Association of Birth Order with Cardiovascular Disease Risk Factors in Young Adulthood: A Study of One Million Swedish Men

Aline Jelenkovic1,2,3*, Karri Silventoinen3,4, Per Tynelius5, Mikko Myrskylä6, Finn Rasmussen5

1 Department of Genetics, Physical Anthropology and Animal Physiology, University of the Basque Country Universidad del País Vasco/Euskal Herriko Unibertsitatea, Leioa, Spain, 2 IKERBASQUE, Basque Foundation for Science, Bilbao, Spain, 3 Department of Public Health, Hjelt Institute, University of Helsinki, Helsinki, Finland, 4 Population Research Unit, Department of Social Research, University of Helsinki, Helsinki, Finland, 5 Child and Adolescent Public Health Epidemiology, Department of Public Health Sciences, Karolinska Institutet, Stockholm, Sweden, 6 Max Planck Institute for Demographic Research, Rostock, Germany

Abstract

Background: Birth order has been suggested to be linked to several cardiovascular disease (CVD) risk factors, but the evidence is still inconsistent. We aim to determine the associations of birth order with body mass index (BMI), muscle strength and blood pressure. Further we will analyse whether these relationships are affected by family characteristics.

Methods: BMI, elbow flexion, hand grip and knee extension strength and systolic and diastolic blood pressure were measured at conscription examination in 1 065 710 Swedish young men born between 1951 and 1975. The data were analysed using linear multivariate and fixed effects regression models; the latter compare siblings and account for genetic and social factors shared by brothers.

Results: Fixed effect regression analysis showed that birth order was inversely associated with BMI: second and third born had 0.8% and 1.1% (p<0.001) lower BMI than first-born, respectively. The association pattern differed among muscle strengths. After adjustment for BMI, first-born presented lower elbow flexion and hand grip strength than second-born (−5.9 N and −3.8 N, respectively, p<0.001). Knee extension strength was inversely related to birth order though not always significantly. The association between birth order and blood pressure was not significant.

Conclusions: Birth order is negatively associated with BMI and knee extension strength, positively with elbow flexion and hand grip strength, and is not associated with blood pressure among young men. Although the effects are small, the link between birth order and some CVD risk factors is already detectable in young adulthood.

Citation: Jelenkovic A, Silventoinen K, Tynelius P, Myrskylä M, Rasmussen F (2013) Association of Birth Order with Cardiovascular Disease Risk Factors in Young Adulthood: A Study of One Million Swedish Men. PLoS ONE 8(5): e63361. doi:10.1371/journal.pone.0063361

Editor: Alejandro Lucia, Universidad Europea de Madrid, Spain

Received January 22, 2013; Accepted April 2, 2013; Published May 16, 2013

Copyright: © 2013 Jelenkovic et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Funding: This work was supported by a Postdoctoral fellowship from the Basque Governments Department of Education, Universities and Research. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

* E-mail: aline.jelenkovic@helsinki.fi

Introduction

Cardiovascular diseases (CVD) are the leading cause of mortality worldwide and thus a major public health problem [1]. Obesity and hypertension are among the most important risk factors for CVD [2–4]. Previous studies have also shown that skeletal muscle strength, which is highly related to muscle mass, is inversely associated with the incidence of CVD [5–9]. CVD risk factors may, in turn, be influenced by several modifiable and non-modifiable secondary risk factors. Non-modifiable risk factors can include, but are not limited to, age, sex, ethnicity and some life history characteristics such as birth order, family size and maternal age at birth.

