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The effects of competition outcomes on health: Evidence from the lifespans of U.S. Olympic medalists☆

Adriaan Kalwij

Utrecht University School of Economics, PO Box 80125, 3508 TC Utrecht, the Netherlands

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ABSTRACT

This paper investigates the effects of competition outcomes on health by using U.S. Olympic medalists' lifespans and medal colors as a natural experiment. Whereas the life expectancies of gold and bronze medalists do not differ significantly, life expectancy of silver medalists is about 2.4 and 3.9 years less than these former, respectively. These findings are readily explainable by insights from behavioral economics, psychology, and human biology, which suggest that (perceived) dissatisfactory competition outcomes may adversely affect health. Competition outcomes that affect socioeconomic status (SES) could, therefore, play an important causal role in the positive SES-health gradient among the general population.

> I think, if I was an Olympic athlete, I would rather come in last than win the silver, if you think about it. You know, you win the gold, you feel good. You win the bronze, you think, "Well, at least I got something." But if you win that silver, that's like, "Congratulations, you almost won." Of all the losers, you came in first of that group . . . You're the number one loser.

Jerry Seinfeld, 1998

Both by nature and through institutional design, competitions are an integral part of human lives, from college entrance exams and scholarship applications to jobs, promotions, contracts, and awards. Competition outcomes can particularly affect socioeconomic status (SES), which is often empirically measured by income, education, wealth, or occupation. This paper aims to provide insights into competition outcomes' causal role in the well-documented positive and persistent association between SES and health or lifespan (Kitagawa and Hauser, 1973; Duleep, 1989; Marmot et al., 1991; Smith 1999; Huisman et al., 2004; Cutler et al., 2006; Dow and Rehkopf, 2010; Cutler et al., 2011; Evans et al., 2012; Mackenbach et al., 2016).

One channel though which competition outcomes could seemingly affect individual health is SES, whose positive effect on health could explain the positive association between SES and health or lifespan (hereafter, the SES-health gradient).[1] An argument supporting this positive effect, albeit one that may have become less relevant over time in developed countries, is that low SES is associated with poverty and accompanying health problems. Balan-Cohen (2008), for example, finds that a senior income assistance program implemented in the U.S. between 1930 and 1955 reduced mortality among poor elderly men through, among other factors, a decrease in infectious diseases. A second supporting argument is that those with higher SES engage in less risky health behavior (Balia and Jones, 2008; Stringhini et al., 2010), which could explain the positive effect of education on health and lifespan (Kawachi et al., 2010; Van Kippersluis et al., 2011). A third argument is that low SES individuals live in more stressful environments and experience more adverse events than high SES individuals. Such adverse events, and the concomitant

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E-mail address: a.s.kalwij@uu.nl (A. Kalwij).

[1] Other explanations for this gradient include a health effect on SES (Currie and Madrian, 1999; García-Gómez et al., 2013) and the consequences of early life circumstances on later life health and SES (Barker, 1997; Case et al., 2005).

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emotional responses, may negatively impact health by increasing the levels of "bad" stress hormones (McEwen and Sapolsky, 1995; Brunner, 1997; McEwen, 1998; Baum et al., 1999; Kubzansky et al., 1999; Seeman et al., 2001; Cohen et al., 2006; Juster et al., 2010; McEwen and Gianaros, 2010).[2] Matthews et al., (2010), however, in their literature overview, conclude that there is no strong causal evidence in support of this psychosocial argument, although they recognize its potential relevance for the health consequences of the work-related stress generated by low control, effort-reward imbalance, job insecurity, or job loss (Karasek, 1979; Siegrist, 1996; Kristenson et al., 2004; Siegrist and Marmot, 2004; Kuhn et al., 2009; László et al., 2010; Lipowicz et al., 2016).[3] Stress is also associated with risky health behavior (Kouvonen et al., 2005; Umberson et al., 2008), such as smoking or excessive alcohol consumption. Nonetheless, the empirical evidence to support the above arguments tend to be mostly based on associations, so the economics literature in general concludes that there is no strong empirical evidence for an SES effect on health or mortality in developed countries (Smith, 1999; Cutler et al., 2011; Cesarini et al., 2016).

On the other hand, insights from behavioral economics, psychology, and human biology suggest that although competition outcomes can affect health, it may not be through their effect on SES but through the appraisals of these outcomes. Although the gains and losses of competition are often well defined and can affect SES, individuals are not emotionless—they have affective responses that may depend on both factual and counterfactual outcomes (Kahneman and Miller, 1986; Kahneman and Varey, 1990; Roese, 1997; Epstude and Roese, 2008). Thus, an individual's emotional appraisal of his or her own competition performance (a stressor) serves as a cognitive mediator of coping and the related psychological stress reaction (Lazarus, 1993; Lupien et al., 2007).[4] Because the stress hormones released in this situation (e.g., glucocorticoids) are neurotoxic and adversely affect health (Sapolsky et al., 1986; Sapolsky, 2000,2005; Epel et al., 2004; Lupien et al., 2007; McEwen 2007, 2008), competition outcomes could be a third factor explaining the SES-health gradient (Cutler et al., 2011). If so, it would mean that they can affect both SES *and* health.

The aim of this paper, therefore, is to empirically test whether competition outcomes affect health through their effects on SES or through the appraisals of these outcomes. To this end, the analysis takes advantage of U.S. Olympic medalists' lifespans and medal colors as a natural experiment, using the former to assess health and the latter to measure competition outcomes. As detailed in the next section, if the ranking of Olympic sports competition outcomes is positively related to medalist SES and unrelated to medalist health at the start of the Olympics, two predictions can be made that relate to the two previous explanations for a positive SES-health gradient among the general population: First, if a competition outcome affects health through its effect on SES (i.e., SES affects health positively) and not through other channels, gold medalists should have the highest life expectancy; bronze medalists, the lowest life expectancy; and silver medalists, somewhere between the two. Second, if a competition outcome affects health through the appraisal of the outcome and not through other channels, then gold and bronze medalists should have the same but silver medalists a lower life expectancy. This latter prediction assumes that gold and bronze medalists tend to appraise their medals as a win, while silver medalists tend to appraise their second place as a loss and, through the associated psychological stress, have their health compromised and life expectancy reduced.

