**Twin’s birth-order differences in height and body mass index from birth to old age: a pooled study of 26 twin cohorts participated in the CODATwins project**

Yoshie Yokoyama (1), Aline Jelenkovic (2) (3), Reijo Sund (2), Joohon Sung (4) (5), John L Hopper (6) (4), Syuichi Ooki (7), Kauko Heikkilä (8), Sari Aaltonen (2) (8), Adam D Tarnoki (9) (10), David L Tarnoki (9) (10), Gonneke Willemsen (11), Meike Bartels (11), Toos CEM van Beijsterveldt (11), Kimberly J Saudino (12), Tessa L Cutler (6), Tracy L Nelson (13), Keith E Whitfield (14), Jane Wardle† (15), Clare H Llewellyn (15), Abigail Fisher (15), Mingguang He (16) (17), Xiaohu Ding (16), Morten Bjerregaard-Andersen (18) (19) (20), Henning Beck-Nielsen (20), Morten Sodemann (21), Yun-Mi Song (22), Sarah Yang (4) (5), Kayoung Lee (23), Hoe-Uk Jeong (24), Ariel Knafo-Noam (25), David Mankuta (26), Lior Abramson (25), S Alexandra Burt (27), Kelly L Klump (27), Juan R Ordoñana (28) (29), Juan F Sánchez-Romera (30) (29), Lucia Colodro-Conde (28) (31), Jennifer R Harris (32), Ingunn Brandt (32), Thomas Sevenius Nilsen (32), Jeffrey M Craig (33) (34), Richard Saffery (33) (34), Fuling Ji (35), Feng Ning (35), Zengchang Pang (35), Lise Dubois (36), Michel Boivin (37) (38), Mara Brendgen (39), Ginette Dionne (37), Frank Vitaro (40), Nicholas G Martin (41), Sarah E Medland (41), Grant W Montgomery (42), Patrik KE Magnusson (43), Nancy L Pedersen (43), Anna K Dahl Aslan (43) (44), Per Tynelius (45), Claire MA Haworth (46), Robert Plomin (47), Esther Rebato (3), Richard J Rose (48), Jack H Goldberg (49), Finn Rasmussen (45), Yoon-Mi Hur (50), Thorkild IA Sørensen (51) (46) (52), Dorret I Boomsma (11), Jaakko Kaprio (8) (53) (54), Karri Silventoinen (2) (55)

1. Department of Public Health Nursing, Osaka City University, Osaka, Japan.

2. Department of Social Research, University of Helsinki, Helsinki, Finland.

3. Department of Genetics, Physical Anthropology and Animal Physiology, University of the Basque Country UPV/EHU, Leioa, Spain.

4. Department of Epidemiology, School of Public Health, Seoul National University, Seoul, Korea.

5. Institute of Health and Environment, Seoul National University, Seoul, South-Korea.

6. The Australian Twin Registry, Centre for Epidemiology and Biostatistics, The University of Melbourne, Melbourne, Victoria, Australia.

7. Department of Health Science, Ishikawa Prefectural Nursing University, Kahoku, Ishikawa, Japan.

8. Department of Public Health, University of Helsinki, Helsinki, Finland.

9. Department of Radiology and Oncotherapy, Semmelweis University, Budapest, Hungary.

10. Hungarian Twin Registry, Budapest, Hungary.

11. Department of Biological Psychology, VU University Amsterdam, Amsterdam, Netherlands.

12. Boston University, Department of Psychological and Brain Sciencies, Boston, MA, USA.

13. Department of Health and Exercise Sciencies and Colorado School of Public Health, Colorado State University, USA.

14. Psychology and Neuroscience, Duke University, Durham, NC, USA.

15. Health Behaviour Research Centre, Department of Epidemiology and Public Health, Institute of Epidemiology and Health Care, University College London, London, UK.

16. State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou, China.

17. Centre for Eye Research Australia, University of Melbourne, Melbourne, Australia.

18. Bandim Health Project, INDEPTH Network, Bissau, Guinea-Bissau.

19. Research Center for Vitamins and Vaccines, Statens Serum Institute, Copenhagen, Denmark.

20. Department of Endocrinology, Odense University Hospital, Odense, Denmark.

21. Department of Infectious Diseases, Odense University Hospital, Odense, Denmark.

22. Department of Family Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, South-Korea.

23. Department of Family Medicine, Busan Paik Hospital, Inje University College of Medicine, Busan, Korea.

24. Department of Education, Mokpo National University, Jeonnam, South Korea.

25. The Hebrew University of Jerusalem, Jerusalem, Israel.

26. Hadassah Hospital Obstetrics and Gynecology Department, Hebrew University Medical School, Jerusalem, Israel.

27. Michigan State University, East Lansing, Michigan, USA.

28. Department of Human Anatomy and Psychobiology, University of Murcia, Murcia, Spain.

29. IMIB-Arrixaca, Murcia, Spain.

30. Department of Developmental and Educational Psychology, University of Murcia, Murcia, Spain.

31. QIMR Berghofer Medical Research Institute, Brisbane, Australia.

32. Norwegian Institute of Public Health, Oslo, Norway.

33. Murdoch Childrens Research Institute, Royal Children's Hospital, Parkville, Victoria, Australia .

34. Department of Paediatrics, University of Melbourne, Parkville, Victoria, Australia.

35. Department of Noncommunicable Diseases Prevention, Qingdao Centers for Disease Control and Prevention, Qingdao, China.

36. School of Epidemiology, Public Health and Preventive Medicine, University of Ottawa, Ottawa, Ontario, Canada.

37. École de psychologie, Université Laval, Québec, Canada.

38. Institute of Genetic, Neurobiological, and Social Foundations of Child Development, Tomsk State University, Russian Federation.

39. Département de psychologie, Université du Québec à Montréal, Montréal, Québec, Canada.

40. École de psychoéducation, Université de Montréal, Montréal, Québec, Canada.

41. Genetic Epidemiology Department, QIMR Berghofer Medical Research Institute, Brisbane, Australia.

42. Molecular Epidemiology Department, QIMR Berghofer Medical Research Institute, Brisbane, Australia.

43. Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden.

44. Institute of Gerontology, School of Health Sciences, Jönköping University, Jönköping, Sweden.

45. Department of Public Health Sciences, Karolinska Institutet, Stockholm, Sweden.

46. MRC Integrative Epidemiology Unit, University of Bristol, Bristol, U.K.

47. King's College London, MRC Social, Genetic & Developmental Psychiatry Centre, Institute of Psychiatry, Psychology & Neuroscience, London, UK.

48. Indiana University Bloomington, Bloomington, IN, USA.

49. Department of Epidemiology, School of Public Health, University of Washington, Seattle, WA, USA .

50. Department of Education, Mokpo National University, Jeonnam, South Korea.

51. Institute of Preventive Medicine, Bispebjerg and Frederiksberg Hospitals, Copenhagen, The Capital Region, Denmark.

52. Novo Nordisk Foundation Centre for Basic Metabolic Research (Section on Metabolic Genetics), and Department of Public Health, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark.

53. National Institute for Health and Welfare, Helsinki, Finland.

54. Institute for Molecular Medicine FIMM, Helsinki, Finland.

55. Osaka University Graduate School of Medicine, Osaka University, Osaka, Japan.

† deceased

Abstract

We analyzed birth order differences in means and variances of height and body mass index (BMI) in monozygotic (MZ) and dizygotic (DZ) twins from infancy to old age. The data were derived from the international CODATwins database. The total number of height and BMI measures from 0.5 to 79.5 years of age was 397,466. As expected, first-born twins had greater birth weight than second-born twins. With respect to height, first-born twins were slightly taller than second-born twins in childhood. After adjusting the results for birth weight, the birth order differences decreased and were not statistically significant anymore. First-born twins had greater BMI than the second-born twins over childhood and adolescence. After adjusting the results for birth weight, birth order was still associated with BMI until 12 years of age. No interaction effect between birth order and zygosity was found. Only limited evidence was found that birth order influenced variances of height or BMI. The results were similar among boys and girls and also in MZ and DZ twins. Overall, the differences in height and BMI between first and second born twins were modest even in early childhood, while adjustment for birth weight reduced the birth order differences but did not remove them for BMI.