Birth order has been shown to be associated with several CVD risk factors in childhood, adolescence and young adulthood [10–17]. The mechanisms underlying these associations are, however, unclear and seem to be largely affected by the social, cultural and biological context [18]. It has been suggested that the lower birth weight observed in first-born implies a tendency to infant catch-up growth [19], which has been in turn associated with adverse metabolic and cardiovascular profile [20–24]. However, although the most common finding across studies indicates that first-borns face more disadvantageous levels of CVD risk factors, the evidence is still inconsistent. Birth order was inversely related to BMI in young men [13] and women [12]; however, positive [25] and non-significant [14,26] relationships have also been reported. Increased adiposity has been associated with first-born status [11–13], but two recent studies detected that apart from the only children status, the last-born child presents an elevated risk of overweight and obesity in childhood [15,16]. The birth order effect on blood pressure has also shown divergent results, with non-significant [13], negative [10,14,17] and J-shaped associations [27]. Finally, despite the beneficial role of muscular fitness in the prevention of diseases [28], whether muscle strength is influenced by birth order has not been studied yet.
The decline of fertility rate during the recent decades is decreasing the family size and consequently increasing the proportion of first born status in many countries [29]. Although birth order cannot be altered, identification of its impact is relevant for developing prevention and treatment strategies toward individuals at high risk. Accordingly, the aims of the present study are a) to assess the association of birth order with BMI, muscle strength and blood pressure and b) to investigate whether these relationships are affected by family characteristics in a large population of young Swedish men.

Materials and Methods

Ethics Statement

This study has been approved by the Ethical Review Board, Stockholm, Sweden. According to the current regulations, the Ethical Review Board waived the need for informed consent from the participants because this is a large register-based study without need to contact the participants.

Data Collection

This longitudinal dataset was created by a record-linkage between the nationwide Swedish Military Service Conscription Register (MSCR), the Swedish Multi-Generation Register (MGR) and the Swedish Population and Housing Censuses (PHCs) using personal identification numbers. Conscription examination, which predates active military service, was mandatory in Sweden by law for all young male Swedish citizens in our study cohorts. Only males with severe handicap or a chronic disease were exempted from the conscription examination. In this study, we analysed cohorts born from 1951 to 1975 (conscription year 1969–1993). In the entire data set, we had conscription data available for 1 133 812 men. We excluded all multiple births (1.7% of the data). In addition, to keep the sample age-homogenous, men aged less than 17 or more than 20 years at conscription were excluded (18 027 men) since they represented only a small fraction of the whole study population (1.6%).

During the conscription examination, height, weight, elbow flexion, hand grip and knee extension strength, and diastolic (DBP) and systolic blood pressure (SBP) were measured according to a standardized protocol described elsewhere [30]. The measurement protocol of the muscle strength measures was not revealed to us by the Swedish Army. However, there were no systematic differences evident in the mean values of the measures between conscription offices, suggesting that a uniform protocol was used. The values of elbow flexion, hand grip and knee extension strength in these data were also close to values in a previous study of 31- to 35-year-old Swedish Army. However, there were no systematic differences of errors of misclassification, we excluded these men from further analyses. In addition, we had missing values for muscle strength in 3841 men. For blood pressure, the limits for accepted values were 84 to 100 mmHg for DBP and 120 to 180 mm Hg for SBP, with missing or invalid cases in 13641 men. In the final dataset, we had valid measures from all anthropometric and blood pressure traits on 1 065 710 men. Since BMI was not normally distributed, logarithmic transformation was applied. Information about conscription age and conscription centre was obtained from the MSCR. Based on continuous data in the MGR we created categorical variables for birth order (1, 2, ..., 6+) and number of children in the family (1, 2, ..., 6+). Biological sisters were also taken into account for the calculation of birth order and family size. Information on parental education and occupational socioeconomic position (SEP) was derived from the PHCs conducted in 1960, 1970, 1980 and 1990 as described in detail elsewhere [32].