Estimating the effects of medal color on Olympic medalist lifespan and empirically testing these predictions should then throw light on competition outcomes' causal role in the positive SES-health gradient among the general population. More specifically, empirical support for prediction one would suggest that competition outcomes that affect SES contribute to the positive SES-health gradient by SES affecting health. Empirical support for prediction two would suggest that competition outcomes that affect SES contribute to the positive SES-health gradient by the appraisals of the outcomes affecting health. On the other hand, if the empirical relation between medal color and life expectancy cannot be reconciled with either of these two predictions, then the empirical evidence can be inconclusive regarding competition outcomes' implications for the SES-health gradient in general.

In an experimental study related to this paper, Rablen and Oswald (2008) demonstrate that the life expectancy of a Nobel Prize winner is one to two years longer than that of a nonwinning nominee, which they suggest is consistent with an SES effect on life expectancy. Their somewhat cautious conclusion is supported by Redelmeier and Singh (2000) finding that Academy Award winners for Best Actor or Best Actress have a four-year longer life expectancy than nonwinning nominees.[5] It is also suggested by Leive's (2018) empirical evidence for the U.S. that the higher post-Olympic wages of silver medalists in track and field relative to gold medalists may account for the former's lower mortality rate. On the other hand, Clarke et al. (2012) find no statistically significant differences between the life expectancies of gold, silver, and bronze Olympic medalists, suggesting that their health is unaffected by competition outcomes. This finding might, however, be the result of their pooling data from many countries with no regard for cultural or institutional differences.[6] This present study's first contribution to the literature is that, in contrast to Clarke et al. (2012), it draws a sample exclusively from the Unites States, a country in which sports are socially ingrained and have been professionalized since the early 20th century (Davies, 2012). If, therefore and based on the arguments discussed above, there is a relationship between medal color and life expectancy, one would expect it to be present for the U.S. This U.S. medalist sample is much larger and arguably less selective than the one used by Leive (2018)[7]. Even more important, and yielding the second contribution to the literature, the analysis in this present study explicitly considers, in contrast to Leive (2018), bronze medalists whose lifespans enable an empirical distinction between the effects of competition outcomes on health through their effect on SES or through the appraisals of these outcomes.

[2] These and other studies cited here show that stress hormones related to psychological stress affect the immune and endocrine systems, which may impair tissue growth and repair; increase the risk for hypertension, diabetes, arterial disease, and infectious diseases; and hasten aging.

[3] Furthermore, outcomes of financial decisions could affect testosterone and stress (cortisol) levels (Nofsinger et al., 2018).

[4] Lazarus (1993), in his delineation of different stress types, defines psychological stress as harm, that is psychological damage caused by, for instance, an irrevocable loss that leads to emotion-focused coping and is associated with sadness. Lupien et al. (2007), on the other hand, refers to it as a relative stressor (as opposed to absolute stressors like heat, exercise, or hunger) that necessitates a cognitive interpretation in order to elicit a response that might lead to a physiological reaction.

[5] On the other hand, Sylvestre et al. (2006), find that these Academy Award winners' gain in life expectancy is actually smaller and not statistically significant.

[6] For example, athletes' appraisals of, and the SES related to, Olympic competition outcomes might depend on how much a country's general population cares about medal color and this latter's (relative) rewards.

[7] The selectiveness of Leive's (2018) U.S. sample of Olympic track and field medalists is reflected in his finding that among this sample, silver medalists have a lower mortality rate than gold medalists. The data described in Section 2 cover the same Olympics and when only applying the selection criterium of non-missing dates of births and deaths, I find for a sample of 139 U.S. track and field medalists that, on average, silver medalists live about 1.5 years *less* than gold medalists.

The paper is structured as follows: Section 1 discusses how medal color can affect U.S. medalists' life expectancies, after which Section 2 describes the data. Section 3 then outlines the statistical model, and Section 4 presents the empirical results, which are interpreted in Section 5. Finally, Section 6 summarizes the main findings and discusses their implications for the SES-health gradient among the general population.

1. U.S. Olympic medalists' life expectancy: two predictions

In the U.S., the professionalization of sports competitions, together with the accompanying money and fame, began as early as the mid-19th century. After the professionalization of baseball in the Northeast in 1869, other sports gradually followed suit until sports professionalization had spread across the nation (Davies, 2012). The importance of sports in the U.S. is exemplified by the central role played by sports competitions in the country's education system since the first half of the 20th century (Davies, 2012). This professional environment ensures that U.S. athletes are well prepared and strongly incentivized to excel.

The best three outcomes of Olympic sports competitions have a clear ordering: the winners receive a gold medal; the runners-up, a silver medal; and those in third position, a bronze medal. Historically, however, even though the first modern Olympics took place in 1896 in Athens, Greece, third place prizes were not introduced until the 1904 Olympics, when they were also retroactively awarded to third-place winners of the 1896 and 1900 Olympics. Except for boxing, judo, taekwondo, and wrestling, in which the bronze medals go to eliminated semi-finalists (boxing) or winners of repechage brackets, most Olympic sports that use a knockout format have a third-place game to determine who wins the bronze.

Against this background, with gold an objectively better outcome than silver, and the latter a better outcome than bronze, the empirical analysis assumes an increasing monotonic relation between the ranking of Olympic sports competition outcomes and medalist SES. That is, it is assumed that during their lives, on average, gold medalists have the highest; bronze medalists the lowest SES; and silver medalists' SES somewhere between the two. A second assumption is that, because all U.S. Olympic medalists are elite athletes, their health at the start of the Olympics is unrelated to the color of medal won.[8] Accordingly, the medalists' SES, as measured by medal color, should be unrelated to their health at the time of the Olympics. At the same time, it should be noted that although maintaining these two assumptions in the analysis is arguable reasonable and necessary to clear exposition, their relaxation, to a certain extent, leaves the main conclusion of this paper unchanged (see Section 5).