Key words: birth order, BMI, height, zygosity

It is well known that growth patterns of twins during the third trimester of pregnancy differ from those of singletons. In addition to having two fetuses in *utero*, there are twin-specific factors, such as birth order (Glinianaia et al., 2000; Gielen, et al., 2007), zygosity (Loos,et al., 2005; Daw, et al., 1975; Buckler & Green, 2008) and chorionicity (Gruenwald, 1970; Ananth, et al., 1998; Naeye, et al., 1966; Bleker, et al., 1979; Gielen M, et al., 2009; van Beijsterveldt et al. 2015), which are associated with intrauterine twin growth. Previous studies of twins have reported that the second-born twin is, on average, lighter than the first-born twin at birth (Glinianaia et al., 2000; Gielen, et al., 2007; van Baal and Boomsma, 1998). The factors determining birth order have a greater influence on birth weight than zygosity or chorionicity (Gielen, et al., 2007; Sheay, et al., 2004).

The lower birth weight for second-born twins could be due to the fact that first-born twins have higher placental weights and have more often a central insertion of the umbilical cord, which are both positively correlated with birth weight. Possibly, first-born twins are also more optimally positioned with respect to nutrients intake (Gielen et al., 2006; Heinonen, et al, 1996). In addition, previous studies have shown that first-born twins are, on average, taller and heavier than second-born twins until adolescence (Silventoinen et al., 2007; Pietiläinen et al., 2002). Second-born twins have also higher morbidity and mortality (Armson, et al., 2006; Smith, et al., 2007; Shinwell et al., 2004; Luo, et al., 2014).

The persistence of the birth-order association suggests that prenatal factors can have long-lasting effects on body size. However, it is not known how these associations may change over the life course. Studies on age-dependent birth order differences in height and body mass index (BMI) are scarce, and small sample sizes make comparisons of the existing results difficult. Further, it is not known whether the factors behind birth order differences in height and BMI also induce variance differences. In this study, we aim to analyze birth-order differences in means and variances of height and BMI among MZ and DZ twins from infancy to old age and to test whether they can be explained by differences in birth weight. The data were derived from the large international CODATwins database, which was intended to collect together height and weight measurements from all twin cohorts in the world.

**Data and methods**

In the CODATwins database (Silventoinen, et al., 2015), there are 960,859 height and weight measures from twins at ages ranging from 0.5 to 103 years. Information on birth order, height and weight measures were self-reported (67%), parentally reported (19%), or based on measures by nurses and clinicians (14%). In this study, we included the following cohorts with information on birth order: Australian Twin Registry, Boston University Twin Project, Carolina African American Twin Study of Aging, FinnTwin12, FinnTwin16, Gemini Study, Guangzhou Twin Eye Study, Guinea-Bissau Twin Study, Hungarian Twin Registry, Japanese Twin Cohort, Korean Twin-Family Register, Longitudinal Israeli Study of Twins, Michigan Twins Study, Murcia Twin Registry, Norwegian Twin Registry, Peri/Postnatal Epigenetic Twins Study, Qingdao Twin Registry of Children, Quebec Newborn Twin Study, Queensland Twin Register, Swedish Young Male Twins Study of Adults, Swedish Young Male Twins Study of Children, South Korea Twin Registry, Swedish Twin Cohorts, Twins Early Developmental Study, West Japan Twins and Higher Order Multiple Births Registry and Young Netherlands Twin Registry. Height and weight measurement protocols, sample frames and other basic information of these cohorts have been described elsewhere (Silventoinen, et al., 2015). Age was classified to 1-year age groups from age 1 to 19 years (e.g., age 1 refers to 0.5–1.5 years range), and 10-year age groups from age 20 to 79 years (e.g., 20–29, . . . , and age 70–79 years). Since the number of twin participants at 80 years of age or older was small, this group was excluded from the analyses.

In total, we had 429,587 height and BMI measurements at ages 0.5-79.5 years with information on birth order. Additionally we had information on birth weight from 107,782 and birth length from 54,941 twin individuals. BMI was calculated as weight (kg)/square of height (m2). Outliers were checked by visual inspection of histograms for each age and sex group. They were removed to obtain an approximately normal distribution of height, whereas the distribution of BMI was allowed to be positively skewed. The number of observations removed (n=1134) represented less than 0.3% of the whole database. We also excluded extreme birth length (<25cm or >65 cm) or birth weight (<500g or >6000g) values. For the purpose of this study, we restricted the analyses to one observation per individual in each age group. The total number of height and BMI measures in this study was 397,466; in 307,606 of these cases we had information also on birth weight.

Equality of mean values between first- and second- born twins by zygosity, age group and sex was tested using fixed effects regression analysis corrected for clustering of twin pairs. Equality of variances was tested using the Levene’s clustered test based on the 10% trimmed mean (Iachine et al. 2010). This clustered version of the Levene’s test is robust under the non-normality of outcomes. The interaction effects between zygosity and birth order were tested using Bonferroni correction of multiple testing with alpha level 0.0005 (0.05/100 tests). Percentage difference (%) between first- and second-born twins in mean values [(first born mean-second born mean) / second born mean] \* 100 and standard deviations (SD) [(first born SD-second born SD) / second born SD] \* 100 of height and BMI were calculated by sex. We also tested how the adjustment for birth weight affected the birth order difference on height and BMI in the cohorts having this information available using the fixed effects multiple regression model in each age groups. Statistical analyses were conducted using the Stata statistical software package (version 12.0; StataCorp, College Station, Texas, USA).

The pooled analysis was approved by the ethical board of the Department of Public Health, University of Helsinki. The data collections procedures of participating twin cohorts were approved by local ethical boards following the regulation in each country. Only anonymized data were delivered to the data management center at University of Helsinki.

**Results**

Table 1 provides the mean birth length and birth weight according to birth order, sex and zygosity. In MZ twins, the first-born male twins had greater length than the second-born male twins. However, in DZ twins, average birth length was not significantly different between the first-born and the second-born twins. In MZ and DZ twins, the first-born twins had greater birth weight than the second-born twins. The SDs of birth weight in the first-born and the second-born twins in MZ and DZ twins were significantly different except in MZ boys.

Descriptive statistics by birth order, age, and sex in MZ and DZ twins are presented in Table 2 and 3 for height, respectively. Sample size for each birth order, age, and sex group ranged between 421 and 5,407 individuals from age 1 through 19 years, and between 117 and 4,398 individuals in adulthood (≥20 years). The 6 and ≥70-year age groups in MZ twins had the smallest sample sizes. In MZ twins, significantly taller height in the first-born than in the second-born twins were observed at the age of one, three, five, eight and 10 years in men and from the age of one to three, seven and 12 years in women (Table 2). However, in DZ twins, average height was not significantly different between the first-born and the second-born twins (Table 3). The SDs of height in the first-born and the second-born twins in MZ and DZ twin were not significantly different in the majority of age groups. Results were similar in men and women.

Table 4 and 5 shows the respective results for BMI. The sample sizes are same as for height. In MZ twins, the first-born twins had greater BMI than the second-born twins except the 18 and ≥50-year age groups in men, and the 40-49 year age group in women. Statistical significance was attained in the majority of age groups until 12 years age groups (Table 4). In DZ twins, first-borns had greater BMI than the second-born twins except the 14 and 60-69 years old men. The differences were also statistically significant particularly until 5 years of age. The SDs of BMI in the first-born and the second-born twins in MZ twins were not significantly different. However, the SDs of BMI in the first-born and the second-born twins in DZ twins were significantly different at the age of one, three, 10, 15, 17, and 18 years in men, and the age of 16, 18, and 20-29 years in women (Table 5).

