**Human Reproduction Vol.22, No.11 pp. 3002–3008, 2007** doi:10.1093/humrep/dem239
Advance Access publication on September 20, 2007

# Big and tall soldiers are more likely to survive battle: a possible explanation for the 'returning soldier effect' on the secondary sex ratio

**Satoshi Kanazawa**[1,2,3,4]

[1]*Interdisciplinary Institute of Management, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK;* [2]*Department of Psychology, University College London, London, UK;* [3]*Department of Psychology, Birkbeck College, University of London, London, UK*

[4]Correspondence address. Interdisciplinary Institute of Management, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK. Tel: +44-20-7955-7297; Fax: +44-20-7955-7005; E-mail: s.kanazawa@lse.ac.uk

**BACKGROUND: It is widely known that more boys are born during and immediately after wars, but there has not been any ultimate (evolutionary) explanation for this 'returning soldier effect'. Here, I suggest that the higher sex ratios during and immediately after wars might be a byproduct of the fact that taller soldiers are more likely to survive battle and that taller parents are more likely to have sons. METHODS: I analyze a large sample of British Army service records during World War I. RESULTS: Surviving soldiers were on average more than one inch (3.33 cm) taller than fallen soldiers. CONCLUSIONS: Conservative estimates suggest that the one-inch height advantage alone is more than twice as sufficient to account for all the excess boys born in the UK during and after World War I. While it remains unclear why taller soldiers are more likely to survive battle, I predict that the returning soldier effect will not happen in more recent and future wars.**

*Keywords:* generalized Trivers–Willard hypothesis; offspring sex ratio

### The puzzle: the 'returning soldier effect'

It has been widely observed that more boys than usual are born during and immediately after the World Wars in most of the belligerent nations (James, 1987, pp. 733–734). Cartwright (2000, p. 121) dubs this phenomenon as the 'returning soldier effect'.

MacMahon and Pugh (1954) were among the first to observe the effect. They demonstrate that the sex ratio among whites in the USA rose during World War II, but not during World War I. Others have since documented the phenomenon repeatedly (Lowe and McKeown, 1951; van der Broek, 1997; Ellis and Bonin, 2004). In one of the most comprehensive demonstrations, Graffelman and Hoekstra (2000) conclusively show that the secondary sex ratio (sex ratio of live births) increased during and immediately after World Wars in all belligerent nations (Austria, Belgium, Denmark, France, Germany, the Netherlands, USA and UK), except for Italy and Spain. In the succinct words of the scientist who has studied sex ratios (of both humans and other animals) more than anybody else, 'there can be no reasonable doubt that sex ratios (proportions male at birth) have risen during and just after major wars' (James, 2003, p. 1133).

While there may be no reasonable doubt that the phenomenon exists, there are no satisfactory explanations for it. In particular, to the best of my knowledge, few have proposed an ultimate (evolutionary) explanation for the increased number of boys born during and immediately after wars. One attempt at an ultimate explanation is the view that sons have greater expected reproductive success than daughters during and immediately after wars in which many men die (Trivers, 1985, pp. 286–288; Bisioli, 2004). It is impossible for parents to know how long the war (or any other situation of greater male mortality) will last. If the war lasts longer than, say, 15 years, long enough for the newborn boys to reach sexual maturity, then parents who have more sons may on average achieve greater inclusive fitness than parents who have more daughters.

Some offer proximate explanations of the returning soldier effect. Grant's (1998, 2003) 'maternal dominance hypothesis' contends, first, that the mother, not the father, determines the sex of the offspring and, second, that dominant, 'tough' women high in testosterone are more likely to have sons. With respect to the returning soldier effect, Grant (1998, pp. 156–163) argues that women become 'tougher' during wars because they have to take over some of the traditionally male roles in society in the absence of men, and they as a result have more boys presumably because their testosterone levels increase during wars. However, there is very little human evidence for the maternal dominance hypothesis in general, and as an explanation for the returning soldier effect in particular. It also cannot explain why the secondary sex ratio remains high for a few years after the end of the war.