In particular, these assumptions enable two predictions about medalist life expectancies that relate to the two possible explanations for a positive SES-health gradient among the general population. The first explanation, a positive SES effect on health, is empirically testable because it predicts that gold medalists (with the highest average SES) will have the highest life expectancy; bronze medalists, the lowest; and silver medalists, somewhere in between. The second explanation, that the appraisals of competition outcomes affect health, finds support in behavioral economics, psychology, and human biology. In the framework of counterfactual thinking (Kahneman and Miller, 1986; Kahneman and Varey, 1990; Markman et al., 1993; Roese, 1997; Epstude and Roese, 2008), an individual (here, an Olympic medalist) appraises a competition outcome (medal color) ex post as a win or a loss. According to Medvec et al. (1995), Medvec and Savitsky (1997), and David and Willingham, (2006), silver medalists on average appraise their medals as a loss and are ex post dissatisfied, while bronze and gold medalists on average appraise them as a win and are ex post satisfied with their outcomes.[9] As further expounded by Medvec et al. (1995), whereas gold medalists appraise the outcomes as wins, which leads to satisfaction, silver medalists make close counterfactuals with bronze and gold medalists and allow the thought "I almost . . . " to dominate their feelings. For these latter, a bronze medal would add little, so they are left with an appraisal of having lost gold and a feeling of dissatisfaction with their silver medal. Hence, for silver medalists, this upward counterfactual comparison reduces satisfaction. Bronze medalists, in contrast, discount the silver, as it would add little, and make a close counterfactual comparison with fourth place, which is a big difference with bronze as it would have left them with no medal, so their feelings are dominated by "At least I . . . .". For bronze winners, therefore, this downward counterfactual comparison increases satisfaction and prompts an appraisal of their medals as a win.[10] Empirical findings in Medvec et al. (1995) are in support of these theoretical arguments. Based on video footage of medalists' immediate reactions after the Olympic sports competitions and of the award ceremonies, they find that, on average, silver medalists look less satisfied than bronze medalists with their medals and that this is unrelated to how well they were expected to perform. In additional they find, based on video footage of interviews with medalists, that silver medalists' counterfactual thoughts were more focused on "I almost" (won gold) and bronze medalists' counterfactual thoughts were more focused on "at least I" (won bronze/a medal).

In the above analyses, medal color and fourth place are considered close counterfactuals; that is, counterfactuals whose outcomes are within the medalists' reach. Such close counterfactual comparisons exemplify the concept of emotional amplification (Kahneman and Miller, 1986), which in the Olympic context is facilitated by the natural ordering of the sports competition outcomes and the very close performances of the medalists (Medvec and Savitsky, 1997). Further amplification may also occur because of the significance assigned to the stressor in the ex post appraisal (Lazarus, 1993), which might be particularly relevant for Olympic medalists. That is, for Olympians, winning a medal follows many years of dedication to the sport, a sustained long-term effort that is likely to intensify affective responses (Van Dijk et al., 1999). Moreover, Olympic athletes often have only one chance at a medal, making its loss not only irreversible but subject to a lifetime of regret, a likely ingredient for psychological harm (Lazarus, 1993).

Given the above arguments, it seems probable that the Olympic credo of "It is more important to participate than to win" (Young, 1994) fails to reflect most silver medalists' feelings, and that, on average, they appraise silver medals won as gold medals lost and are dissatisfied with their ultimate rankings. As previously pointed out, this dissatisfaction leads to the secretion of stress hormones—possibly over an extended time period given the young age at which most silver medalists experience dissatisfaction—which compromises their health. This adverse effect on health of appraising a competition outcome as a loss (i.e., a dissatisfactory

[8] In support of this assumption, Leive (2018) interprets the finding that gold and silver medalists are of similar height as evidence of no health differences between medalists at the time of the Olympics. I also refer to Leive (2018) for an excellent discussion on the exogeneity of medal color when analyzing its effect on mortality.

[9] I use the word "(dis)satisfaction" in order to distinguish this paper from those that employ the term "disappointment" for a psychological reaction to a comparison of an ex ante expectation with an actual competition outcome (Bell, 1985; Loomes and Sugden, 1986). In addition, Herbert (1955), in a rational agent model, introduces a pay-off function based on satisfactory and unsatisfactory outcomes rather than a continuous utility function.

[10] McGraw et al., (2005) suggest an alternative interpretation, arguing that silver medalists are disappointed because they expected gold, whereas bronze medalists are satisfied because they did not expect to win a medal.

Table 1
Sample frequencies by olympics[*].

Cells: Frequencies	Medalists[a]	Women[b]	Gold medals	Silver medals	Bronze medals	Alive[c]
1904 St. Louis (S)	246	5	108	120	114	0
1906 Athens (S)	14	0	9	6	6	0
1908 London (S)	52	0	32	16	15	0
1912 Stockholm (S)	73	0	45	25	36	0
1920 Antwerp (S)	132	8	111	45	37	0
1924 Paris (S)	156	15	96	36	49	0
1924 Chamonix (W)	12	1	1	10	1	0
1928 Amsterdam (S)	76	16	47	24	17	0
1928 St. Moritz (W)	13	1	6	6	2	0
1932 Los Angeles (S)	168	21	81	46	61	1
1932 Lake Placid (W)	32	2	10	21	3	0
1936 Berlin (S)	86	14	51	29	16	1
1936 Garmisch-Partenkirchen (W)	16	0	2	0	14	0
1948 London (S)[d]	2	0	1	1	1	0
1948 St. Moritz (W)[d]	1	0	0	1	0	0
1904–1948 Olympics			600	386	372	

Notes: S = summer games; W = winter games.
[*] The 1908 and 1920 games included several Winter Olympics sports events.
[a] A total of 978 medalists; the column total is 1,079 because about 9.6 percent of the medalists won medals at more than one Olympics.
[b] A total of 67 female medalists. The column total is 83 because about 24 percent of female medalists won medals in more than one Olympics.
[c] On December 31, 2014. Evelyn Furtsch (born 1914; 1932 Los Angeles; athletics) passed away in 2015 and Adolph Kiefer (born 1918; 1936 Berlin; swimming) passed away in 2017 (see, e.g., https://en.m.wikipedia.org).
[d] Three athletes (Earl Thomson, Jack Heaton, and Miguel de Capriles) won medals in both the 1936 and 1948 Olympics.

outcome) leads to the second prediction that bronze and gold medalists should have the highest and silver medalists the lowest life expectancy.

