence over 1900-1960
Tennis	✘	✘	✓	✘	✓	↑
Rugby	✓	✓	✓	✓	✘	↑
Golf	✘	✘	✓	✘	✓	↓
Cricket	✓	✓	✓	✓	✘	→
Football	✓	✘	✘	✓	✘	→
Horse racing	✓	✘	✘	✘	✘	↑
Boxing	✓	✘	✘	✘	✘	↓

Key:
✓= more likely to apply: ✘ less likely to apply
Arrows show the direction of improvement between 1900-1960 and 1960-2020

Exposure to risk and injury differs significantly for different sports; in some cases injuries may be disabling or life-limiting. Much has been written about the long-term effects of head injuries and concussion in four of our sports: rugby, football, horse racing and boxing. The ranking in Table 1 suggests that football, horseracing and boxing carry the most risk for these injuries, with a lower risk for rugby. This seems intuitively correct. Other sports are gentler on the body with the exception of rugby. Being an octogenarian tennis player or golfer is not unusual, but it would be extremely unlikely for the other sports.

Training regimes are designed to optimise performance while reducing the risk of injury. Fitness science and dietary regimes is big business today and increasingly sophisticated – not least in elite sports. The mental and physical conditioning that it involves and the application of advanced analytics have transformed training and fitness regimes with the aim of optimising both performance and endurance. However, we are reminded of the illegal use of stimulants and substance abuse in some sports which are designed to achieve this and of the scandals down the years. At this point we do not have the data to know whether these practices have shortened lives or not.

Table 1 shows that sports with the longest lived players are more likely to be associated with privileged backgrounds, whereas in sports that aren't tend to lean the other way. Boxing is renowned for giving deprived youngsters an aim in life, with the possibility of becoming rich.

It's a common stereotype that rugby is played by people from more affluent backgrounds; one might suppose this to partly explain the greater longevity seen by its players. But Welsh rugby captains are more likely to come from less privileged backgrounds, yet have the same levels of longevity.

In the general population, life expectancy is known to be affected by education levels. Members of sporting elites may well have higher educational attainment levels, which could be a factor in increased longevity. Research also shows differences of 10 or more years in adult life expectancy between men in the general population from the poorest and richest deciles. The question is whether the differences we see are related to the sport in question or the background of its players.

Whether leadership is also a factor depends on how the concept is defined. England rugby coach Eddie Jones maintains that, in terms of determining team tactics, a rugby captain has bigger role on the field than a football captain. In cricket, the captain has total responsibility for tactics once a game is underway, so arguably carrying the most responsibility. Leadership qualities are also seen off the field of play - Manchester United and England centre forward Marcus Rashford's campaign for children in poverty is a notable example.

The results of our study show that captaincy of a team can lead to greater longevity, although this conclusion is based on only three team sports in a small sample. It seems uncontentious that successful team captains need to be decisive, with tactical and motivational skills – all of which arguably contribute to success in later life. More research is needed on whether there is also a link with success in non-sporting careers, for example managerial professions. If we look at other professions, like politics, we can see that successful politicians tend to live longer than the general population - this is clearly exemplified by the lifespan of British prime ministers, which are well above average!

Selection refers to the pool of players from which our sporting legends have emerged, rather than team selection. We have included this as a factor because sporting events that are open to all comers draw from a much wider net of players, in terms of social and ethnic backgrounds and professional status. We see this especially in tennis and golf; the fact that only one of the Wimbledon finalists from the more recent time period is British suggests there are also cultural factors to consider. Similar cultural factors arguably apply in golf where British success has been much better.

4. Conclusions

No research is perfect and there are limitations of this study beyond those already discussed especially in terms of its completeness. There's a temptation to believe that these differences, such as the degree of physicality and the risk of injury, are intrinsic and unique to each individual sport, but our results suggest that background factors such as education are also important.