James (2003) offers an alternative proximate mechanism. During wars, couples are reunited only during short leaves from the armed services. They are expected to have frequent intercourse during such short leaves and, as a result, more likely to conceive during the early phase of the cycle, when the estrogen/gonadotrophin ratio in women is high. Mammalian (including human) sex ratio is higher when the maternal estrogen level is higher at the time of conception (James, 1996). Hence, couples who have high frequencies of intercourse (such as briefly reunited soldiers on short leaves and their wives) are more likely to conceive sons. While very plausible on the surface, James' (2003) proximate explanation currently lacks empirical support, including rigorous quantitative evidence for the crucial assumption that coital frequency is higher during wartime and remains high for a few years afterwards [although James (1981, 1983) provides indirect evidence].

Thus the puzzle remains: *Why* (as opposed to how) are more boys born during and immediately after wars? What ultimate mechanism can account for it?

Before going further, it is important to point out that, while there is indeed no reasonable doubt that more boys are born during and immediately after wars, and the absolute number of excess boys is large in large populations, the *relative* increase in the secondary sex ratio is very small. For example, MacMahon and Pugh (1954) report that the sex ratio among whites in the USA increased from the baseline of 51.406 to 51.481 during 1942–1946. In other words, during World War II, the sex ratio increased by three-quarters of a 10th of a boy per 100 births.

Graffelman and Hoekstra's (2000) more recent and comprehensive analysis of all belligerent nations in both World Wars produces the same results. For example, in the UK, the baseline sex ratio during peacetime is 51.2 (Graffelman and Hoekstra, 2000, p. 439, Table 1). This increases to 51.365 during wartime (1914–1920, 1939–1948). In terms of odds ratio, this translates into an increase in odds of having a boy by only 0.7% (the odds of having a boy during peacetime: $0.512/0.488 = 1.049$; the odds of having a boy during wartime: $0.51365/0.48635 = 1.056$; the wartime increase in odds: $1.056/1.049 = 1.007$).

## Generalized Trivers–Willard hypothesis (gTWH)

In their classic paper, Trivers and Willard (1973) suggest that parents might under some circumstances be able to vary the sex ratio of their offspring in order to maximize their reproductive success. The Trivers–Willard hypothesis (TWH) proposes that, for all species for which male fitness variance exceeds female fitness variance, male offspring of parents in better material condition are expected to have greater reproductive success than their female siblings, because their greater size allows them to outcompete their intrasexual rivals and monopolize available reproductive opportunities. The converse is true of offspring of parents in poorer material and nutritional condition, because smaller males, who are not intrasexually competitive, are excluded from mating opportunities. Parental condition affects the reproductive prospects of female offspring to a much lesser extent. Almost all females get to reproduce some offspring, even though no female can produce a large number due to their greater obligatory investment into each offspring (Trivers, 1972).

While the TWH in its original formulation has specifically to do with material (and, for humans, economic) condition of parents and their ability to vary the sex ratio of their offspring in response to such condition, the basic insight behind it may be more general. The fundamental assumption underlying the TWH is that if males are expected to attain greater reproductive success than females, *for whatever reason*, then parents may have more sons than daughters. If, in contrast, females are expected to attain greater reproductive success than males, *for whatever reason*, then parents may have more daughters than sons. While female fitness variance is much smaller than male fitness variance among mammalian species, there is still variance among females, and some women do better than others, in terms of the quality, if not quantity, of their offspring.

Kanazawa (2005) thus proposes the gTWH:

*gTWH: parents who possess any heritable trait which increases male reproductive success at a greater rate (or decreases male reproductive success at a smaller rate) than female reproductive success in a given environment will have a higher-than-expected offspring sex ratio (more males). Parents who possess any heritable trait which increases female reproductive success at a greater rate (or decreases female reproductive success at a smaller rate) than male reproductive success in a given environment will have a lower-than-expected offspring sex ratio (more females).*

Unlike Grant's (1998, 2003) maternal dominance hypothesis, the gTWH is completely mute on which parent determines or influences the sex of the offspring. There has been emerging evidence for the gTWH with respect to a variety of heritable traits which increase the reproductive success of offspring of one sex or the other (see Kanazawa, 2007, for review).

One of these heritable traits which has been shown to affect secondary sex ratios is body size: big and tall parents are more likely to have sons (Kanazawa, 2005). Taller men have greater reproductive success than shorter men (Pawlowski *et al.*, 2000; Nettle, 2002a), but shorter women have greater reproductive success than taller women (Nettle, 2002b). And body size (height and weight) is substantially heritable (Chambers *et al.*, 2001; Silventoinen *et al.*, 2001). The gTWH would therefore predict that taller and heavier parents will have a higher-than-expected number of sons, and shorter and lighter parents will have a lower-than-expected number of sons (or a higher-than-expected number of daughters).