Statistical Analyses

To study the association between birth order and CVD risk factors, linear regression analyses adjusted for different covariates were performed. Since BMI was log-transformed, the estimated regression coefficients for this variable can be interpreted as percentage changes (logBMI*100 = % change). Model 1 adjusted for birth year, conscription age and centre. Model 2 added controls for maternal age and parental SEP and education. We continued to analyse within family associations by using fixed effects regression models (Model 3 and 4). These models compare brothers born to the same mother and remove the confounding influences of all fixed observed and unobserved genetic and social characteristics shared by the brothers [33]. Importantly, the fixed effects approach does not remove the potential confounding influence on non-shared factors. Model 5 was adjusted for the same covariates as those included in Model 1, and in Model 4 only maternal age was added, because fixed effects already controls for parental SEP and education. Moreover, since body size is a well-recognized factor that affects muscle strength [34], CVD risk factors were additionally adjusted for height (Model 5) and BMI (Model 6). This adjustment takes into account the effect of body size or mass, and thus allows to analyse the body size/mass-independent association between birth order and CVD risk factors. Confidence intervals and p-values were adjusted for clustering of brothers within families and were estimated using Stata/IC 12.0 (StataCorp, College Station, Texas, USA).

Results

Characteristics of the Participants

The characteristics of the sample are reported separately by birth order in Table 1. Some trends were detected across birth cohorts, in such a way that in more recent ones average number of children in the family was lower, there was a greater proportion of high parental SEP and education, and individuals were taller and heavier (results not shown). In Table 1 we summarize the mean values for all men, according to their birth order, as an average for all birth years. Mean age at conscription (18.3 years) did not differ among birth order groups, and as expected, average maternal age increased with birth order, from 24.4 years (1st born) to 36.6 years (6th born). Higher birth order was associated with older cohorts, larger families and lower proportion of high parental SEP (non-manual workers at higher and middle level) and education (more than 13 years). Regarding anthropometric and blood pressure traits, from birth order 1 to 6+ height and weight showed an average decrease of 1.7 cm and 1.4 kg respectively, whereas BMI remained stable. For all three muscle strength measures, second born presented the greatest mean values. For elbow flexion and hand grip strength, no defined pattern was observed. For knee extension strength, average value decreased monotonically with birth order (570.7 N to 540.3 N for 2nd and 6th born respectively). The trends for SBP and DBP differed: whereas SBP showed
Table 1. Subjects characteristics according to birth order.