Because the interaction effects between birth order and zygosity were not statistically significant after Bonferroni correction for height or BMI (nominal p-values 0.047-0.008), data from MZ and DZ twins were combined in the further analyses. Figure 1 illustrates the percentage difference (%) in the mean and SD of height between the first-born and the second-born twins in men and women in the pooled data of MZ and DZ twins. Figure 2 presents the same results for BMI. Both for height and BMI, the first-born twins showed almost always higher mean values than the second-born twins. The mean differences in height between the first-born and the second-born twins ranged from -0.1% to 0.3% in men (at the age of 15 years and 5 years) and from -0.3% to 0.4% in women (at the 15 and ≥70-year age groups). The first-born male twins presented up to 1.4% greater BMI than the second-born male twins until 17 years of age and decreased with age in adulthood. The mean differences between the first-born and the second-born twins ranged from 0.2% to 1.4% in women (at the age of 15 years and 18 years). For SD the differences were small and did not show any systematic pattern varying from negative to positive.

Table 6 shows the results of fixed effects regression analysis of height and BMI at each age in the sub-cohort with information on birth weight. Adjustment for birth weight decreased the birth order differences in height and BMI. After adjusting for birth weight, birth order was associated with height at the age of one, three, five, seven and 10 years in men, whereas birth order was not associated with height in women. Moreover, as adjusting for birth weight, birth order was associated with BMI from the age of one to five, seven, 10, 11 and 12 years in men, and from the age of one to five, seven, 10 and 12 years in women.

**Discussion**

The CODATwins study established database with data on body size from twin cohorts in different countries from infancy to old age. Previous studies in twins have reported that the second-born twin was lighter than the first-born twin at birth (Glinianaia et al., 2000; Gielen M, et al., 2007) and our results from this very large international database are consistent with these studies. First-born twins were slightly taller than second-born twins in MZ pairs at some ages until 12 years of age. After adjustment for birth weight, birth order was associated with height in males only at some ages until 10 years of age. We did not find any strong evidence that birth order differences varied according to zygosity since the interaction effects between zygosity and birth order were not statistically significant after Bonferroni correction. These results suggest that birth order has a slight influence on height in twins during childhood mainly explained by birth weight.

Meanwhile, the current study revealed birth order differences in mean BMI until 12 years of age in MZ pairs, and in mean values of BMI until 5 years of age in DZ twin pairs. These birth order differences in mean values of BMI were generally modest but still statistically significant. Adjustment for birth weight reduced these differences, but a significant association of birth order with BMI remained until 12 years of age. Jelenkovic et al. (2015) reported that DZ twins are consistently taller than MZ twins, but mean BMI is not significantly different between MZ and DZ twins at young ages. Based on our study, birth order difference seems to associate more strongly with BMI than zygosity difference. For SDs of height and BMI the results were not statistically significant and did not show any systematic pattern either. Thus, it seems that the factors behind the mean differences between first-born and second-born twins were not associated with variances.

According to the Developmental Origins of Health and Disease hypothesis, birth weight is associated with disease risk later in life and is a determinant of adult health (Barker, 1998; Brodsky and Christou, 2004). This appears more salient for twins, who are born earlier and weigh less as compared to singletons (Loos, et al., 2005). However, it is indicated that growth of twins is not equal to growth of singletons after 29 weeks of gestation (Loos, et al., 2005), and the optimal intrauterine growth and lowest morbidity is achieved earlier in gestation for twins than for singletons (Luke, et al., 1993; Soucie, et al., 2006). In addition, previous studies in twins have reported that the second-born twin was lighter than the first-born twin at birth (Glinianaia et al., 2000; Gielen M, et al., 2007). Moreover, low birth weight predicts lower adult BMI in twins (Johansson & Rasmussen, 2001; Pietiläinen et al., 2001). Whitfield et al. (2001) reported that the correlation between birth weight and BMI in adulthood was positive, and the correlation is due to genetic factors and non-shared environmental factors. Gielen et al. (2007) indicated that the factors determining birth order, which is one of twin-specific factors, have a greater influence on birth weight than zygosity, chorionicity and fusion of the placentas. However it was not known how the birth order differences change over the life course. We found residual differences in BMI between the first-born and the second-born twins until 12 years of age in boys and girls after adjusting for birth weight. Our findings are in accordance with a previous Dutch study showing that the first-born twins were slightly heavier form three to 12 years of age (Silventoinen et al., 2007).

The reasons for the birth order difference in BMI in twins are not clear. It is possible that vascular and placental circumstances are important. Twins offer an opportunity to distinguish between maternal factors (smoking, alcohol, and total placental weight) affecting both twins and factors unique to each twin, such as individual placental weight and site of the insertion of the umbilical cord. Gielen et al. (2007) reported that the individual placental weight has a stronger association with birth weight than the total placental weight. This suggests that the unique factors are more important than the maternal factors. While placental factors appear to be important, consideration of chorionicity is also necessary.

There are three types of MZ twins based on chorionicity. MZ twins can either share one chorion and one amnion, each twin can have own amnion, or MZ twins can, like all DZ twins, each have their own chorion and amnion. Sharing the same chorion could create either a more similar or a more dissimilar prenatal environment (van Beijsterveldt et al. 2015). Kent et al. (2011) reported that monochorionic twins had higher rates of marginal and velamentous placental cord insertion, and noncentral cord insertion contributed to birth weight discordance in monochorionic twin pregnancies. Antoniou et al. (2011), who examine the genetic and environmental etiology of the umbilical cord in a large population of twins, indicated that partly genetic and unique environmental factors influence a number of the morphological characteristics of the overall umbilical cord development. Thus, even in the very early stages of life, twins can experience unique environmental influences (Antoniou et al., 2011). Unfortunately, our database does not have information on chorionicity, which is gathered reliably in few cohorts.

The birth order of twins is determined in early pregnancy, and the first twin at the beginning of pregnancy intrinsically remains in this position (Bronshtein et al., 1998). However, the relationship between the amniotic sac and the cervix, which remains relatively constant throughout gestation, may change near term or during labor in about 10% of twin pairs discordant for sex leading to a change in the anticipated twin order (Bronshtein et al., 1998). Since we did not find the interaction effects between birth order and zygosity, potential prenatal environmental differences between MZ and DZ twins do not seem to modify the birth order differences in BMI or height. However, we observed that birth order effects on BMI appear to last longer in MZ twins than in DZ twins, which may reflect the differences in chorionicity. The differences of intrauterine environment between the first-born and the second-born twins need more detailed research.

Birth order differences have been analyzed previously for perinatal and neonatal outcomes. Previous studies (Smith, et al., 2002; Sheay, et al., 2004; Smith, et al., 2005; Armson, et al., 2006; Smith, et al., 2007) have reported an increased risk of perinatal death of second-born compared with first-born twins. It has been proposed that this may be mainly a problem of more stillbirths in the second twins (Smith, et al., 2002). Luo et al. (2014) reported that perinatal mortality risk differences in second vs first twins depended on their relative birth size, and vaginal delivery at term was associated with a substantially greater risk of perinatal mortality in second twins. These early deaths would have resulted in such pairs not being included in our database.

With regard to neonatal morbidity, the studies of Hacking et al. (2001) and Donovan et al. (1998) both found that second-born twins have increased risk for respiratory distress syndrome. Shinwell et al. (2004) reported that very low birthweight (< 1500g) second twins were at increased risk for acute and chronic lung disease and neonatal mortality, irrespective of mode of delivery. Moreover, Marttila et al. (2004), who analyzed respiratory distress syndrome by gestational age in singletons, first-born and second-born twins, indicated that first-born twins had a significantly lower incidence of respiratory distress syndrome compared with second-born twins and singletons, except at less than 28 weeks of gestation. By being delivered by the same mother at the same time and gestational age, these factors cannot influence postnatal difference in growth, perinatal mortality, and neonatal morbidity risk between the second-born and the first-born twins. So, any such differences are likely to be attributable to birthweight, fetal growth, and intrauterine environment. Our study suggests that the impact of early morbidity, to the degree that it is indexed by birth order, is limited in time to early childhood, and more so on BMI than height.

The major strength of the present study is the large sample size of our international database of twin cohorts with height and weight measures covering almost the whole lifespan. However, a limitation is that countries or geographical regions are not equally represented, and the database is heavily weighted toward Caucasian populations. Accordingly, we could not study in detail possible ethnic differences in birth order differences. In addition, the number of twin participants in the oldest age groups is small. Multiple testing may have resulted in false-positive differences between the first-born and the second-born twins. However, mean values showed a consistent pattern across age and sex groups in both MZ and DZ twins, which provides considerable robustness to the results. Finally a large majority of height, weight and birth order measures are self- or maternally reported. This probably increases random error which lead to decreasing effect sizes. Our results may thus be underestimations of the real birth order differences.