If this finding is generalizable, then it can potentially provide an ultimate explanation for biased sex ratios, including society-wide patterns like the returning soldier effect. If the population distribution of any of the relevant traits (any heritable trait that has a sexually dimorphic effect on the reproductive success of the offspring) shifts slightly during and immediately after wars, then the gTWH can possibly explain why there are more boys born then. If, for example, taller and bigger soldiers are more likely to survive wars, to be reunited with their wives after demobilization, while shorter and smaller soldiers are more likely to die, never to get an(other) opportunity to reproduce, then the gTWH would predict that more boys will be born during and immediately after wars. The returning soldier effect would then be a byproduct of the gTWH, where soldiers who would have produced daughters were more likely to be killed during the war and did not get an opportunity to do so. Such a byproduct of the gTWH is expected to be temporary, as younger generations of men who were unaffected by the combat experience (and thus preserve the normal distribution of height) become of reproductive age and start having children, and as the surge of baby boom created by postwar reunion of soldiers with their wives gradually wanes.

The question then is: is it possible that there was a significant difference in body size between the soldiers who survived the battle and those who were killed?

## Surviving and fallen British soldiers during World War I

### *Data*

In order to examine whether soldiers who survive wars are different in body size than soldiers who do not, I examine the service records of British soldiers in World War I. The record series 'WO (War Office) 363' in the National Archives in Kew Gardens outside London contains service records of every single man who enlisted for the British armed forces between 1914 and 1920 (Spencer, 2001, pp. 23–34). Each soldier's record typically begins with the attestation form, which lists the soldier's name, address, age, marital status and next of kin, among other demographic information at the time of enlistment. Then each enlistee undergoes a thorough medical examination, where their height, chest girth and (less frequently) weight, and vision are measured and recorded. The record also contains the details of each soldier's service for its entire duration, where and how long he was posted at a particular domestic or foreign location, when he was granted leaves, if he received any medal of honor for his service, and his ultimate fate. It records whether he was discharged after a given length of service, demobilized at the end of the conflict or killed in action or died of wounds or diseases acquired during service. WO363 contains the records of enlisted men and non-commissioned officers only; it excludes the records of commissioned officers.

The original records for 6.5 millions soldiers were kept in the War Office Record Store on Arnside Street in London after World War I (http://www.nationalarchives.gov.uk/catalogue/DisplayCatalogueDetails.asp?CATID=13422&CATLN=3&FullDetails=True). On 8 September 1940, incendiary bombs dropped during an air raid campaign by the German Luftwaffe caused fire at the War Office Record Store, and destroyed approximately two-thirds of the records (WO363 is thus known as the 'burnt documents'). The surviving records, many of which were charred and water damaged, were subsequently stored on 23 608 reels of microfilm, in alphabetical order of the soldier's last name. All 23 608 reels are currently kept at the National Archives in Kew Gardens for free public access for anyone who visits the National Archives in person, but they are not online or accessible from a remote site.

### *The sample*

Because WO363 records exist only as the original handwritten forms photographed on microfilm, and because the information is not coded or digitized in any way, it is impossible to draw a representative sample of the soldiers. I have therefore decided to code each soldier's record into a computer file, starting with the first record on the first reel (A1), in strict alphabetical order by the last name, without skipping any record. I have thus transcribed the first 1000 records. The last names range in alphabetical order from Ababreltom to Ablett.

This is obviously not a representative sample of men who enlisted for British military service during the 1914–1920 period. For example, to the extent that many Irish last names begin with M or O, my sample probably underrepresents soldiers from Ireland (which was part of the UK until 1921). However, I do not expect Irish nationality to be correlated with either the independent variables of interest (height and weight) or the dependent variable (survival).

Nor do I have any reason to believe that the alphabetical order of the soldier's last name or the probability of the soldier's record's survival of the fire on 8 September 1940, in London, to be correlated with the soldier's body size or his ultimate fate in the war. I therefore believe that, while my sample is not a representative sample in the technical sense, it is nonetheless an *unbiased* sample with respect to the current purpose of determining whether British soldiers who survived World War I were significantly taller than those who did not.