2. Data

The data on the U.S. Olympic medalists are taken from Sports Reference, 2014, an online data source currently being incorporated into the statistical section of the International Olympic Committee's web site. In addition to athletes' Olympic sports achievements, this data set also includes Olympic medalists' vital statistics. As previously mentioned, however (Section 1), no third place prizes were awarded at the 1896 and 1900 Olympics, so medalists at these Olympics are excluded from the sample, which also affects seven medalists from the 1904, 1906 and 1908 Olympics who won their first medals at the 1900 Olympics. Also excluded are those who won their first medal after the 1936 Olympics (that being the 1948 Olympics at the earliest) because missing death dates could mean that they are either still alive or have passed away but on an unknown date. On the other hand, because all except one such medalist from the earlier Olympics were born in the 19th century[11], almost all medalists with missing death dates can reasonably be assumed to be deceased. The raw sample thus consists of 1,014 U.S. medalists who won their first medal at the Olympics between 1904 and 1936. A further 22 medalists are dropped because of unknown birth and death dates and 14 medalists are dropped because of unknown death dates. The final sample consists of 978 medalists.

This paper also makes use of population mortality rates taken from the 1900–2014 life tables provided by the U.S. Social Security Administration (Bell and Miller, 2005) and the Human Mortality Database (2017). This latest available life table information is merged with the medalist sample data by gender, age, and year of birth to yield annual population mortality rates based on these variables (see Appendix Fig. A1).

Table 1 lists the information by Olympics for the final sample of 978 U.S. medalists. Three Olympic medalists who had already won a medal at the 1936 Olympics also won medals at the 1948 Olympics (bottom two rows). Two medalists were still alive on December 31, 2014 (last column). The distribution of medal colors shows that U.S. medalists have won gold medals relatively often (600 out of 1,358 medals). Medalists' ages at the time of win and lifespans measured in full years are calculated based on the years of birth, death, and the Olympics. As Table 2 shows, the medalists' median lifespan of 75 years is five years higher than that of the general population. The gender difference in median lifespan among Olympic medalists is 6 years in favor of women and resembles that of the general population (not reported in the table).

When examining life expectancy and survival rates by medal color in Table 2 and Fig. 1, the color is determined by a medalist's best overall Olympic performance. It is gold for medalists who have won at least one gold medal, silver for those who have won at least one silver medal but no gold medals, and bronze for those who have won at least one bronze medal but no silver or gold medals during their lives. Fig. 1 then reveals that the survival function of bronze medalists for the whole age range lies above that of gold medalists, whose survival function in turn lies above that for silver medalists. These survival function differences translate into gold medalists' median lifespan that is four years longer than that of silver medalists and two years shorter than that of bronze medalists (Table 2). Medalists who either won more than one medal or won medals at more than one Olympics, however, have a shorter lifespan than medalists who won one medal or won medals at one Olympics (see Appendix Tables A1 and A2 for number of medalists and lifespan distribution by Olympics and Olympic sports). Additional unreported results from log-rank tests reject the null hypotheses of survival function equality by gender, medal color, sports, Olympics, more than one medal won, and medals won at more than one Olympics. Furthermore, log-rank tests reject the null-hypothesis of equal survival functions of gold and silver medalists and of bronze and silver medalists while the null-hypothesis of equal survival functions of gold and bronze medalists is not rejected.

3. Mortality rate model

The effects of medal color on lifespan, after controlling for other observed characteristics, are estimated using a proportional

[11] The one exception is Manuela Kalili (1932 Olympics), born in 1912.

Table 2
Lifespan distribution by medalist characteristic.

	Number of medalists	Lifespan (in years)		
		25th percentile	50th percentile	75th percentile
General population[a]		58	70	80
All medalists	978	64	75	84
Male medalists	911	63	75	83
Female medalists	67	70	81	89
Bronze medalist (best performance)	243	66	78	86
Silver medalist (best performance)	277	62	72	82
Gold medalist (best performance)	458	64	76	84
One medal	757	64	76	85
More than one medal	221	61	72	81
Won medals at one Olympics	892	64	76	84
Won medals at more than one Olympics	86	63	71	79

[a] Based on a weighted average of mortality rates of the U.S. medalists' national cohorts and gender, conditional on reaching 25 (the average age at which medalists won their medals).

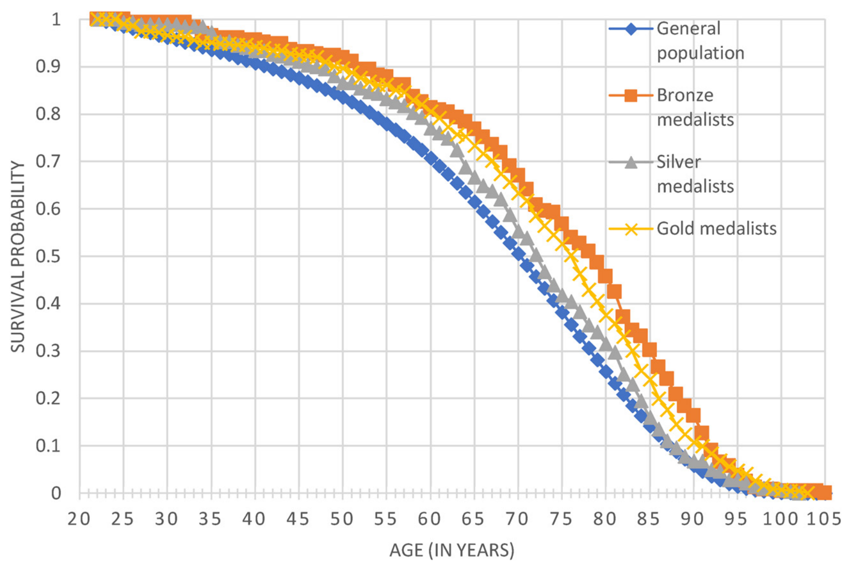

Fig. 1. Survival functions. Medal color is based on best overall performance. All medalists survived to at least age 23.