For now, we note that our sporting legends generally show greater longevity than that of the average male, especially after 1960. Boxing is the main exception, while horseracing and football have figures very close to average – some only slightly higher than average. While this does confirm significant variance in longevity and survival rates, our results raise further interesting questions. In considering future directions of research, there are many avenues worth exploring.

Previous research has shown that participation in sport has many advantages. Aside from health benefits, it can have a positive influence on younger participants, encouraging leadership qualities; it can even be a route out of poverty if played to an elite level. However, until now we did not have the evidence base to link sporting prowess to longevity in the wider population. This report has provided a step in that direction.

If playing sport generally increases longevity as well as improving health, as suggested by our study, this would strengthen the case for participation throughout our lives. There is a research gap for example in knowing whether the years spent post-sporting careers are healthy or unhealthy years. Anecdotal evidence suggests there is much variability but tends to give a distorted picture. Research published in the Mayo Clinic Proceedings in 2018 found that leisure-time sports that involve more social interaction boosted life expectancy by the most.

There are, as previously discussed, some limitations in this study beyond those already discussed. Our reliance on historical sporting records means that we weren't able to extend our investigations to women in sport, or indeed to other sports. We chose the sports for this research based on when records of participation began. While it would be possible to investigate survivorship for other sports, like snooker, downhill skiing, F1 racing or athletics, it would be harder to analyse completed lives.

In future work we intend working closely with sporting associations to fill these gaps. Other lines of research could include exploring differences between amateur and professional players or following their wellbeing and subsequent careers after their sporting careers end. The financial rewards are now so great that it may be possible to study whether financial inducements are a factor. The scope of what can be studied is limited only by data availability.

We encourage anyone interested in pursuing this research to the next stage to get in touch by email at lesmayhew@ilcuk.org.uk.

Annex A

1. Extracting age of death for a given percentile of survivors

Our life tables are based on a single year of age. To compare survivorship based on year of birth, we require the age x_p to which a given percentile of the population survives l_p. This is given by interpolation as:

$$x_P = \frac{l_x - l_P}{l_x - l_{x+1}} + x \qquad l_x > l_P > l_{x+1}$$

Where x is age and l_x is the number surviving to x, and $l_{x=1}$ is the number surviving to age $x+1$

2. Survivorship or expected percentile (analogy with life expectancy)

$$e_P = \frac{1}{l_0} \sum_P l_P$$

Where l_0 is the radix – usually 100,000 or 100 – and l_p is the number surviving to a given percentile or percentile range

3. Mortality

Here we test whether mortality among our sporting legends is less then expected, when compared with the general male population.

For each percentile considered, we construct a one-tailed test which is formally defined as follows:

Case A

H_0: There is no difference between the underlying probability of a sporting legend dying in a specified percentile range and a member of the general male population.

H_1: The probability of a sporting legend dying in a specified percentile range is less than the probability of a member of the general male population dying in the same range.

With a test statistic of:

$$z = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0 \times (1 - p_0)}{n}}}$$

where $\hat{p}$ is the observed proportion of deaths at the specified percentile cut-off in this case 0.1, 0.25, 0.5, 0.75, 0.95, 0.99.

The test statistic z can then be compared to the normal distribution.

Case B

We can also reverse the question and ask whether mortality among sporting legends is greater than expected as compared with the general population. We do this by reversing the sign of z and finding its position on the normal distribution. In this case the hypotheses are:

H_0: There is no difference between the true underlying probability of a sporting legend dying in a specified percentile range and a member of the general male population.

H_1: The probability of a sporting legend dying in a specified percentile range is greater than the probability of a member of the general male population dying in the same range.

The results for each sporting category and hypothesis are given below (including three measures of statistical significance).

Our decision rule of whether to accept or reject H_0 is based on the probability of its occurrence. If p is 0.05 or less, we reject H_0 and accept the alternative hypothesis.

Significance levels Case A	Probability of null hypothesis being correct
*	0.05
**	0.01
***	0.001

Significance levels Case B	Probability of null hypothesis being correct
†	0.05
††	0.01
†††	0.001

The following tables (a-f) set out the results from each step of the analysis.