|                         | All orders Mean (SD) | 1st born Mean (SD) | 2nd born Mean (SD) | 3rd born Mean (SD) | 4th born Mean (SD) | 5th born Mean (SD) | 6th born Mean (SD) |
|-------------------------|----------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| **Socio-demographic**   |                      |                    |                    |                    |                    |                    |                    |
| Conscription age (years)| 18.3 (0.5)           | 18.3 (0.5)         | 18.3 (0.5)         | 18.3 (0.6)         | 18.3 (0.5)         | 18.3 (0.5)         | 18.3 (0.5)         |
| Birth year              | 1963.0 (7.3)         | 1963.3 (7.3)       | 1963.3 (7.3)       | 1962.5 (7.2)       | 1961.5 (6.89)      | 1960.7 (6.65)      | 1959.9 (6.45)      |
| Family size (number of children) | 2.6 (1.2)     | 2.2 (0.9)         | 2.5 (0.8)          | 3.3 (0.9)          | 4.1 (1.0)          | 5.0 (1.0)          | 5.7 (0.9)          |
| Maternal age (years)    | 27.3 (5.73)          | 24.4 (4.81)        | 27.7 (4.8)         | 30.6 (5.0)         | 32.9 (5.08)        | 34.5 (4.7)         | 36.6 (4.69)        |
| High SEP (%) fathers/mothers | 32.1/18.6    | 35.0/22.1         | 33.9/21.9          | 28.6/14.6          | 20.9/9.4           | 14.3/5.6           | 8.6/3.0            |
| High education (%) fathers/mothers | 14.7/14.6  | 16.7/17.5         | 15.2/14.7          | 12.9/11.4          | 9.0/7.1            | 5.1/3.9            | 2.3/1.8            |
| **Anthropometrics and blood pressure** |             |                    |                    |                    |                    |                    |                    |
| Height (cm)             | 179.2 (6.5)          | 179.4 (6.5)        | 179.3 (6.5)        | 179.0 (6.5)        | 178.5 (6.55)       | 178.1 (6.4)        | 177.5 (6.5)        |
| Weight (kg)             | 69.5 (10.3)          | 69.7 (10.2)        | 69.5 (10.1)        | 69.3 (10.4)        | 69.1 (10.7)        | 68.6 (10.8)        | 68.1 (10.6)        |
| BMI (kg/m²)             | 21.62 (2.81)         | 21.65 (2.81)       | 21.59 (2.76)       | 21.62 (2.85)       | 21.64 (2.93)       | 21.59 (2.99)       | 21.59 (2.98)       |
| Elbow flexion strength (N) | 387.4 (84.3)     | 385.1 (84.1)       | 389.3 (84.4)       | 388.7 (84.4)       | 388.9 (84.8)       | 387.8 (84.3)       | 388.6 (83.4)       |
| Hand grip strength (N)  | 616.3 (97.7)         | 614.4 (97.8)       | 618.4 (97.1)       | 617.2 (98.0)       | 616.3 (97.7)       | 617.2 (98.0)       | 615.7 (99.1)       |
| Knee extension strength (N) | 567.3 (117.3)    | 569.0 (117.6)      | 570.7 (117.2)      | 564.1 (117.1)      | 556.1 (116.2)      | 548.4 (114.4)      | 540.3 (112.7)      |
| SBP (mmHg)              | 128.4 (10.8)         | 128.6 (10.9)       | 128.4 (10.8)       | 128.3 (10.8)       | 128.3 (10.9)       | 128.3 (10.7)       | 128.6 (11.0)       |
| DBP (mmHg)              | 67.4 (10.0)          | 67.4 (10.0)        | 67.3 (9.9)         | 67.5 (9.9)         | 67.8 (9.9)         | 68.0 (10.0)        | 68.5 (10.0)        |
| N of observations       | 1 065 710            | 450 151            | 364 761            | 156 753            | 56 332             | 21 220             | 16 943             |

Mean values and (standard deviations).
BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; SD, standard deviation.
doi:10.1371/journal.pone.0063361.t001
the greatest mean values for birth order 1 and 6+, DBP increased monotonically from the second born.

**Regression Analysis**

Table 2 shows the linear regression analyses assessing the birth order effect on CVD risk factors. Model 1 presents the results adjusted for conception age, birth year and conscription centre. Adjustment for maternal age and parental social factors (Model 2) increased the magnitude of the regression estimates, with highly significant associations for all outcomes (except for knee extension at birth order 3). Birth order showed inverse associations with BMI, knee extension strength and blood pressure, and positive associations with elbow flexion and hand grip strength.

Comparisons between fixed effects regression estimates in Table 3 (Model 4) with conventional linear regression estimates in Table 2 (Model 2) show substantial changes for most outcomes. In fixed effects models the associations are stronger for BMI and weaker for elbow flexion and SBP. Since fixed effects regression model reveals the confounding influences of all fixed observed and unobserved genetic and social characteristics shared by the brothers including family size, we are now focusing mainly on Models 4, 5 and 6.

Second and third born young men had 0.8% and 1.1% (p<0.001) lower BMI compared with first-born men (Model 4 and 5), but differences became weaker with higher birth order. Elbow flexion strength showed a significant association only after adjustment for height (p<0.05, Model 5) or BMI (p<0.001, Model 6), that is, once the effect of body size and mass were taken into account. The second born presented 2.20 N and 3.83 N more elbow flexion strength (after controlling for height and BMI, respectively) than the first-born. For hand grip strength, second-born were respectively 0.36*** (6.25 N and 5.92 N adjusted for height and BMI, respectively) than the first-born. Since fixed effects regression models showed that all associations were non-significant, it must be noted, however, that even if non-significant, the results were very similar before and after adjustment for birth weight (results not shown).