hazard rate model (Cox, 1972) in which the mortality rate of medalist i at age t with covariates $\boldsymbol{x}_i(t)$ is defined as follows:

$$\lambda(t|c_i, g_i, \boldsymbol{x}_i(t), \boldsymbol{\beta}) = \lambda_{c_i g_i}(t) exp(\boldsymbol{x}_i(t)'\boldsymbol{\beta}) \quad (1)$$

where $\lambda_{c_i g_i}(t)$ is the population mortality rate at age t for individuals born in year c_i of gender g_i. $\boldsymbol{x}_i(t)$ includes a constant, and the covariates are allowed to vary with age to accommodate medalists winning medals at more than one Olympics. For a dummy variable, as are all covariates except age, the exponent of the corresponding k^{th} element of the parameter vector $\boldsymbol{\beta}$, $\exp(\beta_k)$, is the odds ratio corresponding to this covariate. This means, (exp (β_k)-1), when multiplied by 100, is interpreted as the percentage increase in the mortality rate for a unit increase in the dummy variable (from 0 to 1).

Because lifespan is measured in full years, a discrete-time proportional hazard rate model is estimated (see, e.g., Cameron and Trivedi, 2005) in which medalist age measured in full years a is assumed constant within a calendar year and the covariates are constant on the age interval $[a, a+1$, with $a \in \{0, 1, 2, .., A\}$. A is the maximum lifespan of medalists in full years. Given (1), the probability that a medalist is dead at age $a+1$, conditional on being alive at age a, can be written as

$$\lambda^d(a|c_i, g_i, \boldsymbol{x}_i(a), \boldsymbol{\beta}) = 1 - exp\left(-\mu_{c_i g_i}(a) exp(\boldsymbol{x}_i(a)'\boldsymbol{\beta})\right) \quad (2)$$

with $\mu_{c_i g_i}(a) = \int_a^{a+1} \lambda_{c_i g_i}(s) ds$.

The parameter estimates are obtained by maximum likelihood from a sample of n medalists:

$$\hat{\boldsymbol{\beta}} = argmax_{\boldsymbol{\beta}} log \prod_{i=1}^{n} \prod_{a=A_{0i}}^{A_i} \left(\exp\left(-\mu_{c_i g_i}(a)\exp(\boldsymbol{x}_i(a)'\boldsymbol{\beta})\right)\right)^{1-m_{ia+1}} \times \left(1 - \exp\left(-\mu_{c_i g_i}(a)\exp(\boldsymbol{x}_i(a)'\boldsymbol{\beta})\right)\right)^{m_{ia+1}},$$

where A_i is the age of medalist i in the last year alive or in 2013 if the medalist is still alive at the end of the observation period (December 31, 2014).[12] A_{0i} is the age of winning the first Olympic medal, and m_{ia+1} is equal to 1 if medalist i turned a years old and died during the age interval $(a, a+1)$; 0 otherwise.

$\mu_{c_i g_i}$ is the annual population mortality rate among the general population (from the U.S. life tables; see Section 2) with the same age a, birth year c_i and gender g_i as medalist i. By using annual population mortality rates as specified in (2), the mortality rate model can flexibly control for gender differences; an age gradient; the time effects (e.g., due to medical advances or adverse health

[12] Because no life table information is available from 2015 onward, the lifespans of two medalists are right censored at December 31, 2014 (see Table 1).

events such as the 1918 Spanish flu epidemic); and different gender, age, and time effects across cohorts. As expressed in (1), the medalists' age-specific mortality rates are assumed to be proportional to the age-specific population mortality rates for individuals with the medalist's same birth year and gender, although the inclusion of time-variant covariates also allows the proportionality factor to vary with age. Likewise, gender and age are included as covariates to permit gender-based mortality differences and the mortality age gradient to vary between medalists and the general population. The proportionality assumption embedded in the mortality rate model is assessed by adding interactions between the covariates and age and testing the null hypothesis that all parameters corresponding to these interactions are equal to 0.

Also included as a covariate is a medalist's best Olympic performance up to and including age a, whether it be a bronze, silver, or gold medal. This inclusion enables testing of the two different predictions made in Section 1: (i) Gold medalists will have the highest and bronze medalists the lowest life expectancy, and (ii) silver medalists have a lower life expectancy than bronze and gold medalists. The model also includes covariates indicating whether more than one medal was won and whether medals were won at more than one Olympics up to and including age a. These two covariates control for possible adverse health effects from a more intensive or longer period of training (Maffetone and Laursen, 2016), which also provides more opportunities for a better overall Olympic performance. Finally, because the selection of Olympic athletes may vary over time and because U.S. medalists' performances may vary by sports, the model also controls for different Olympics and different sports, which latter could also be related to mortality risk (Clarke et al., 2012; Antero-Jacquemin et al. 2014).

Table 3
Estimation results.

Mortality rate model Covariate	Model 1 Coeff. (*SE*)	Model 2 Coeff. (*SE*)	Model 3 Coeff. (*SE*)
Constant	-0.60** (0.10)	-0.77** (0.12)	-0.97** (0.18)
Female medalist	0.01 (0.13)	0.02 (0.13)	0.00 (0.14)
Age (in years, minus 25)[a]	0.008** (0.002)	0.008** (0.002)	0.012** (0.002)
Gold medalist (best performance is gold)[b]		0.13 (0.08)	0.13 (0.10)
Silver medalist (best performance is silver)[b]		0.31** (0.09)	0.31** (0.10)
Won more than one medal			0.10 (0.11)
Won medals at more than one Olympics			0.31* (0.15)
Control for sports type	No	No	Yes
Control for different Olympics	No	No	Yes
Number of medalists	978	978	978
Number of parameters	3	5	35
Value log-likelihood function (/1,000)			
Null hypothesis; cells contain p-values			
No gender and age effects	0.001**	0.000**	0.000**
No effects of medal color		0.002**	0.003**
No effects of more than one medal or Olympics			0.002**
No effects of sports type			0.564
No effects of different Olympics			0.001**
A proportional hazard specification	0.329	0.565	0.085

Notes: The coefficient estimates (Coeff.) are of parameter vector β from (1) and standard errors are in parentheses (SE). Statistical significance at the 5 percent level is denoted with * and significance at the 1 percent level with **.
[a] The average age of medalists competing at the Olympics, 25, is subtracted from age to facilitate the interpretation of the intercept coefficient.
[b] The omitted reference category is "bronze medalist" (best performance is bronze).