In order to ascertain whether my particular decision to code the first 1000 cases has any effect on my conclusions, I have drawn alternative samples of first $n$ cases which includes 100 dead soldiers with usable (non-missing) values on height ($n = 1053$), the first 1100 cases ($n = 1100$) and the first $n$ cases which includes 1000 usable values on height ($n = 1122$). None of my substantive conclusions below change as a result of using any of these alternative samples.

### *Dependent variable*

The dependent variable of interest here is whether the soldier survived the war (0 if he survived the war, 1 if he was killed). I did not make a distinction among the causes of death. Sometimes the soldier's fate is recorded as 'killed in action' and other times as 'died of wounds'. A few soldiers died of an accident while on duty. If the soldier died of any cause during his military service, I record him as being killed. In a few instances where the soldier's survival status was not apparent in the handwritten records in WO363, I consulted the (purportedly comprehensive) list of fallen British soldiers at the web site of the Commonwealth War Graves Commission (http://www.cwgc.org/).

Similarly, there are many ways a British soldier could survive World War I. Most were 'discharged' from service after a contracted period of service. These soldiers usually filled out a discharge form, which recorded the date of discharge and a forwarding civilian address. In some cases, the soldier was 'demobilized' after the end of the conflict in World War I. In a surprising number of cases, the soldier deserted the unit. Once again, regardless of the reason for survival, I recorded the soldier as having survived if he was not killed during his service.

### *Independent variables*

My main independent variables of interest are the soldier's height and weight at the time of enlistment. These were taken during the routine medical examination at the beginning of his service. For some reason, weight was not measured nearly as frequently as height and 'chest girth' (the chest measurement when fully expanded). Some of the forms used for medical examination had spaces for height and chest girth, but not for weight. Other forms had spaces for height, weight, chest girth, vision for left and right eye, as well as other medical measurements. In addition to height, weight and chest girth, I recorded the soldier's age at enlistment and marital status (1 if currently married, 0 otherwise).

### *Results*

In my sample of 1000, 102 soldiers are recorded as killed and 898 as survived. All subsequent comparisons, however, use somewhat smaller numbers due to missing data on the independent variables.

The surviving soldiers in my sample have a significantly higher mean height than fallen soldiers (in cm): 168.63 versus 166.26, $t_{(896)} = 3.526$, $P < 0.001$, 95% confidence interval of the mean difference $= 2.37 \pm 1.32$. The surviving soldiers are also significantly heavier (in kg): 60.46 versus 56.84, $t_{(393)} = 2.852$, $P < 0.01$, 95% confidence interval $=$ $3.62 \pm 2.49$) and significantly older (26.2 versus 23.9 years, $t_{(955)} = 2.894$, $P < 0.01$, 95% confidence interval $= 2.3 \pm$ 1.6). The two groups are not different in chest girth (91.29 versus 89.79, $t_{(902)} = 1.220$, *ns*) or marital status (0.41 versus 0.24, $t_{(917)} = 1.301$, *ns*). While the mean difference in height between the surviving and fallen soldiers is 2.37 cm, the median difference is greater at 3.33 cm (168.43 versus 165.10, $\chi^2 = 13.46$, asymptotic $P < 0.001$).

In a binary logistic regression with the survival of the soldier as the dependent variable and height, weight, and age as the independent variables, height is the only variable which marginally significantly predicts the soldier's survival independently ($b = -0.059$, $\mathrm{SE} = 0.031$, $e^b = 0.943$, $P < 0.06$). Neither weight nor age independently predicts survival once height is controlled (weight: $b = -0.016$, $\mathrm{SE} = 0.026$, $e^b = 0.984$, *ns*; age: $b = -0.037$, $\mathrm{SE} = 0.025$, $e^b = .964$, *ns*). The odds ratio of 0.943 for height means that every centimeter on a soldier's height decreases the odds of being killed by 6% or increases the odds of survival by 6% ($1/0.943 = 1.060$).

While the mean and median differences in height between surviving and fallen soldiers are both significant at $P <$ 0.001, the median difference (3.33 cm) is larger than the mean difference (2.37 cm). In order to provide a *statistically conservative* estimate of what potential consequences in offspring sex ratio this height difference might have, I will focus on the mean difference in the subsequent analysis. The reader should keep in mind that my choice of the mean difference deliberately *underestimates* the potential consequences for offspring sex ratio.