**Discussion**

During the last decades, major changes in population demography and family structure have occurred as consequence of the social and economic transition [35]. In this population-based cohort of more than one million young men, detailed information is presented on the association of birth order with several CVD risk factors, some of which have not been reported before. Our results revealed that in young adulthood, birth order effect is small on BMI and muscle strength, and non-apparent on blood pressure. First-borns seem to face more disadvantageous conditions of BMI, elbow flexion and hand grip strength, but more favourable level of knee extension strength.

The negative relationship detected between birth order and BMI in this population is in agreement with other studies carried out in young men of southern Brazil [13] and in young Bengali females [12]; however, positive [25] and non-significant [14,26] associations were non-significant. It must be noted, however, that even if non-significant, the results were very similar before and after adjustment for birth weight (results not shown).

---

**Table 2. Regression coefficients for the effect of birth order on CVD risk factors with first-born as reference category.**

|                      | logBMI*100 | Elbow flexion strength | Hand grip strength | Knee extension strength | SBP | DBP |
|----------------------|------------|------------------------|--------------------|------------------------|-----|-----|
|                      | B         | CI                     | B                  | CI                     | B   | CI  |
| Model 1              |           |                        |                    |                        |     |     |
| 2nd born             | -0.30***  | -0.35, -0.25 4.15***   | 3.80,450           | 4.00***                | 3.60,441 | 1.62*** | 1.14,2.10 | -0.15*** | -0.19, -0.10 | -0.09*** | -0.13, -0.05 |
| 3rd born             | -0.05     | -0.12,0.01 4.81***    | 4.34,28           | 3.10***                | 2.55,365 | -1.70*** | -2.42, -1.13 | -0.25*** | -0.31, -0.19 | -0.14*** | -0.19, -0.09 |
| 4th born             | 0.22**    | 0.11,0.33 6.73***     | 6.00,746          | 2.48***                | 1.63,333 | -5.23*** | -6.21, -4.24 | -0.20*** | -0.29, -0.10 | -0.13*** | -0.21, -0.05 |
| 5th born             | 0.09      | -0.09,0.26 6.55***    | 5.40,70           | 3.09***                | 1.75,443 | -9.68*** | -11.21, -8.14 | -0.11    | -0.26,0.04   | 0.16**  | -0.28, -0.03 |
| 6th born             | 0.22*     | 0.01,0.43 7.90***     | 6.55,24           | 2.38**                 | 0.76,401 | -14.78*** | -16.59, -12.98 | 0.12     | -0.06,0.30   | 0.06    | -0.09,0.21   |
|                      |           |                        |                    |                        |     |     |
| Model 2              |           |                        |                    |                        |     |     |
| 2nd born             | -0.39***  | -0.44, -0.34 6.54***   | 6.17,692          | 6.02***                | 5.58,645 | 3.00*** | 2.49,351   | -0.52*** | -0.57, -0.48 | -0.31*** | -0.35, -0.27 |
| 3rd born             | -0.36***  | -0.43, -0.28 8.49***   | 7.97,91          | 6.49***                | 5.88,710 | 1.30*** | 0.58,201    | -0.95*** | -1.02, -0.89 | -0.54*** | -0.60, -0.48 |
| 4th born             | -0.32**   | -0.44, -0.20 10.81***  | 10.02,11.61      | 6.59***                | 5.67,752 | -0.40   | -1.47,677   | -1.14*** | -1.24, -1.04 | -0.68*** | -0.77, -0.59 |
| 5th born             | -0.61***  | -0.82, -0.45 10.68***  | 9.47,11.88      | 7.60***                | 6.19,902 | -3.45*** | -5.06, -1.83 | -1.21*** | -1.37, -1.06 | -0.83*** | -0.96, -0.69 |
| 6th born             | -0.60***  | -0.82, -0.37 12.43***  | 11.01,13.86     | 7.74***                | 6.02,947 | -7.03*** | -8.95, -5.11 | -1.13*** | -1.32, -0.95 | -0.74*** | -0.90, -0.58 |

B: Unstandardized regression coefficient; BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; CI, 95% confidence interval. 