4. Empirical results

In line with Clarke et al. (2012), the estimates of model 1 (Table 3) show that at age 25 Olympic medalists have about a 45 percent lower (100 x (exp(-0.60)-1)) mortality rate than the general population. As medalists grow older, however, this mortality advantage decreases by a significant[13] 0.8 percentage points per year until it vanishes around age 100. On the other hand, as reported by Coate and Sun (2013), the insignificant effect of "Female medalist" suggests that gender differences in Olympic medalists' mortality rates resemble those in the general population.

The results for model 2, which includes medal color based on medalists' best performances, indicate that, at every age, the mortality rate of a silver medalist is 36 percent higher (100 x (exp (0.31)-1); p-value = 0.0005) than that of a bronze medalist (the omitted reference category). The mortality rate of a gold medalist, in contrast, does not differ significantly from that of a bronze medalist (p-value = 0.0955).

The model 3 results show that controlling for having won more than one medal, having won medals at more than one Olympics, sports type, and different Olympics does not affect the estimated effects of medal color on mortality rate: The mortality rate of a silver medalist is 36 percent higher (p-value = 0.0013) than that of a bronze medalist and the mortality rate of a gold medalist does not differ significantly from that of a bronze medalist (p-value = 0.1880). There are no jointly significant effects of sports type on mortality (third-to-last row) and the effects of the different Olympics (second-to-last row) on mortality, on the other hand, are jointly significant.[14]

Interestingly, having won medals at more than one Olympics increases mortality which suggests possible adverse health effects from a longer period of training (Maffetone and Laursen, 2016). Lastly, the final set of test results (bottom row) indicate no rejection in any of the three models of the null hypothesis that interactions between the covariates and age have no effects on mortality rate. Rather, these results support the proportionality assumption embedded in the mortality rate models.

4.1. A Robustness checks

Table 4 reports the outcomes of several robustness tests of potential influences on the model 3 estimation results (Table 3). First, because modeling a medalist's best performance (gold, silver, or bronze) ignores the possible effects on health of the number of medals by color, model 4 (Table 4) includes these numbers as covariates. Based on the results, an additional bronze or gold medal has no significant effect on the mortality rate, but an additional silver medal significantly increases the mortality rate by about 22 percent (100 x (exp(0.20)-1)). To avoid any arbitrary choice between modeling best performance or number of medals by color, I then estimate model 4 (or model 3 in Table 3) on the basis of a

[13] In discussing the empirical findings, I draw conclusions based on a 5 percent level of statistical significance. The reported p-values and levels of significance (at the 1 and 5 percent levels) provide as well insights into possible issues related to multiple comparisons tests being carried out.

[14] Other unreported estimation results indicate that only bobsledding medalists have a significantly higher mortality rate than medalists in athletics (the reference group), possibly because bobsledding is a power sports (Zwiers et al., 2012), and that the effects of the different Olympics on mortality show no interpretable pattern.

Table 4
Robustness checks.

Mortality risk model Covariate	Model 4 Coeff. (*SE*)	Model 5 Coeff. (*SE*)	Model 6 Coeff. (*SE*)	Model 7 Coeff. (*SE*)	Model 8 Coeff. (*SE*)	Model 9 Coeff. (*SE*)
Gold medalist[a]		0.13	0.15	0.12	0.12	0.11
(best performance is gold)		(0.10)	(0.10)	(0.11)	(0.09)	(0.09)
Silver medalist[a]		0.33**	0.31**	0.34**	0.28**	0.33**
(best performance is silver)		(0.10)	(0.10)	(0.12)	(0.09)	(0.10)
Number of gold medals	0.03					
	(0.06)					
Number of silver medals	0.20**					
	(0.07)					
Number of bronze medals	−0.05					
	(0.07)					
Number of medalists	978	757	911	719	952	827
Number of parameters	35	33	34	25	35	29
Value log-likelihood function (/1,000)	−3.92	−3.04	−3.65	−2.90	−3.82	−3.32

Notes: The coefficient estimates (Coeff.) are of parameter vector β from (1) and standard errors are in parentheses (SE). Statistical significance at the 5 percent level is denoted with * and significance at the 1 percent level with **.
Model 4 includes number of medals instead of best performance, model 5 includes only one-time medalists, model 6 includes only men, model 7 excludes third-place sports competitions, model 8 excludes the 1906 and 1924 Winter Olympics, and model 9 excludes team sports. All specifications include an intercept and control for gender, age, more than one medal won (except models 4 and 5), medals won at more than one Olympics (except models 4 and 5), the number of Olympics at which medals were won (model 4 only), sports type, and the different Olympics.
[a] The omitted reference category is "bronze medalist" (best performance is bronze).

subsample of medalists who won only one medal. These estimates (model 5; Table 4) reveal that the effects of medal colors on the mortality rate are virtually identical to those from model 3 (Table 3). These findings could thus be interpreted as support for using medalist best performance in place of number of medals by color.

Second, concerning sample composition, the results for a subsample of men (model 6; Table 4) are very similar to those obtained for a sample of men and women (model 3; Table 3). This similarity, however, probably results from having only 67 women in the sample, which unfortunately prevents a thorough investigation of possible gender differences in medal color effects on mortality rate. Next, as explained in Section 1, not only do several sports hold a third-place competition for bronze in addition to the final competition for silver and gold, but medals won at certain Olympics have been either retroactively downgraded or only retroactively recognized.[15] Because either change could have influenced appraisals of medal color or the relation between medal color and SES, both could potentially have affected the empirical results. Yet the estimation results from models 7 and 8 (Table 4) show no effects of these events on the model 3 results (Table 3). Model 9 (Table 4) further tests the relation between medal color and mortality by checking for any influences of group versus individual events as there might be differences in how medal colors relate to SES or are appraised. Once again, the main model 3 results (Table 3) remain robust to the exclusion of team sports.