Figure 1 shows the distribution of soldiers' height by their survival status. The top panel shows the distribution of height among soldiers who survived World War I, and the bottom panel shows the distribution of height among soldiers who were killed. The vertical line that runs through both panels indicates the mean height of the surviving soldiers (168.63 cm). It is evident that the distribution of height among the fallen soldiers in the bottom panel has a lower mean than the distribution of height among the surviving soldiers.

## What difference does a one-inch difference make?

It thus appears that British soldiers who survived World War I were slightly but significantly taller than those who were killed.

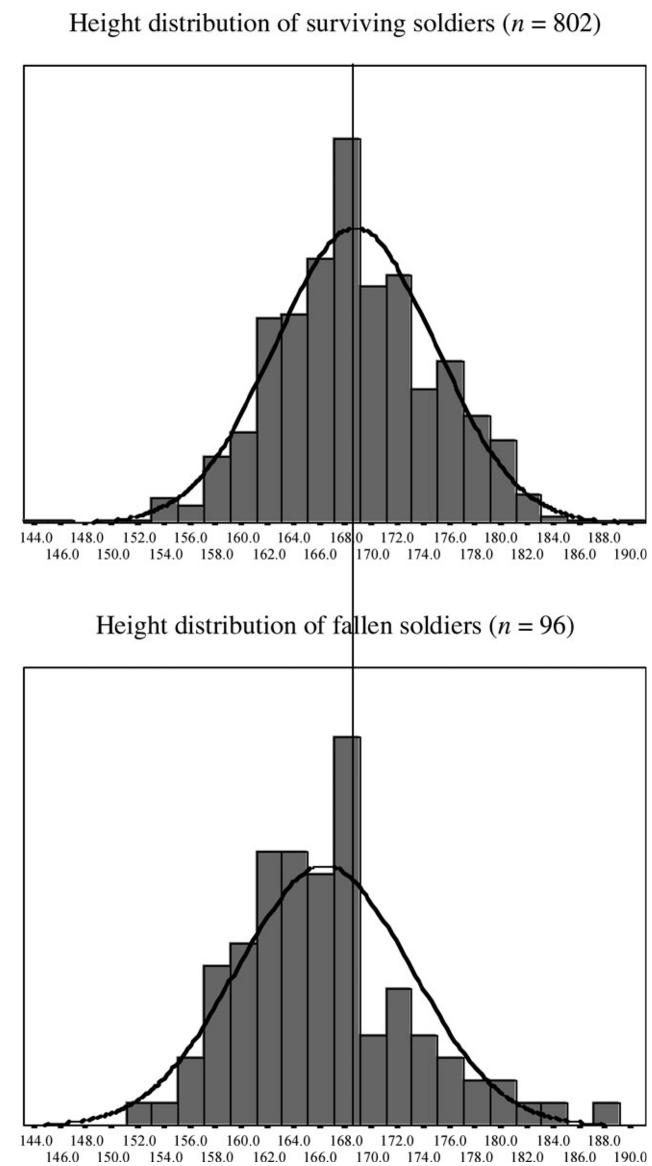


**Figure 1:** Height distributions of surviving soldiers (top panel) and fallen soldiers (bottom panel), British troops during the World War I The solid vertical line indicates the mean height of surviving soldiers (168.63 cm)

The mean height difference is nearly one inch (2.37 cm). But what difference can such a small height difference make in offspring sex ratio? Is it really sufficient to account for all the excess boys born during and after World War I in the UK?

Unfortunately, this question cannot be answered with historical data from the UK from the same period. There are no datasets that contain both the height of the general population of the UK during 1914–1920 *and* the sex of their offspring. In order to estimate the effect of height on the offspring sex ratio, I use the National Longitudinal Study of Adolescent Health (Add Health) from the USA. To my knowledge, Add Health is the *only* data set with a large, nationally representative sample of a population, in which researchers measure respondents' height rather than relying on their self-reports. Given that most men want to be taller than they are (Calden *et al.*, 1959), it is important not to rely on self-reports of height in estimating its effect on offspring sex ratio.

The use of Add Health in the following analysis, however, crucially assumes that the effect of height on offspring sex ratio remains roughly comparable both across time (from early 20th to early 21st century) and across the Atlantic (in the UK and in the USA). Both TWH and gTWH are purported to describe not only species-typical phenomena applicable to all human societies at all times, but also a fundamental biological process hypothesized to operate among all species with sexually dimorphic fitness variance.