*P<0.05; **P<0.01; ***P<0.001.

Model 1: Adjusted for birth year, conscription age and conscription centre.

Model 2: Additionally adjusted for maternal age, fathers and mothers social position and education.

doi:10.1371/journal.pone.0063361.t002
associations have also been reported. Accordingly, first-born status has been related to elevated adiposity [11–13], and lower birth order showed to enhance the positive association between socioeconomic status and central adiposity in young adult Filipino males [36]. In these Swedish cohorts the greatest decrease was observed between birth order 1 and 2, and then BMI differences decreased by higher birth order. That is, first-born had 0.8% higher BMI than the second born and 1.2% higher than the fifth born. This indicates that although the effect is modest, the most disadvantageous position is the first-born. Our findings are in agreement with the tendency to post-natal catch-up growth observed in some first-born [19], which in turn has been associated with increased risk of obesity and higher adiposity in later life [20–23]. In the literature, although there is a trend towards disadvantageous conditions for firstborns, whether only child and firstborn status are differentially influenced remains largely unknown. In the present study, the exclusion of families with only one child from the analyses showed slightly weaker associations between birth order and BMI; however, Siervo et al. [13] detected that the exclusion magnified the effect. Celi et al. [37] observed no difference between being an only child or first-born in schoolchildren from Italy, and concluded that the status of firstborn is the aspect that proved to affect overweight or obesity. In contrast, two recent studies found that apart from the only child status, the last-born child presents an increased risk of overweight and obesity in Japanese and Danish schoolchildren [15,16].

Muscle strength is an indicator of physical fitness, which is considered as one of the most important health markers nowadays [9,38]. Skeletal muscle strength has been inversely associated with the incidence of CVD [5–9] and with increased risk of obesity, metabolic syndrome and all-cause and CVD mortality [9,39,40]. The role of muscular fitness in the prevention of diseases has become increasingly recognized [28]. However, to our knowledge, no study has analysed the influence of birth order on muscle strength. Although some studies carried out in this [41] and other populations [42–44] have shown that different muscle strengths are correlated among them, the present work suggests that birth order is differently associated with the three measures of muscle strength. The elbow flexion test showed unfavourable results for first-born young men with 3.83 N lower strength (body mass-
allowed us to detect the within families variation with adequate power. In addition, this is the first study to investigate the long-
term consequences of birth order on muscle strength. Since
military conscription was mandatory during the study period,
participation bias due to selection does not exist. But our study also
has some limitations. First, our sample included only men and thus
our results cannot be directly generalized to women. Second, the
analysed sample was collected in young adulthood. This fact could
be one of the reasons for the relatively small or non-significant
birth order effect observed in this population, because more
disadvantageous CVD risk factors levels tend to be observed in
later life. Third, although military conscription was mandatory
during the study period, disability or a severe chronic disease was a
valid reason to be exempted, thus our cohort represents mainly
healthy Swedish men at baseline. And finally, it should be
mentioned that in the present study the association are significant
because of a very large sample size, that is, in smaller samples
some of the differences would not become statistically significant.

To summarize, the birth order effect on the analysed CVD risk
factors in young adulthood is in general small and dependent on
family characteristics. Birth order influence may vary in strength
over time and place, but due to the unprecedented large
population based dataset and that observed and unobserved
characteristics shared by brothers were accounted for by fixed
effect regression models, it is unlikely that birth order can have a
substantially greater influence, at least in similar populations. Our
findings indicate that birth order is inversely associated with BMI
and knee extension, positively with elbow flexion and hand grip
strength, and not associated with blood pressure. Since these
associations may increase through adulthood, the birth order
impact on CVD risk factors has public health implications because
it can be used to target prevention and treatment strategies toward
individuals at high risk. Finally, linking CVD risk factors with birth
order suggests that part of the disadvantageous conditions
observed in the populations could be attributed to the worldwide
trend to smaller families and higher proportion of first-borns.