(a) Cumulative % of deaths

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10	10.8	3.7	7.6	5.5	8.5	23.5	19.0	10
10-25	20.3	20.4	17.7	21.8	19.1	33.8	39.7	25
25-50	50.0	44.4	39.2	43.6	36.2	77.9	55.6	50
50-75	74.3	66.7	62.0	65.5	66.0	92.6	81.0	75
75-95	95.9	92.6	96.2	87.3	87.2	100.0	93.7	95
95-99	98.6	100.0	100.0	94.5	97.9	100.0	100.0	99
99+	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100

(b) z scores

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10	0.23	-1.54	-0.71	-1.12	-0.34	3.72	2.39	0.00
10-25	-0.94	-0.79	-1.49	-0.54	-0.93	1.68	2.69	0.00
25-50	0.00	-0.82	-1.91	-0.94	-1.90	4.61	0.88	0.00
50-75	-0.13	-1.41	-2.66	-1.63	-1.43	3.36	1.09	0.00
75-95	0.37	-0.81	0.49	-2.63	-2.44	1.89	-0.49	0.00
95-99	-0.30	0.74	0.89	-3.32	-0.78	0.83	0.80	0.00

c) p-values (case A)

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10	0.30	0.03	0.12	0.07	0.18	0.50	0.50	0.25
10-25	0.09	0.11	0.03	0.15	0.09	0.48	0.50	0.25
25-50	0.25	0.10	0.01	0.09	0.01	0.50	0.41	0.25
50-75	0.22	0.04	0.00	0.03	0.04	0.50	0.43	0.25
75-95	0.32	0.10	0.34	0.00	0.00	0.49	0.16	0.25
95-99	0.19	0.38	0.41	0.00	0.11	0.40	0.39	0.25

d) p-level c)

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10		*						
10-25			*					
25-50			*		*			
50-75		**	**	*	*			
75-95				**	**			
95-99				***				

(e) p-values (case B)

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10	0.20	0.47	0.38	0.43	0.32	0.00	0.00	0.25
10-25	0.41	0.39	0.47	0.35	0.41	0.02	0.00	0.25
25-50	0.25	0.40	0.49	0.41	0.49	0.00	0.09	0.25
50-75	0.28	0.46	0.50	0.47	0.46	0.00	0.07	0.25
75-95	0.18	0.40	0.16	0.50	0.50	0.01	0.34	0.25
95-99	0.31	0.12	0.09	0.50	0.39	0.10	0.11	0.25

(f) p-level

Percentile range	Football	Cricket	Rugby	Tennis	Golf	Boxing	Jockeys	General male population
0-10						† † †	† †	
10-25						†	† †	
25-50						† † †		
50-75						† † †		
75-95						†		
95-99								

4. Testing for whether number alive in year T exceeds expectations

Let the probability of survival to age z for someone born in year t, sport i be:

$$S^i(z_t, t)$$

If n_t are born in year t then the expected number surviving to age z is $S^i(z_t, t)$

Let the years range from t_0 to year T where in our case T ranges from 1900 to 2020.

The total number expected to be alive in year T is:

$$E_T = \sum_{t=t_o}^{t=T} n_t^i S^i(z_t, t)$$

If the total number observed to be alive is O_t then the observed to expected survival ratio in year is

T is $\frac{O_T}{E_T}$

An index figure of 1 or greater means that the number alive is equal to or greater than expected based on general mortality from year of birth and if it is less than 1 survival is less than expected.

The test used to verify whether the ratio is significantly different from unity is called the mid-p exact test whose calculation can be found at: https://www.openepi.com/SMR/SMR.htm.

For further information on test, see: O.S. Miettinen, American Journal of Epidemiology, 1974, 99:5, pp 325-332.