Among male respondents who have had at least one child by the third (last available) wave of Add Health in 2001–2002 ($n = 696$), controlling for education and income (as measures of social class predicted to influence offspring sex ratio by the original TWH) and weight, height has a significantly positive effect on the probability of having a son as the first child ($b = 0.0535$, $e^b = 1.0550$, $P < 0.05$).

The odds ratio ($e^b$) of 1.0550 for one-inch increment in height translates into 1.0513 for a height difference of 0.9345 inches (2.37 cm) ($b = 0.0535 \times 0.9345 = 0.0500$, $e^{0.0500} = 1.0513$). It means that an increase in height of 2.37 cm increases the odds of having a son by 5.13%. Notice that, according to Graffelman and Hoekstra's (2000) analysis, this is *more than seven times* the actual increase in the odds of having a son during and immediately after World War I in the UK (0.7%). It therefore follows that, if at least one-seventh of British male population experienced combat duties in World War I, then the one-inch height difference between the surviving and fallen soldiers can account for all the excess boys born during and immediately after the war.

As it turns out, nearly one-third (32.39%) of young British men between the ages of 15 and 40 were mobilized during World War I. In 1911, in the last British Census conducted before the outbreak of World War I, the number of men between the ages of 15 and 40 in England and Wales was 15 081 844 (Census of England and Wales, 1915, pp. 90–91, Table 29). Unfortunately, the exact number of adult males in Scotland and Ireland in 1911 is not available. However, in 1911, England and Wales accounted for 85.76% of the total population of the UK ($36\,316/42\,138 = 0.8576$) (Hickes and Allen, 1999, p. 6). Assuming that the population age structure in Scotland and Ireland in 1911 was roughly comparable to that in England and Wales in the same year, it means that the total number of adult males between 15 and 40 in the UK was ~17.6 million ($15\,081\,844/0.8576 = 17\,586\,105$). More than 5.7 million British men were mobilized during World War I (Spencer, 2001, p. xi). Thus the proportion of adult males who served in the British military during World War I is $5.7/17.6 = 0.3239$.

It, therefore, appears that the very slight (2.37 cm) height advantage of surviving soldiers compared to their fallen comrades is *more than twice as sufficient* to account for the returning soldier effect observed in the UK during and immediately after World War I. This conclusion assumes that surviving and returning soldiers were no more or no less likely to father a child during and immediately after World War I than the rest of the (unmobilized) male population. If, as some (James, 1981,1983) suggest, returning soldiers after many years of separation from their wives are *more* likely to father a child, then it would have required an even smaller proportion of the British male population to have been mobilized to produce the observed increase in the number of boys. Further, recall that the use of the median height difference (3.33 cm) would also have required a similarly smaller proportion of the British male population to have been mobilized.

## Why do taller soldiers have better chance of survival in war?

If the height advantage of surviving soldiers over fallen soldiers in the British armed forces during World War I generalizes to the soldiers of other belligerent nations in both World Wars, then the phenomenon, combined with the tendency of taller parents to have more sons, can potentially explain the returning soldier effect, where more boys are born during and immediately after wars. More empirical research is necessary, both to replicate the findings above in the UK and to extend it to other western nations found to have experienced the returning soldier effect during and after World Wars (Graffelman and Hoekstra, 2000).

It remains unclear *why* taller soldiers are more likely to survive battle than shorter soldiers. I can offer three speculations. First, taller and heavier soldiers, especially during the less prosperous times of the early 20th century, may have been physically stronger and more fit, as well possibly as genetically and developmentally healthier. They might, therefore, have been better able to resist diseases and even wounds sustained during combat, which might have killed their shorter and lighter counterparts.

Second, height is known to be correlated with intelligence (Schreider, 1964; Tanner, 1969; Porter, 1892; Jensen and Sinha, 1993). Some (Miller, in press) suggest that both height and intelligence are indicator of underlying genetic health, while others (Kanazawa and Reyniers, 2007) contend that the extrinsic correlation stems from assortative mating of intelligent men and beautiful women, on the one hand, and that of tall men and beautiful women, on the other. The correlation between height and IQ among men in the Add Health data is

$r = 0.0943$, $n = 6642$, $P < 0.001$. The positive correlation between height and intelligence has two possible consequences. While the WO363 records that I use in my analysis include only enlisted men and non-commissioned officers, and excludes commissioned officers, it is possible that taller and thus more intelligent men were able to climb the ranks of non-commissioned officers to such ranks as lance corporal and sergeant, and were able to avoid the most dangerous combat situations because of their relative seniority (I thank William H. James and Dominic D. P. Johnson for independently suggesting this possibility to me).