In conclusion, the first-born twins had greater BMI and are slightly taller than the second-born twins. Birth order showed a significant association with BMI before 12 year of age. However, in generally, the differences in BMI and height between first-born and second- born twins were very modest even in early childhood. Adjustment for birth weight reduced the birth order differences but did not fully remove them for BMI. Evidence that birth order affects variances of height and BMI was limited.

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Table 1. Number of twin individuals, mean and standard deviation of birth length (cm) and birth weight (kg) by birth order, sex and zygosity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Boys |  | Girls |
|  |  | Birth order | N | Mean | *p* valuea | SD | *p* valueb |  | N | Mean | *p* valuea | SD | *p* valueb |
| Monozygotictwins | Birth length | 1 | 5304 | 47.0 | 0.002 | 3.58 | 0.001 |  | 5101 | 46.3 | 0.132 | 3.58 | 0.085 |
| 2 | 5293 | 46.8 | 3.69 |  | 5070 | 46.2 | 3.64 |
| Birth weight (kg) | 1 | 9617 | 2.54 | <0.001 | 0.56 | 0.067 |  | 10383 | 2.43 | <0.001 | 0.54 | <0.001 |
| 2 | 9524 | 2.51 | 0.57 |  | 10330 | 2.39 | 0.55 |
| Dizygotictwins | Birth length | 1 | 9160 | 47.4 | 0.207 | 3.55 | 0.009 |  | 7967 | 46.8 | 0.191 | 3.60 | 0.018 |
| 2 | 8914 | 47.4 | 3.65 |  | 8132 | 46.7 | 3.64 |
| Birth weight (kg) | 1 | 17468 | 2.63 | <0.001 | 0.57 | 0.005 |  | 16562 | 2.53 | <0.001 | 0.55 | 0.001 |
| 2 | 17098 | 2.58 | 0.58 |  | 16800 | 2.47 | 0.56 |

*p* valuea: *p* value for equality of means, *p* valueb: *p* value for equality of variances,

SD: standard deviation.

Table 2. Number of twin individuals, mean and standard deviation of height (cm) by birth order, age and sex in monozygotic twins

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Men |  | Women |
|  | Birth order | N | Mean | *p* valuea | SD | *p* valueb |  | N | Mean | *p* valuea | SD | *p* valueb |
| Age 1 | 1 | 2843 | 73.6 | 0.029 | 4.54 | 0.176 |  | 2994 | 72.4 | 0.014 | 4.55 | 0.267 |
| 2 | 2838 | 73.5 | 4.59 |  | 2991 | 72.3 | 4.55 |
| Age 2 | 1 | 2310 | 86.5 | 0.121 | 4.41 | 0.047 |  | 2339 | 85.4 | 0.020 | 4.42 | 0.307 |
| 2 | 2293 | 86.4 | 4.46 |  | 2323 | 85.3 | 4.44 |
| Age 3 | 1 | 2830 | 95.8 | 0.044 | 4.45 | 0.264 |  | 3140 | 94.9 | 0.002 | 4.39 | 0.775 |
| 2 | 2834 | 95.7 | 4.47 |  | 3125 | 94.8 | 4.38 |
| Age 4 | 1 | 1600 | 102.1 | 0.181  | 5.17 | 0.045 |  | 1594 | 101.0 | 0.116 | 5.13 | 0.118 |
| 2 | 1588 | 101.9 | 5.33 |  | 1595 | 100.9 | 5.29 |
| Age 5 | 1 | 1272 | 110.8 | 0.018 | 5.91 | 0.770 |  | 1341 | 110.2 | 0.299 | 6.16 | 0.496 |
| 2 | 1266 | 110.7 | 5.93 |  | 1328 | 110.1 | 6.06 |
| Age 6 | 1 | 528 | 114.1 | 0.279 | 6.45 | 0.856 |  | 427 | 112.9 | 0.834 | 5.66 | 0.180 |
| 2 | 512 | 113.7 | 6.40 |  | 421 | 112.9 | 5.88 |
| Age 7 | 1 | 2345 | 123.6 | 0.216 | 6.62 | 0.134 |  | 2540 | 122.9 | 0.020 | 6.49 | 0.973 |
| 2 | 2330 | 123.5 | 6.72 |  | 2536 | 122.8 | 6.53 |
| Age 8 | 1 | 1057 | 127.6 | 0.016 | 6.35 | 0.322 |  | 1020 | 127.0 | 0.077 | 6.42 | 0.209 |
| 2 | 1042 | 127.4 | 6.23 |  | 1021 | 126.8 | 6.56 |
| Age 9 | 1 | 1042 | 133.0 | 0.143 | 6.97 | 0.509 |  | 1005 | 132.0 | 0.232 | 6.93 | 0.590 |
| 2 | 997 | 132.8 | 7.04 |  | 986 | 131.8 | 6.92 |
| Age 10 | 1 | 1988 | 140.0 | 0.044 | 7.18 | 0.737 |  | 2088 | 139.8 | 0.115 | 7.41 | 0.199 |
| 2 | 1924 | 139.9 | 7.19 |  | 2048 | 139.7 | 7.47 |
| Age 11 | 1 | 1530 | 143.4 | 0.470 | 7.15 | 0.959 |  | 1588 | 144.2 | 0.180 | 7.30 | 0.003 |
| 2 | 1470 | 143.3 | 7.12 |  | 1530 | 144.0 | 7.48 |
| Age 12 | 1 | 2032 | 151.4 | 0.434 | 8.30 | 0.884 |  | 2127 | 152.3 | 0.036 | 8.01 | 0.030 |
| 2 | 1955 | 151.3 | 8.24 |  | 2053 | 152.1 | 8.18 |
| Age 13 | 1 | 692 | 157.9 | 0.693 | 9.30 | 0.301 |  | 642 | 157.3 | 0.269 | 7.40 | 0.494 |
| 2 | 620 | 157.6 | 9.39 |  | 591 | 157.2 | 7.54 |
| Age 14 | 1 | 1328 | 165.4 | 0.815 | 8.95 | 0.808 |  | 1497 | 161.8 | 0.441 | 6.68 | 0.066 |
| 2 | 1280 | 165.4 | 9.09 |  | 1468 | 161.8 | 6.85 |
| Age 15 | 1 | 658 | 171.5 | 0.433 | 8.68 | 0.968 |  | 639 | 164.5 | 0.615 | 7.32 | 0.029 |
| 2 | 639 | 171.7 | 8.70 |  | 606 | 165.1 | 7.00 |
| Age 16 | 1 | 1074 | 175.5 | 0.731 | 7.61 | 0.546 |  | 1311 | 164.4 | 0.398 | 6.56 | 0.067 |
| 2 | 1028 | 175.5 | 7.56 |  | 1257 | 164.5 | 6.34 |
| Age 17 | 1 | 1100 | 177.7 | 0.315 | 7.29 | 0.608 |  | 1411 | 165.6 | 0.710 | 6.62 | 0.601 |
| 2 | 1074 | 177.8 | 7.47 |  | 1388 | 165.8 | 6.59 |
| Age 18 | 1 | 1253 | 178.9 | 0.207 | 7.05 | 0.085 |  | 826 | 166.1 | 0.450 | 6.48 | 0.495 |
| 2 | 1253 | 178.9 | 6.89 |  | 812 | 166.1 | 6.64 |
| Age 19 | 1 | 639 | 179.2 | 0.345 | 7.04 | 0.250 |  | 717 | 166.1 | 0.255 | 6.98 | 0.279 |
| 2 | 607 | 179.3 | 6.85 |  | 702 | 165.9 | 6.83 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age 20-29 | 1 | 2890 | 179.2 | 0.117 | 6.90 | 0.412 |  | 3488 | 164.5 | 0.881 | 6.50 | 0.839 |
| 2 | 2878 | 179.0 | 6.98 |  | 3478 | 164.6 | 6.47 |
| Age 30-39 | 1 | 2305 | 178.1 | 0.360 | 7.04 | 0.494 |  | 3378 | 164.0 | 0.233 | 6.67 | 0.554 |
| 2 | 2290 | 177.9 | 6.92 |  | 3349 | 164.0 | 6.62 |
| Age 40-49 | 1 | 1420 | 177.2 | 0.295 | 7.04 | 0.370 |  | 1886 | 163.2 | 0.924 | 6.65 | 0.436 |
| 2 | 1355 | 177.1 | 7.03 |  | 1844 | 163.1 | 6.58 |
| Age 50-59 | 1 | 1038 | 176.4 | 0.805 | 7.02 | 0.181 |  | 1601 | 162.5 | 0.613 | 6.50 | 0.047 |
| 2 | 1029 | 176.3 | 7.22 |  | 1609 | 162.4 | 6.70 |
| Age 60-69 | 1 | 506 | 174.9 | 0.386 | 6.40 | 0.006 |  | 880 | 161.7 | 0.660 | 6.30 | 0.297 |
| 2 | 494 | 174.4 | 6.99 |  | 878 | 161.9 | 6.47 |
| Age 70-79 | 1 | 126 | 173.7 | 0.412 | 7.09 | 0.199 |  | 273 | 161.3 | 0.378 | 6.91 | 0.162 |
| 2 | 117 | 173.1 | 7.48 |  | 268 | 160.8 | 6.61 |