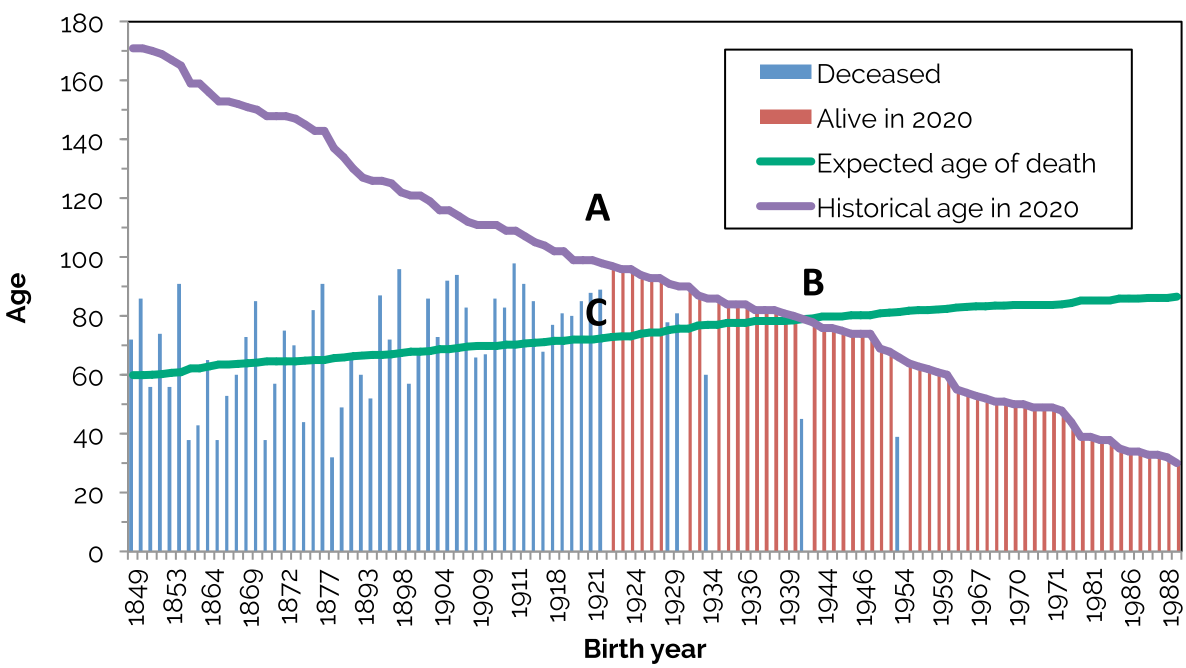
Annex B: The death and survivorship of Wimbledon Gentlemen's Singles finalists

Figure 2 in Section 1B ("Living sportsmen") showed how we compare survivorship in our sporting legends to that of the general male population.

In this annex we apply the method to Wimbledon Gentlemen's Singles finalists – 110 in all. The columns in Figure B1 show the birth order of the finalists and their ages of death, or their age if they were alive in 2020. The upward sloping green line shows their expected age of death (based on birth year) when they reached age 20. The purple line sloping diagonally from left to right is the historical age of each player with reference to 2020. For example a person born in 1900 would have a historical age of 120 (2020-1900).

Interpretation is as follows. Deceased players either live for a longer or shorter period than expected – those with ages of death above the upward sloping line lived for longer than expected, and vice versa. Of the 55 players who died between 1841 and 2020, 32 (58%) exceeded their expected age of death. A further 17, who were still alive in 2020 (triangle ABC), also exceeded their expected age of death. If Wimbledon finalists had conformed to what we would expect from the general population, 71 would be dead, which is 29% higher than the actual figure of 55. It's also relevant to note that this means that 50% of all Wimbledon finalists since its inception were still alive in 2020.

Figure B.1



About the ILC

The International Longevity Centre UK (ILC) is the UK's specialist think tank on the impact of longevity on society. The ILC was established in 1997, as one of the founder members of the International Longevity Centre Global Alliance, an international network on longevity.

We have unrivalled expertise in demographic change, ageing and longevity. We use this expertise to highlight the impact of ageing on society, working with experts, policy makers and practitioners to provoke conversations and pioneer solutions for a society where everyone can thrive, regardless of age.

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