4.2. Life expectancy

The life expectancies of medalists by medal color, calculated based on the model 3 estimates (Table 3), are for men born in 1895 who won their only medal at age 25 (i.e., the sample average) and competed in athletics at the 1920 Antwerp Olympics.[16] As Table 5 shows, all these medalists have a predicted life expectancy that exceeds that of the general population, one that ranges from about three years for silver medalists to seven years for bronze medalists (columns 1 & 2). The life expectancies of bronze and gold medalists, in contrast, are not significantly different from each other, but silver medalists have a significantly lower life expectancy than either gold or bronze medalists (columns 3 & 4). More specifically, the life expectancy of silver medalists is about 2.4 and 3.9 years lower than that of gold medalists and bronze medalists, respectively.

Finally, the point estimates suggest that bronze medalists enjoy a higher life expectancy than gold medalists, as also apparent from Fig. 1 and Table 3. While all statistical tests provided on this difference show it is insignificant, some possible explanations for it are that winning a gold medal might have required more intense training over a longer time period, which adversely affects health (Maffetone and Laursen, 2016), that gold medalists pursued lower paid occupations than silver medalists after their sports careers (Leive, 2018), or that the fame and glory associated with winning gold induces risky health behavior (Epstein and Epstein 2013).

5. Interpretation of the main results

The primary empirical findings are that both bronze and gold medalists have significantly higher life expectancies than silver medalists, and that life expectancies of bronze and gold medalists do not differ significantly from each other. To interpret these results, I draw on the two assumptions introduced in section 1: (i) an increasing monotonic relation between the ranking of Olympic sports competition outcomes and medalist SES and (ii) no relation between this ranking and medalist health at the start of the Olympics.

Given these two assumptions, the main results, even though they suggest that competition outcomes affect health, do not support the contention that they do so through their effects on SES. Were such the case, then bronze medalists would have a significantly lower life expectancy than silver medalists. Rather, based on the arguments outlined in Section 1, the result that silver medalists have a significantly lower life expectancy than gold and bronze medalists can be interpreted as indicating an adverse effect on health of a (perceived) dissatisfactory competition outcome.

5.1. Alternative assumptions

Although these two assumptions for interpreting the empirical results from Section 4 may seem reasonable, their validity could always be called into question. It is therefore worth noting that

[15] The 1906 Olympics are considered intercalated games and not officially recognized by the International Olympic Committee, while the 1924 Winter Olympics were only made an official Olympic event in 1926.
[16] Due to the proportionality assumption imbedded in the mortality rate model, the main conclusions remain when the medalist characteristics are changed.

Table 5
Predicted life expectancy by medal color.

Cells: Years	Life expectancy[a] Prediction	Difference from population life expectancy Prediction	Difference from bronze medalist Prediction	Difference from gold medalist Prediction
Population	67.73			
Bronze medalists	74.76**	7.03**		
	(1.46)	(1.46)		
	[0.000]	[0.000]		
Silver medalists	70.84**	3.11*	−3.92**	−2.38*
	(1.21)	(1.21)	(1.06)	(1.04)
	[0.000]	[0.010]	[0.000]	[0.022]
Gold medalists	73.23**	5.49**	−1.54	
	(1.44)	(1.44)	(1.14)	
	[0.000]	[0.000]	[0.178]	

Notes: Standard errors are in parentheses and p-values are in brackets. Statistical significance at the 5 percent level is denoted with * and significance at the 1 percent level with **.

[a] Conditional on being alive at age 25. The predictions are based on Monte Carlo simulations and are for men born in 1895 who, when being medalists, won their only medal in athletics at the 1920 Antwerp Olympics at age 25.

both assumptions can be relaxed to a certain extent without affecting the above interpretations. As regards (i), if SES affects health, assuming a decreasing rather than increasing monotonic relation between SES and Olympic competition outcome rankings[17] would predict a higher life expectancy for silver medalists than for gold medalists, an observation for which Table 5 provides no support. On the other hand, assuming no relation between SES and the outcome rankings would not allow an assessment based on Olympic medalists data of whether SES affects health. Nevertheless, even if there would be no relation between SES and the outcome rankings, the results given in Table 5 can still be interpreted as indicating an adverse effect on health of a dissatisfactory competition outcome. Hence, the above interpretation of the main empirical results holds irrespective of the assumed monotonic relation between SES and Olympic competition outcome rankings.

On the other hand, if rather than assuming no relation, one assumed a monotonically decreasing or increasing relation between outcome rankings and medalist health at the start of the Olympics (ii),[18] then, if SES affects health, the predictions under a monotonicity assumption could be either a monotonically increasing, monotonically decreasing, or nonexistent relation between the outcome rankings and life expectancy. Table 5, however, supports none of these predictions. However, if competition outcomes affected health through the appraisals of the outcomes, then under this alternative assumption, dependent on the strength of the assumed relation, the predicted non-monotonic relation between outcome rankings and life expectancies could be tilted. For instance, bronze and gold medalists could have significantly different life expectancies, and one of these could even be lower than the life expectancy of silver medalists. Again, however, Table 5 provides no empirical support for such predictions. Hence, the main empirical results cannot be reconciled with the alternative assumption of a monotonically decreasing or increasing relation between competition outcome rankings and medalist health at the start of the Olympics.

6. Summary and Discussion

By estimating the effects of U.S. Olympic medalists' medal colors on their lifespans, this analysis shows that the life expectancies of bronze and gold medalists differ insignificantly from each other but are significantly higher than the life expectancy of silver medalists. The latter is in fact about 2.4 and 3.9 years lower than those of gold and bronze medalists, respectively. The reduced life expectancy of winning silver can be considered substantial when compared to, for instance, the associations between smoking or education and life expectancy: Compared to non-smokers, smokers have a seven years lower life expectancy (Rogers and Powell-Griner, 1991) and individuals with less than 12 years of schooling have a four years lower life expectancy than individuals who went to college (Kitagawa and Hauser, 1973; Duleep, 1989). Interpreted based on insights from behavioral economics, psychology, and human biology, these findings for U.S. Olympic medalists suggest that whereas, on average, bronze and gold medalists appraise their medals as a win, silver medalists appraise them as a loss (Medvec et al., 1995) and, through the associated psychological stress (Lazarus, 1993), have their health compromised and life expectancy reduced (Epel et al., 2004; Sapolsky, 2005; Lupien et al., 2007, Lupien et al., 2008).