*p* valuea: *p* value for equality of means, *p* valueb: *p* value for equality of variances,

SD: standard deviation.

Table 3. Number of twin individuals, mean and standard deviation of height (cm)

by birth order, age and sex in dizygotic twins

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Men |  | Women |
|  | Birth order | N | Mean | *p* valuea | SD | *p* valueb |  | N | Mean | *p* valuea | SD | *p* valueb |
| Age 1 | 1 | 5088 | 74.8 | 0.051 | 4.11 | 0.531 |  | 4759 | 73.4 | 0.113 | 4.06 | 0.359 |
| 2 | 4962 | 74.6 | 4.11 |  | 4821 | 73.2 | 4.14 |
| Age 2 | 1 | 4184 | 87.4 | 0.340 | 4.22 | 0.265 |  | 3815 | 86.3 | 0.141 | 4.34 | 0.189 |
| 2 | 4102 | 87.2 | 4.28 |  | 3871 | 86.1 | 4.27 |
| Age 3 | 1 | 5407 | 96.6 | 0.074 | 4.43 | 0.822 |  | 5085 | 95.6 | 0.159 | 4.55 | 0.257 |
| 2 | 5266 | 96.4 | 4.42 |  | 5208 | 95.4 | 4.62 |
| Age 4 | 1 | 2993 | 102.4 | 0.873 | 5.27 | 0.872 |  | 2818 | 101.3 | 0.745 | 5.21 | 0.119 |
| 2 | 2954 | 102.5 | 5.31 |  | 2848 | 101.1 | 5.25 |
| Age 5 | 1 | 2349 | 112.0 | 0.126 | 6.07 | 0.478 |  | 2099 | 111.1 | 0.143 | 6.37 | 0.602 |
| 2 | 2259 | 111.5 | 6.13 |  | 2189 | 110.7 | 6.41 |
| Age 6 | 1 | 583 | 114.5 | 0.819 | 6.88 | 0.311 |  | 455 | 114.2 | 0.261 | 7.55 | 0.180 |
| 2 | 552 | 114.8 | 7.15 |  | 469 | 113.6 | 7.39 |
| Age 7 | 1 | 3986 | 124.8 | 0.232 | 6.59 | 0.266 |  | 3877 | 123.8 | 0.359 | 6.71 | 0.239 |
| 2 | 3981 | 124.5 | 6.72 |  | 3864 | 123.8 | 6.65 |
| Age 8 | 1 | 1478 | 129.2 | 0.533 | 6.42 | 0.154 |  | 1279 | 128.3 | 0.192 | 6.82 | 0.721 |
| 2 | 1433 | 128.9 | 6.65 |  | 1318 | 127.9 | 6.87 |
| Age 9 | 1 | 1445 | 134.5 | 0.664 | 7.30 | 0.271 |  | 1354 | 133.9 | 0.994 | 7.25 | 0.830 |
| 2 | 1449 | 134.2 | 7.14 |  | 1316 | 133.9 | 7.38 |
| Age 10 | 1 | 3171 | 141.8 | 0.097 | 7.02 | 0.226 |  | 2994 | 141.2 | 0.578 | 7.35 | 0.539 |
| 2 | 3148 | 141.4 | 7.21 |  | 2973 | 141.0 | 7.39 |
| Age 11 | 1 | 2385 | 145.2 | 0.130 | 7.23 | 0.505 |  | 2146 | 145.1 | 0.691 | 7.77 | 0.279 |
| 2 | 2288 | 144.6 | 7.41 |  | 2153 | 145.4 | 7.92 |
| Age 12 | 1 | 3152 | 152.5 | 0.945 | 7.82 | 0.617 |  | 3031 | 153.3 | 0.813 | 8.36 | 0.444 |
| 2 | 3021 | 152.3 | 7.92 |  | 3048 | 153.3 | 8.24 |
| Age 13 | 1 | 1035 | 158.8 | 0.887 | 8.77 | 0.051 |  | 898 | 158.4 | 0.938 | 7.80 | 0.964 |
| 2 | 965 | 158.7 | 9.36 |  | 896 | 158.7 | 7.98 |
| Age 14 | 1 | 2353 | 165.6 | 0.888 | 8.94 | 0.031 |  | 2332 | 162.8 | 0.358 | 6.74 | 0.529 |
| 2 | 2266 | 165.8 | 8.62 |  | 2370 | 162.5 | 6.87 |
| Age 15 | 1 | 1143 | 172.2 | 0.878 | 8.84 | 0.729 |  | 1042 | 165.4 | 0.547 | 7.18 | 0.358 |
| 2 | 1078 | 172.3 | 8.87 |  | 1013 | 165.7 | 7.03 |
| Age 16 | 1 | 1990 | 176.0 | 0.855 | 7.52 | 0.827 |  | 2086 | 165.4 | 0.952 | 6.61 | 0.174 |
| 2 | 1940 | 175.8 | 7.46 |  | 2090 | 165.5 | 6.43 |
| Age 17 | 1 | 2159 | 178.5 | 0.317 | 7.30 | 0.415 |  | 2230 | 166.4 | 0.758 | 6.32 | 0.035 |
| 2 | 2092 | 178.0 | 7.16 |  | 2224 | 166.4 | 6.70 |
| Age 18 | 1 | 1680 | 179.4 | 0.444 | 6.95 | 0.573 |  | 1281 | 166.8 | 0.434 | 6.77 | 0.267 |
| 2 | 1614 | 179.2 | 6.91 |  | 1320 | 166.3 | 6.49 |
| Age 19 | 1 | 1044 | 180.4 | 0.973 | 6.72 | 0.362 |  | 1099 | 167.2 | 0.662 | 6.60 | 0.187 |
| 2 | 1049 | 179.8 | 6.86 |  | 1047 | 167.3 | 6.47 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age 20-29 | 1 | 4036 | 179.9 | 0.191 | 6.69 | 0.624 |  | 4398 | 165.8 | 0.255 | 6.56 | 0.167 |
| 2 | 4121 | 179.4 | 6.74 |  | 4270 | 165.5 | 6.50 |
| Age 30-39 | 1 | 3221 | 179.2 | 0.674 | 6.82 | 0.209 |  | 4120 | 165.2 | 0.594 | 6.58 | 0.069 |
| 2 | 3351 | 178.9 | 6.64 |  | 3887 | 165.0 | 6.43 |
| Age 40-49 | 1 | 2403 | 178.9 | 0.791 | 6.69 | 0.775 |  | 2877 | 164.6 | 0.836 | 6.36 | 0.961 |
| 2 | 2411 | 178.9 | 6.70 |  | 2775 | 164.9 | 6.33 |
| Age 50-59 | 1 | 2678 | 178.0 | 0.532 | 6.73 | 0.281 |  | 3261 | 164.1 | 0.898 | 6.20 | 0.081 |
| 2 | 2634 | 177.7 | 6.56 |  | 3086 | 164.3 | 6.05 |
| Age 60-69 | 1 | 1265 | 175.9 | 0.927 | 6.73 | 0.657 |  | 1560 | 162.9 | 0.813 | 6.13 | 0.280 |
| 2 | 1276 | 175.8 | 6.85 |  | 1532 | 162.9 | 6.27 |
| Age 70-79 | 1 | 310 | 175.3 | 0.586 | 6.53 | 0.287 |  | 435 | 162.1 | 0.543 | 6.78 | 0.064 |
| 2 | 329 | 175.0 | 6.82 |  | 390 | 161.4 | 6.05 |

*p* valuea: *p* value for equality of means, *p* valueb: *p* value for equality of variances,

SD: standard deviation.