Supporting Information

Table S1 Fixed effects regression coefficients for the
effect of birth order on CVD risk factors – families with
only one child excluded.

(DOCX)

Author Contributions

Conceived and designed the experiments: AJ KS MM FR. Analyzed the
data: AJ. Contributed reagents/materials/analysis tools: KS PT MM FR.
Wrote the paper: AJ. Reviewing and editing of the text: AJ KS PT MM FR.

References

1. World Health Organization (WHO). Cardiovascular diseases (CVDs). Available at: http://www.who.int/mediacentre/factsheets/fs317/en/index.html. Accessed 2012 October.
2. Mancia G (2007) Blood pressure reduction and cardiovascular outcomes: past, present, and future. Am J Cardiol 100: 3F–9F.
3. Melanson KJ, McInnis KJ, Rippe JM, Blackburn G, Wilson PF (2001) Obesity and cardiovascular disease risk: research update. Cardiol Rev 9: 202–207.
4. Khot UN, Khot MB, Bajzer CT, Sapp SK, Ohlman EM, et al. (2003) Prevalence of conventional risk factors in patients with coronary heart disease. JAMA 290: 898-904.
5. Silventoinen K, Magnusson PK, Tynelius P, Batty GD, Rasmussen F (2009) Association of body size and muscle strength with incidence of coronary heart disease and cerebrovascular diseases: a population-based cohort study of one million Swedish men. Int J Epidemiol 38: 110–118.
6. Saaki H, Kasagi F, Yamada M, Fujita S (2007) Grip strength predicts cause-specific mortality in middle-aged and elderly persons. Am J Med 120: 337–342.
7. Rantanen T, Volpato S, Ferrucci L, Heikkinen E, Fried LP, et al. (2003) Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. J Am Geriatr Soc 51: 636–641.
8. Gale CR, Martyn CN, Cooper C, Sayer AA (2007) Grip strength, body composition, and mortality. Int J Epidemiol 36: 220–233.
9. Ortega FR, Silventoinen K, Tynelius P, Rasmussen F (2012) Muscular strength in male adolescents and premature death: cohort study of one million participants. BMJ 345: e7279.
10. Whincup PH, Cook DG, Shaper AG (1989) Early influences on blood pressure: a study of children aged 5–7 years. BMJ 299: 507–509.
Birth Order and Cardiovascular Risk Factors

11. Steffler N, Tershakovec AM, Zemel BS, Leonard MB, Boston RC, et al. (2000) Early risk factors for increased adiposity: a cohort study of African American subjects followed from birth to young adulthood. Am J Clin Nutr 72: 578–383.

12. Ghosh JR, Bandyopadhyay AR (2006) Income, birth order, siblings, and anthropometry. Hum Biol 78: 733–741.

13. Stierwalt M, Horta BL, Stephan BC, Victora CG, Wells JC (2010) First-born carry a higher metabolic risk in early adulthood: evidence from a prospective cohort study. PLoS One 5: e13967.

14. Wells JC, Hallal PC, Reichert FF, Dumith SC, Menezes AM, et al. (2011) Associations of birth order with early childhood growth and adolescent height, body composition, and blood pressure: prospective birth cohort from Brazil. Am J Epidemiol 174: 1028–1035.

15. Ochiai H, Shirasawa T, Ohnuki T, Nishimura R, Morimoto A, et al. (2012) Number of siblings, birth order, and childhood overweight: a population-based cross-sectional study in Japan. BMC Public Health 12: 766.