Alternatively, modern warfare, even in the Great War nearly a century ago, is evolutionarily novel in that it involves weapons, machines, tactics and situations that did not exist in the ancestral environment. Soldiers may therefore have needed general intelligence to fight successfully and survive an evolutionarily novel situation of modern warfare (Kanazawa, 2004). Given that a non-trivial number of British soldiers survived World War I by deserting, they may have needed general intelligence to desert and avoid court-martial successfully. Whalley and Deary (2001) show, however, that *less*, not more, intelligent British soldiers were more likely to survive World War II.

Dominic D. P. Johnson (personal communication) suggests another interesting hypothesis. If vital organs in the body do not increase in size linearly with the body size (height and weight), then it means that taller and heavier soldiers, while they may be more likely to be shot because of their larger body size, have nonetheless more room in their body where they can be 'safely' shot and still survive the injury.

Regardless of the exact reason why taller soldiers are more likely to survive battle, if my explanation for the returning soldier effect is correct, the phenomenon is not likely to be observed and repeated in more recent and future wars. This is because, for my suggested mechanism to work, a substantial proportion of the male population has to be deployed in the war. With the advances in military technologies, however, which allow the modern military to fight wars, not by mano a mano combat of large infantries, but with laser-guided missiles on a computer screen and supersonic fighter jets, military forces of advanced western nations do not require as many soldiers to fight the war successfully as they used to. This transition to smaller military forces is reflected in the discontinuation of conscription in most western nations.

With much smaller proportions of the male population mobilized in wars, the returning soldier effect is not likely to be repeated, even if tall soldiers are still more likely to survive battle and even if tall parents are more likely to have sons. The higher sex ratios among the surviving (and returning) soldiers will not significantly shift the secondary sex ratio in the whole society. There is some evidence that more boys were *not* born during more recent wars, such as the Iran–Iraq wars in 1980–1988 (Ansari-Lari and Saadat, 2002) and the 10-day war in Slovenia in 1991 (Zorn *et al.*, 2002). The lower rate of mobilization might also explain why the returning soldier effect was not observed in the US during World War I, when it was during World War II (MacMahon and Pugh, 1954; Graffelman and Hoekstra, 2000).

## Acknowledgements

I thank William H. James, Dominic D. P. Johnson and two anonymous reviewers for their comments on earlier drafts.

## References

Ansari-Lari M, Saadat M. Changing sex ratio in Iran 1976–2000. *J Epidemiol Community Health* 2002;**56**:622–623.

Bisioli C. Sex ratio of births conceived during wartime. *Hum Reprod* 2004;**19**:218–219.

Calden G, Lundy RM, Schlafer RJ. Sex differences in body concepts. *J Consult Psychol* 1959;**23**:378.

Cartwright J. *Evolution and Human Behavior: Darwinian Perspectives on Human Nature.* Cambridge: MIT Press, 2000.

Census of England Wales. *Summary Tables: Area, Families or Separate Occupiers and Population.* London: Harrison and Sons, 1915.

Chambers ML, Hewitt JK, Schmitz S, Corley RP, Fulker DW. Height, weight, and body mass index. In: Hewitt JK, Emde RN (eds). *Infancy to Early Childhood: Genetic and Environmental Influences on Developmental Change*. London: Oxford University Press, 2001, 292–306.

Ellis L, Bonin S. War and the secondary sex ratio: are they related? *Soc Sci Inf* 2004;**43**:119–126.

Graffelman J, Hoekstra RF. A statistical analysis of the effect of warfare on the human secondary sex ratio. *Hum Biol* 2000;**72**:433–445.

Grant VJ. *Maternal Personality, Evolution, and the Sex Ratio: Do Mothers Control the Sex of the Infant?* London: Routledge, 1998.

Grant VJ. The maternal dominance hypothesis: questioning Trivers and Willard. *Evol Psychol* 2003;**1**:96–107.