Table 4. Number of twin individuals, mean and standard deviation of birth weight (kg) and BMI (kg/m2) by birth order, age and sex in monozygotic twins

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Men |  | Women |
|  | Birth order | N | Mean | *p* valuea | SD | *p* valueb |  | N | Mean | *p* valuea | SD | *p* valueb |
| Age 1 | 1 | 2843 | 17.21 | <0.001 | 1.41 | 0.798 |  | 2994 | 16.84 | <0.001 | 1.42 | 0.755 |
| 2 | 2838 | 17.11 | 1.42 |  | 2991 | 16.74 | 1.42 |
| Age 2 | 1 | 2310 | 16.62 | <0.001 | 1.40 | 0.921 |  | 2339 | 16.17 | <0.001 | 1.38 | 0.915 |
| 2 | 2293 | 16.51 | 1.39 |  | 2323 | 16.04 | 1.38 |
| Age 3 | 1 | 2830 | 16.02 | <0.001 | 1.41 | 0.276 |  | 3140 | 15.68 | <0.001 | 1.50 | 0.217 |
| 2 | 2834 | 15.88 | 1.39 |  | 3125 | 15.58 | 1.47 |
| Age 4 | 1 | 1600 | 15.90 | 0.023 | 1.78 | 0.506 |  | 1594 | 15.71 | 0.001 | 2.01 | 0.355 |
| 2 | 1588 | 15.84 | 1.81 |  | 1595 | 15.59 | 1.98 |
| Age 5 | 1 | 1272 | 15.34 | <0.001 | 1.54 | 0.671 |  | 1341 | 15.13 | <0.001 | 1.64 | 0.360 |
| 2 | 1266 | 15.20 | 1.51 |  | 1328 | 15.01 | 1.64 |
| Age 6 | 1 | 528 | 15.54 | 0.265 | 1.77 | 0.735 |  | 427 | 15.25 | 0.084 | 1.76 | 0.735 |
| 2 | 512 | 15.48 | 1.77 |  | 421 | 15.14 | 1.74 |
| Age 7 | 1 | 2345 | 15.40 | 0.002 | 1.69 | 0.419 |  | 2540 | 15.44 | <0.001 | 1.93 | 0.314 |
| 2 | 2330 | 15.31 | 1.71 |  | 2536 | 15.31 | 1.93 |
| Age 8 | 1 | 1057 | 15.64 | 0.026 | 1.72 | 0.331 |  | 1020 | 15.65 | <0.001 | 1.97 | 0.240 |
| 2 | 1042 | 15.54 | 1.67 |  | 1021 | 15.50 | 1.93 |
| Age 9 | 1 | 1042 | 16.29 | 0.057 | 2.10 | 0.318 |  | 1005 | 16.33 | 0.152 | 2.38 | 0.556 |
| 2 | 997 | 16.23 | 2.17 |  | 986 | 16.22 | 2.39 |
| Age 10 | 1 | 1988 | 16.64 | 0.005 | 2.30 | 0.042 |  | 2088 | 16.67 | <0.001 | 2.45 | 0.502 |
| 2 | 1924 | 16.54 | 2.17 |  | 2048 | 16.56 | 2.40 |
| Age 11 | 1 | 1530 | 17.32 | <0.001 | 2.56 | 0.004 |  | 1588 | 17.37 | 0.035 | 2.72 | 0.374 |
| 2 | 1470 | 17.10 | 2.44 |  | 1530 | 17.30 | 2.80 |
| Age 12 | 1 | 2032 | 17.87 | <0.001 | 2.72 | 0.197 |  | 2127 | 17.92 | <0.001 | 2.74 | 0.999 |
| 2 | 1955 | 17.72 | 2.67 |  | 2053 | 17.77 | 2.71 |
| Age 13 | 1 | 692 | 18.45 | 0.092 | 2.89 | 0.051 |  | 642 | 18.94 | 0.094 | 3.19 | 0.383 |
| 2 | 620 | 18.30 | 2.79 |  | 591 | 18.82 | 3.27 |
| Age 14 | 1 | 1328 | 19.28 | 0.132 | 2.86 | 0.422 |  | 1497 | 19.67 | 0.007 | 3.02 | 0.956 |
| 2 | 1280 | 19.23 | 2.82 |  | 1468 | 19.59 | 3.01 |
| Age 15 | 1 | 658 | 19.64 | 0.194 | 2.92 | 0.416 |  | 639 | 19.95 | 0.168 | 3.20 | 0.503 |
| 2 | 639 | 19.59 | 2.93 |  | 606 | 19.80 | 3.15 |
| Age 16 | 1 | 1074 | 20.68 | 0.138 | 2.99 | 0.106 |  | 1311 | 20.64 | 0.098 | 2.98 | 0.172 |
| 2 | 1028 | 20.55 | 2.87 |  | 1257 | 20.57 | 2.95 |
| Age 17 | 1 | 1100 | 20.94 | 0.387 | 2.72 | 0.850 |  | 1411 | 20.73 | 0.112 | 2.87 | 0.982 |
| 2 | 1074 | 20.88 | 2.68 |  | 1388 | 20.60 | 2.85 |
| Age 18 | 1 | 1253 | 21.32 | 0.479 | 2.57 | 0.098 |  | 826 | 21.00 | 0.286 | 2.82 | 0.170 |
| 2 | 1253 | 21.33 | 2.49 |  | 812 | 20.81 | 2.74 |
| Age 19 | 1 | 639 | 21.66 | 0.513 | 2.51 | 0.900 |  | 717 | 21.00 | 0.892 | 2.76 | 0.300 |
| 2 | 607 | 21.59 | 2.59 |  | 702 | 20.95 | 2.83 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age 20-29 | 1 | 2890 | 23.09 | 0.010 | 2.96 | 0.554 |  | 3488 | 21.85 | 0.010 | 3.69 | 0.340 |
| 2 | 2878 | 22.94 | 2.97 |  | 3478 | 21.73 | 3.57 |
| Age 30-39 | 1 | 2305 | 24.65 | 0.461 | 3.39 | 0.215 |  | 3378 | 22.86 | 0.712 | 4.03 | 0.309 |
| 2 | 2290 | 24.52 | 3.30 |  | 3349 | 22.85 | 4.07 |
| Age 40-49 | 1 | 1420 | 25.44 | 0.137 | 3.59 | 0.042 |  | 1886 | 23.75 | 0.676 | 4.20 | 0.428 |
| 2 | 1355 | 25.25 | 3.33 |  | 1844 | 23.77 | 4.33 |
| Age 50-59 | 1 | 1038 | 25.43 | 0.668 | 3.21 | 0.523 |  | 1601 | 24.65 | 0.384 | 4.30 | 0.368 |
| 2 | 1029 | 25.56 | 3.18 |  | 1609 | 24.55 | 4.13 |
| Age 60-69 | 1 | 506 | 25.59 | 0.852 | 3.20 | 0.264 |  | 880 | 25.24 | 0.168 | 4.26 | 0.312 |
| 2 | 494 | 25.73 | 3.28 |  | 878 | 25.02 | 4.17 |
| Age 70-79 | 1 | 126 | 24.74 | 0.925 | 3.20 | 0.532 |  | 273 | 24.95 | 0.675 | 4.30 | 0.213 |
| 2 | 117 | 24.90 | 3.27 |  | 268 | 24.58 | 3.71 |

*p* valuea: *p* value for equality of means, *p* valueb: *p* value for equality of variances, SD: standard deviation.