16. Haugaaard LK, Ajslev TA, Zimmermann E, Angquist L, Sorensen TI (2013) Timing and number of siblings, breastfeeding and childhood overweight: findings from the Mater-University study of pregnancy and early childhood growth in relation to maternal smoking, parity and infant breast-feeding: longitudinal birth cohort study and analysis. Pediatr Res 52: 863–867.

17. Monteiro PO, Victora CG (2005) Rapid growth in infancy and childhood and obesity in later life—a systematic review. Obes Rev 6: 143–154.

18. Leunissen RW, Kerkhof GF, Stijnen T, Hokken-Koelega AC (2009) Heritability of body size and muscle strength in young adulthood: a study of one million Swedish men. Genet Epidemiol 32: 341–349.

19. Taimen K, Sipila S, Alen M, Heikkinen E, Kaprio J, et al. (2003) Shared genetic and environmental effects on strength and power in older female twins. Med Sci Sports Exerc 35: 272–279.

20. Matsumoto K, Magnusson PK, Tynelius P, Kaprio J, Rasmussen F (2008) Heritability of body size and muscle strength in young adulthood: a study of one million Swedish men. Genet Epidemiol 32: 341–349.

21. Siervo M, Horta BL, Stepniak K, Juonala M, Tynelius P, et al. (2010) Birth order and cardiovascular risk factors in adulthood: a population-based cohort study of 602,361 Swedish men. Eur J Cardiovasc Prev Rehabil 14: 555–560.

22. Power C, Li L, Manor O, Davey Smith G (2003) Combination of low birth weight and childhood blood pressure at age 31–35, 51–55 and 71–75 years. Ergonomics 28: 1563–1574.

23. Lawlor DA, Najman JM, Sterne J, Williams GM, Ebrahim S, et al. (2004) Associations of parental, birth, and early life characteristics with systolic blood pressure at age 5 years: findings from the Mater-University study of pregnancy and its outcomes. Circulation 110: 2417–2423.

24. Wijndaele K, Duvigneaud N, Matton L, Duquet W, Thoms J, et al. (2007) Muscular strength, aerobic fitness, and metabolic syndrome risk in Flemish adults. Med Sci Sports Exerc 39: 233–240.

25. Mooren M, Bousquet MJ, van Leeuwen K, Stolk R, Kaprio J, et al. (2000) Prediction of childhood obesity by infancy weight gain: an individual-level meta-analysis. Paediatr Perinat Epidemiol 16: 19–26.

26. Jarvelin MR, Sevio U, King V, Laurin L, Xu B, et al. (2004) Early life factors and blood pressure at age 31 years in the 1966 northern Finland birth cohort. Hypertension 44: 838–846.

27. Fredrick AM, van Buuren S, Wit JM, Verloove-Vanhorick SP (2000) Body index measurements in 1996–7 compared with 1980. Arch Dis Child 82: 107–112.

28. Power C, Li L, Manor O, Davey Smith G (2003) Combination of low birth weight and high adult body mass index: at what age is it established and what are its determinants? J Epidemiol Community Health 57: 969–973.

29. Lawlor DA, Najman JM, Sterne J, Williams GM, Ebrahim S, et al. (2004) Associations of parental, birth, and early life characteristics with systolic blood pressure at age 5 years: findings from the Mater-University study of pregnancy and its outcomes. Circulation 110: 2417–2423.

30. Wolfler RK (2006) The underappreciated role of muscle in health and disease. Am J Clin Nutr 84: 475–482.

31. Ezeh AC, Bongaarts J, Mberu B (2012) Global population trends and policy options. Lancet 380: 142–148.

32. Silveira DM, Etz P, Leskinen AL, Heikkilä E (2005) Muscular strength profiles and anthropometry in random samples of men aged 31–35, 51–55 and 71–75 years. Ergonomics 28: 1563–1574.

33. Grijalva-Eternod CS, Lawlor DA, Wells JC (2013) Testing a capacity-load options. Lancet 380: e56357.