The ultimate purpose of analyzing U.S. Olympic medalists' lifespans is to provide insights into the SES-health gradient among the general population,[19] whose everyday lives and socioeconomic status (SES) are continually affected by myriad competition outcomes. In this real-world setting, competition outcomes may not provide insights into if health is affected by competition outcomes through their effect on SES or through the appraisals of these outcomes because, for instance, an outcome that is objectively a loss and adversely affects SES may as well be appraised as a loss. In contrast, this paper argues that in the setting of Olympic sports competitions the lifespans of bronze medalists, next to those of silver and gold medalists, enable an empirical distinction between the effects of competition outcomes on health through their effect on SES or through the appraisals of these outcomes. Nonetheless, although an SES effect on health among the general population could explain the SES-health gradient, no empirical support is found for competition outcomes affecting health through their effects on SES, perhaps because medal color is unrelated to medalist SES or because SES does not affect health. Rather, the analysis provides empirical support for individual health being adversely affected by (perceived) dissatisfactory competition outcomes. This paper therefore contributes to the literature by showing that competition outcomes that affect SES could play an important causal role in the SES-health gradient among the general population by also affecting health through their appraisals.

[17] As reflected by Leive's (2018) finding that in a sample of 54 U.S. track and field athletes, silver medalists have, on average, higher post-Olympics earnings than gold medalists.

[18] This alternative assumption would bias the effects of medal colors on life expectancy.

[19] This paper's main findings should also be of interest to professional athletes in that they suggest there might be a need for mental health care to cope with (perceived) losses.

Although the SES-health gradient and its persistence are a major concern to policymakers, the notion of competition outcomes as a causal third factor in the SES-health gradient has not previously been empirically analyzed in the literature. Further research is thus needed to determine its quantitative importance, and external validity, before any solid policy conclusions can be drawn. Nonetheless, the findings reported in this paper, in line with the policy recommendations put forward by Adler and Newman (2002) and Deaton, (2002), support the idea that health disparities could be reduced by facilitating individual access to (mental) health care when needed.

Appendix A.

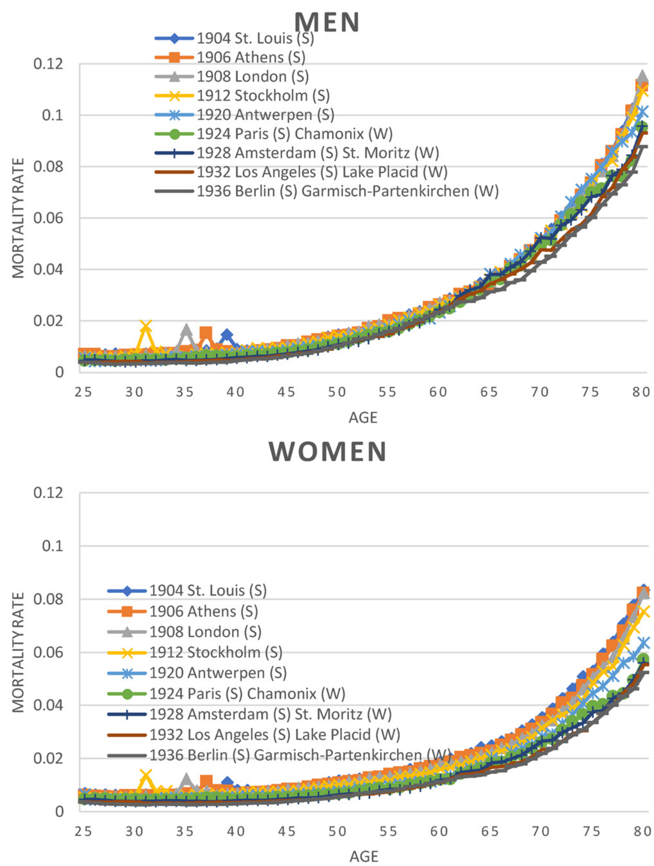

Fig. A1. Annual mortality rates from life tables by gender, age, and year of the olympics.

Table A1
Lifespan distribution by Olympics.

Olympic Games at which first medal was won	Number of medalists	Lifespan (age)		
		25th percentile	50th percentile	75th percentile
1904 St. Louis (S)	246	58	70	81
1906 Athens (S)	7	71	78	84
1908 London (S)	42	56	69	78
1912 Stockholm (S)	65	67	75	83
1920 Antwerp (S)	125	66	76	84
1924 Paris (S)	137	64	76	86
1924 Chamonix (W)	10	71	72	77
1928 Amsterdam (S)	67	62	79	89
1928 St. Moritz (W)	12	57	65	77
1932 Los Angeles (S)	152	69	80	86
1932 Lake Placid (W)	26	63	71	88
1936 Berlin (S)	75	69	81	87
1936 Garmisch-Partenkirchen (W)	14	68	71	84

Notes: S = summer games; W = winter games. The 1908 and 1920 games included several Winter Olympics sports events.

Table A2
Lifespan distribution by sports.

Sports	Number of medalists	Lifespan (age)		
		25th percentile	50th percentile	75th percentile
Athletics	263	64	75	83
Rowing	99	66	77	85
Swimming	81	64	75	86
Ice hockey	41	69	76	85
Gymnastics	38	62	78	86
Sailing	19	66	80	87
Cycling	16	58	74	83
Fencing	21	66	76	87
Football	19	56	69	79
Hockey	14	76	82	86
Basketball	14	71	83	87
Shooting	79	64	73	81
Wrestling	36	63	77	84
Water polo	25	59	73	85
Boxing	32	58	71	84
Bobsledding	23	57	65	69
Rugby	38	62	78	85
Equestrianism	11	67	74	81
Diving	30	62	80	87
Tennis	14	65	72	84
Golf	30	52	65	79
Other sports	41	68	75	82

Notes: "Other sports" include judo, taekwondo, canoeing, weightlifting, ice skating, skiing, figure skating, and art.

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