Hickes J, Allen G. A century of change: trends in UK statistics since 1900. House of Commons Research Paper 99/111, 1999 (http://www.parliament.uk/commons/lib/research/rp99/rp99-111.pdf).

James WH. The honeymoon effect on marital coitus. *J Sex Res* 1981;**17**:114–123.

James WH. Decline in coital rate with spouses' age and duration of marriage. *J Biosoc Sci* 1983;**15**:83–87.

James WH. The human sex ratio. Part I: A review of the literature. *Hum Biol* 1987;**59**:721–752.

James WH. Evidence that mammalian sex ratios at birth are partially controlled by parental hormone levels at the time of conception. *J Theor Biol* 1996;**180**:271–286.

James WH. Sex ratios of births conceived during wartime. *Hum Reprod* 2003;**18**:1133–1134.

Jensen AR, Sinha SN. Physical correlates of human intelligence. In: Vernon PA (ed). *Biological Approaches to the Study of Human Intelligence*. Norwood: Ablex, 1993, 139–242.

Kanazawa S. General intelligence as a domain-specific adaptation. *Psychol Rev* 2004;**111**:512–523.

Kanazawa S. Big and tall parents have more sons: further generalizations of the Trivers-Willard hypothesis. *J Theor Biol* 2005;**235**:583–590.

Kanazawa S. Beautiful parents have more daughters: a further implication of the generalized Trivers-Willard hypothesis (gTWH). *J Theor Biol* 2007;**244**:133–140.

Kanazawa S, Reyniers DJ. Intelligence: what's sex got to do with it? Department of Management, London School of Economics and Political Science, 2007.

Lowe CR, McKeown T. A note on secular changes in the human sex ratio at birth. *Br J Soc* 1951;**5**:91–96.

MacMahon B, Pugh TF. Sex ratio of white births in the United States during the Second World War. *Am J Hum Genet* 1954;**6**:284–292.

Miller GF. The evolutionary genetics behind mental fitness indicators: The G matrix, the *g* factor, and mating intelligence. In: Geher G, Miller GF (eds). *Mating Intelligence: Theoretical and Empirical Insights into Intimate Relationships.* Mahwah: Lawrence Erlbaum, in press.

Nettle D. Height and reproductive success in a cohort of British men. *Hum Nat* 2002a;**13**:473–491.

Nettle D. Women's height, reproductive success and the evolution of sexual dimorphism in modern humans. *Proc R Soc Lond B Biol Sci* 2002b;**269**:1919–1923.

Pawlowski B, Dunbar RIM, Lipowicz A. Tall men have more reproductive success. *Nature* 2000;**403**:156.

Porter WT. The physical basis of precocity and dullness. *Trans Acad Sci St. Louis* 1892;**6**:161–181.

Schreider E. Recherches sur la stratification sociale des charactéres biologiques. *Biotypologie* 1964;**26**:105–135.

Silventoinen K, Kaprio J, Lahelma E, Viken RJ, Rose RJ. Sex differences in genetic and environmental factors contributing to body-height. *Twin Res* 2001;**4**:25–29.

Spencer W. *Army Service Records of the First World War*, third expanded edn. Richmond: Public Record Office, 2001.

Tanner JM. Relation of body size, intelligence test scores and social circumstances. In: Mussen P, Langer J, Covington M (eds). *Trends and Issues in Child Developmental Psychology*. New York: Holt, Rinehart, & Winston, 1969, 182–201.

Trivers RL. Parental investment and sexual selection. In: Campbell B (ed). *Sexual Selection and the Descent of Man 1871–1971*. Chicago: Aldine, 1972, 136–179.

Trivers RL. *Social Evolution.* Menlo Park: Benjamin-Cummings, 1985.

Trivers RL, Willard DE. Natural selection of parental ability to vary the sex ratio of offspring. *Science* 1973;**179**:90–92.

Van der Broek JM. Change in male proportion among newborn infants. *Lancet* 1997;**349**:805.

Whalley LJ, Deary IJ. Longitudinal cohort study of childhood IQ and survival up to age 76. *Br Med J* 2001;**322**:819–823.

Zorn B, Sucur V, Stare J, Meden-Vrtovec H. Decline in sex ratio at birth after 10-day war in Slovenia. *Hum Reprod* 2002;**17**: 3173–3177.

*Submitted on April 6, 2007; resubmitted on June 22, 2007; accepted on June 26, 2007*