Table 5. Number of twin individuals, mean and standard deviation of birth weight (kg) and BMI (kg/m2) by birth order, age and sex in dizygotic twins

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Men |  | Women |
|  | Birth order | N | Mean | *p* valuea | SD | *p* valueb |  | N | Mean | *p* valuea | SD | *p* valueb |
| Age 1 | 1 |  | 5088 | 17.20 | <0.001 | 1.39 | 0.037 |  | 4759 | 16.81 | 0.004 | 1.35 | 0.728 |
| 2 |  | 4962 | 17.04 | 1.34 |  | 4821 | 16.67 | 1.35 |
| Age 2 | 1 |  | 4184 | 16.57 | <0.001 | 1.41 | 0.930 |  | 3815 | 16.20 | 0.006 | 1.38 | 0.423 |
| 2 |  | 4102 | 16.40 | 1.40 |  | 3871 | 16.04 | 1.39 |
| Age 3 | 1 |  | 5407 | 16.03 | 0.003 | 1.54 | 0.003 |  | 5085 | 15.74 | 0.010 | 1.53 | 0.314 |
| 2 |  | 5266 | 15.84 | 1.47 |  | 5208 | 15.63 | 1.57 |
| Age 4 | 1 |  | 2993 | 16.01 | 0.047 | 1.87 | 0.808 |  | 2818 | 15.81 | 0.044 | 1.89 | 0.656 |
| 2 |  | 2954 | 15.82 | 1.89 |  | 2848 | 15.68 | 1.93 |
| Age 5 | 1 |  | 2349 | 15.33 | 0.020 | 1.59 | 0.806 |  | 2099 | 15.24 | 0.049 | 1.68 | 0.195 |
| 2 |  | 2259 | 15.17 | 1.60 |  | 2189 | 15.09 | 1.71 |
| Age 6 | 1 |  | 583 | 15.65 | 0.867 | 2.02 | 0.153 |  | 455 | 15.65 | 0.164 | 2.29 | 0.574 |
| 2 |  | 552 | 15.59 | 2.21 |  | 469 | 15.40 | 2.22 |
| Age 7 | 1 |  | 3986 | 15.50 | 0.018 | 1.85 | 0.077 |  | 3877 | 15.59 | 0.178 | 2.09 | 0.144 |
| 2 |  | 3981 | 15.35 | 1.92 |  | 3864 | 15.41 | 2.03 |
| Age 8 | 1 |  | 1478 | 15.75 | 0.296 | 2.09 | 0.625 |  | 1279 | 15.96 | 0.194 | 2.26 | 0.953 |
| 2 |  | 1433 | 15.63 | 2.04 |  | 1318 | 15.76 | 2.26 |
| Age 9 | 1 |  | 1445 | 16.61 | 0.660 | 2.61 | 0.161 |  | 1354 | 16.77 | 0.181 | 2.80 | 0.765 |
| 2 |  | 1449 | 16.41 | 2.49 |  | 1316 | 16.58 | 2.82 |
| Age 10 | 1 |  | 3171 | 16.70 | 0.060 | 2.43 | 0.002 |  | 2994 | 16.98 | 0.107 | 2.58 | 0.422 |
| 2 |  | 3148 | 16.48 | 2.32 |  | 2973 | 16.77 | 2.68 |
| Age 11 | 1 |  | 2385 | 17.56 | 0.326 | 2.77 | 0.992 |  | 2146 | 17.77 | 0.710 | 3.01 | 0.465 |
| 2 |  | 2288 | 17.40 | 2.80 |  | 2153 | 17.65 | 3.04 |
| Age 12 | 1 |  | 3152 | 18.06 | 0.237 | 2.99 | 0.853 |  | 3031 | 18.26 | 0.294 | 3.05 | 0.391 |
| 2 |  | 3021 | 17.89 | 2.99 |  | 3048 | 18.02 | 3.02 |
| Age 13 | 1 |  | 1035 | 18.59 | 0.875 | 3.25 | 0.572 |  | 898 | 18.95 | 0.853 | 3.35 | 0.876 |
| 2 |  | 965 | 18.52 | 3.20 |  | 896 | 18.85 | 3.35 |
| Age 14 | 1 |  | 2353 | 19.58 | 0.315 | 3.24 | 0.741 |  | 2332 | 19.92 | 0.339 | 3.16 | 0.539 |
| 2 |  | 2266 | 19.58 | 3.16 |  | 2370 | 19.70 | 3.11 |
| Age 15 | 1 |  | 1143 | 20.03 | 0.106 | 3.28 | 0.007 |  | 1042 | 20.23 | 0.898 | 3.26 | 0.911 |
| 2 |  | 1078 | 19.62 | 2.90 |  | 1013 | 20.24 | 3.37 |
| Age 16 | 1 |  | 1990 | 20.87 | 0.290 | 3.03 | 0.800 |  | 2086 | 21.05 | 0.109 | 3.34 | 0.046 |
| 2 |  | 1940 | 20.77 | 3.01 |  | 2090 | 20.75 | 3.11 |
| Age 17 | 1 |  | 2159 | 21.39 | 0.644 | 2.85 | 0.038 |  | 2230 | 21.09 | 0.158 | 2.98 | 0.500 |
| 2 |  | 2092 | 21.30 | 3.04 |  | 2224 | 20.79 | 2.93 |
| Age 18 | 1 |  | 1680 | 21.79 | 0.597 | 2.86 | 0.012 |  | 1281 | 21.29 | 0.148 | 3.02 | 0.024 |
| 2 |  | 1614 | 21.83 | 3.01 |  | 1320 | 20.93 | 2.76 |
| Age 19 | 1 |  | 1044 | 21.91 | 0.785 | 2.61 | 0.969 |  | 1099 | 21.38 | 0.212 | 3.05 | 0.082 |
| 2 |  | 1049 | 21.83 | 2.67 |  | 1047 | 21.12 | 2.84 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Age 20-29 | 1 |  | 4036 | 23.39 | 0.398 | 3.04 | 0.507 |  | 4398 | 22.07 | 0.171 | 3.58 | 0.040 |
| 2 |  | 4121 | 23.37 | 3.11 |  | 4270 | 21.82 | 3.42 |
| Age 30-39 | 1 |  | 3221 | 24.81 | 0.813 | 3.42 | 0.987 |  | 4120 | 23.19 | 0.619 | 4.30 | 0.125 |
| 2 |  | 3351 | 24.75 | 3.41 |  | 3887 | 23.02 | 4.17 |
| Age 40-49 | 1 |  | 2403 | 25.48 | 0.932 | 3.35 | 0.553 |  | 2877 | 24.07 | 0.929 | 4.23 | 0.975 |
| 2 |  | 2411 | 25.39 | 3.40 |  | 2775 | 23.99 | 4.25 |
| Age 50-59 | 1 |  | 2678 | 25.69 | 0.970 | 3.35 | 0.673 |  | 3261 | 24.75 | 0.525 | 4.00 | 0.065 |
| 2 |  | 2634 | 25.63 | 3.28 |  | 3086 | 24.53 | 3.89 |
| Age 60-69 | 1 |  | 1265 | 25.49 | 0.897 | 3.19 | 0.595 |  | 1560 | 25.15 | 0.769 | 4.19 | 0.373 |
| 2 |  | 1276 | 25.64 | 3.29 |  | 1532 | 25.07 | 4.09 |
| Age 70-79 | 1 |  | 310 | 25.34 | 0.909 | 3.35 | 0.279 |  | 435 | 24.99 | 0.905 | 3.86 | 0.610 |
| 2 |  | 329 | 25.31 | 3.20 |  | 390 | 24.87 | 4.03 |

*p* valuea: *p* value for equality of means, *p* valueb: *p* value for equality of variances, SD: standard deviation.

Table 6. Fixed effects regression coefficients for the association of birth order with height and BMI

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Height |  | 　　　　　　　BMI |
|  |  | Model 1 |  |  | Model 2 |  |  | Model 1 |  |  | Model 2 |  |
|  |  | B | *p* value |  | B | *p* value |  | B | *p* value |  | B | *p* value |
| Men | Age 1 | -0.14 | 0.004 |  | -0.02 | 0.565 |  | -0.15 | <0.001 |  | -0.10 | <0.001 |
| Age 2 | -0.10 | 0.120 |  | 0.00 | 0.980 |  | -0.16 | <0.001 |  | -0.11 | <0.001 |
| Age 3 | -0.18 | 0.008 |  | -0.09 | 0.162 |  | -0.15 | <0.001 |  | -0.12 | <0.001 |
| Age 4 | -0.07 | 0.510 |  | 0.00 | 0.978 |  | -0.11 | 0.005 |  | -0.08 | 0.025 |
| Age 5 | -0.30 | 0.017 |  | -0.17 | 0.167 |  | -0.16 | <0.001 |  | -0.11 | 0.005 |
| Age 6 | -0.01 | 0.952 |  | 0.13 | 0.510 |  | -0.03 | 0.635 |  | 0.00 | 0.981 |
| Age 7 | -0.20 | 0.045 |  | -0.12 | 0.238 |  | -0.13 | 0.001 |  | -0.10 | 0.004 |
| Age 8 | -0.21 | 0.169 |  | -0.11 | 0.455 |  | -0.10 | 0.062 |  | -0.06 | 0.250 |
| Age 9 | -0.10 | 0.572 |  | -0.03 | 0.852 |  | -0.07 | 0.376 |  | -0.04 | 0.584 |
| Age 10 | -0.36 | 0.008 |  | -0.24 | 0.064 |  | -0.16 | 0.003 |  | -0.13 | 0.015 |
| Age 11 | -0.29 | 0.089 |  | -0.19 | 0.251 |  | -0.17 | 0.015 |  | -0.14 | 0.044 |
| Age 12 | -0.07 | 0.678 |  | 0.03 | 0.839 |  | -0.18 | 0.004 |  | -0.15 | 0.020 |
| Age 13 | -0.16 | 0.658 |  | -0.08 | 0.813 |  | -0.08 | 0.498 |  | -0.04 | 0.708 |
| Age 14 | 0.04 | 0.895 |  | 0.11 | 0.699 |  | -0.08 | 0.415 |  | -0.05 | 0.608 |
| Age 15 | 0.03 | 0.932 |  | 0.09 | 0.825 |  | -0.29 | 0.042 |  | -0.28 | 0.058 |
| Age 16 | -0.03 | 0.900 |  | 0.05 | 0.845 |  | -0.16 | 0.172 |  | -0.13 | 0.249 |
| Age 17 | -0.28 | 0.239 |  | -0.19 | 0.411 |  | -0.05 | 0.663 |  | -0.04 | 0.735 |
| Age 18 | -0.29 | 0.135 |  | -0.10 | 0.607 |  | -0.07 | 0.475 |  | -0.04 | 0.638 |
| Age 19 | -0.21 | 0.536 |  | -0.02 | 0.962 |  | -0.11 | 0.477 |  | -0.09 | 0.563 |
| Age 20-29 | -0.30 | 0.068 |  | -0.12 | 0.447 |  | -0.08 | 0.341 |  | -0.07 | 0.445 |
| Age 30-39 | -0.59 | 0.095 |  | -0.39 | 0.257 |  | 0.06 | 0.771 |  | 0.10 | 0.616 |
| Age 40-49 | 0.17 | 0.770 |  | 0.22 | 0.697 |  | -0.18 | 0.646 |  | -0.17 | 0.660 |
| Age 50-59 | 0.10 | 0.917 |  | 0.13 | 0.886 |  | -0.01 | 0.990 |  | -0.01 | 0.990 |
| Age 60-69 | -0.35 | 0.795 |  | -0.33 | 0.784 |  | -0.56 | 0.571 |  | -0.56 | 0.577 |
| Age 70-79 | -4.00 | 0.753 |  | -3.88 | 0.807 |  | 1.58 | 0.691 |  | 1.88 | 0.698 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Women | Age 1 | -0.13 | 0.005 |  | 0.00 | 0.970 |  | -0.13 | <0.001 |  | -0.07 | 0.002 |
| Age 2 | -0.15 | 0.015 |  | 0.00 | 0.959 |  | -0.14 | <0.001 |  | -0.08 | 0.002 |
| Age 3 | -0.18 | 0.007 |  | -0.08 | 0.185 |  | -0.12 | <0.001 |  | -0.09 | <0.001 |
| Age 4 | -0.11 | 0.288 |  | -0.05 | 0.618 |  | -0.15 | <0.001 |  | -0.13 | 0.002 |
| Age 5 | -0.24 | 0.056 |  | -0.12 | 0.330 |  | -0.15 | <0.001 |  | -0.11 | 0.008 |
| Age 6 | -0.35 | 0.188 |  | -0.13 | 0.628 |  | -0.18 | 0.033 |  | -0.11 | 0.204 |
| Age 7 | -0.19 | 0.048 |  | -0.12 | 0.223 |  | -0.13 | 0.001 |  | -0.10 | 0.006 |
| Age 8 | -0.35 | 0.031 |  | -0.18 | 0.273 |  | -0.18 | 0.003 |  | -0.11 | 0.059 |
| Age 9 | -0.06 | 0.742 |  | 0.07 | 0.668 |  | -0.16 | 0.046 |  | -0.11 | 0.190 |
| Age 10 | -0.15 | 0.235 |  | -0.04 | 0.729 |  | -0.18 | 0.001 |  | -0.13 | 0.016 |
| Age 11 | -0.04 | 0.820 |  | 0.01 | 0.972 |  | -0.09 | 0.208 |  | -0.07 | 0.306 |
| Age 12 | -0.18 | 0.269 |  | -0.12 | 0.450 |  | -0.17 | 0.007 |  | -0.14 | 0.030 |
| Age 13 | -0.03 | 0.925 |  | 0.07 | 0.833 |  | -0.12 | 0.344 |  | -0.09 | 0.504 |
| Age 14 | -0.25 | 0.191 |  | -0.17 | 0.369 |  | -0.20 | 0.033 |  | -0.18 | 0.053 |
| Age 15 | 0.17 | 0.588 |  | 0.32 | 0.293 |  | -0.11 | 0.506 |  | -0.08 | 0.630 |
| Age 16 | -0.08 | 0.697 |  | 0.02 | 0.924 |  | -0.24 | 0.036 |  | -0.21 | 0.066 |
| Age 17 | -0.12 | 0.538 |  | -0.01 | 0.951 |  | -0.19 | 0.045 |  | -0.17 | 0.071 |
| Age 18 | -0.32 | 0.226 |  | -0.15 | 0.571 |  | -0.28 | 0.047 |  | -0.24 | 0.081 |
| Age 19 | -0.01 | 0.980 |  | 0.10 | 0.728 |  | -0.21 | 0.180 |  | -0.18 | 0.245 |
| Age 20-29 | -0.20 | 0.214 |  | -0.07 | 0.647 |  | -0.18 | 0.097 |  | -0.16 | 0.159 |
| Age 30-39 | -0.16 | 0.457 |  | -0.01 | 0.953 |  | -0.11 | 0.475 |  | -0.09 | 0.565 |
| Age 40-49 | 0.04 | 0.914 |  | 0.10 | 0.790 |  | 0.08 | 0.778 |  | 0.08 | 0.788 |
| Age 50-59 | -0.25 | 0.564 |  | -0.17 | 0.700 |  | 0.05 | 0.889 |  | 0.04 | 0.921 |
| Age 60-69 | 0.22 | 0.675 |  | 0.40 | 0.438 |  | 0.09 | 0.833 |  | 0.12 | 0.802 |
| Age 70-79 | -0.73 | 0.554 |  | -0.41 | 0.736 |  | 0.00 | 0.999 |  | 0.08 | 0.940 |

B: Unstandardized regression coefficient

Model 1: Unadjusted, Model 2: Adjusted for birth weightFigure 1. Mean and standard deviation differences (%) in height between first- and second- born twins

across ages.

Figure 2. Mean and standard deviation differences (%) in BMI between first- and second- born twins across ages.