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Birth Size and Childhood Growth as Determinants of Physical Functioning in Older Age: the Helsinki Birth Cohort Study

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Abbreviations:

CI confidence interval

BMI body mass index

HBCS Helsinki Birth Cohort Study

OR odds ratio

SF-36 Short Form 36

Running head: Birth size, Growth and Physical Functioning

Birth Size and Childhood Growth as Determinants of Physical Functioning in Older Age: the Helsinki Birth Cohort Study

ABSTRACT

The study reports on associations between infant and childhood anthropometric measurements, early growth and the combined effect of birth weight and childhood body mass index (BMI) and older age physical functioning. 1999 individuals belonging to the Helsinki Birth Cohort Study responded to the Short-Form SF-36 physical functioning scale. Infancy and childhood anthropometrics were retrieved from medical records. Risk of lower SF-36 physical functioning at mean age of 61.6 years was increased for those with birth weight less than 2.5kg compared to those weighing 3.0-3.5kg at birth, odds ratio (OR) 2.73 (95% confidence interval (CI): 1.57, 4.72). Gain in weight from birth to age 2 years decreased the risk of lower physical functioning OR for 1-SD increase 0.84 (95% CI: 0.75, 0.94). The risk for lower physical functioning was highest for individuals with birth weight in the lowest third and BMI at 11 years of age in the highest third compared to those with birth weight in the middle third and BMI at age 11 years in the highest third OR 3.08 (95% CI: 1.83, 5.19). Increasing prevalence of obesity in all ages and aging of populations warrant closer investigation of the role of weight trajectories in old age functional decline.

Keywords: birth weight, growth, body mass index, physical functioning, Short Form SF-36, catch-up growth, older persons, infancy, childhood

Population aging has lead to larger numbers of people surviving to very old age. Maintaining adequate physical functioning in older age is crucial for leading an independent life, performing daily tasks and decreasing the need for health and social care (1, 2). Life course epidemiology posits that physical or social exposures taking place during gestation, childhood, adulthood and older age have long-term effects on old age health and functioning (3). Small body size at birth and slow growth during infancy predict chronic diseases such as hypertension, cardiovascular disease and diabetes in late adulthood (4-6). These chronic conditions are known risk factors for decreased physical functioning which in turn strongly predict subsequent disability at the distal end of the lifespan (1, 7). Some evidence exist on the association between lower birth weight and suboptimal infant growth and decreased muscle strength and physical performance in later life (8-13) - the intermediate outcomes in the development of old age disability and premature mortality (14-17). However, little is still known about the relation between early growth and physical functioning in older age.

The association between low birth weight, slow infant growth followed by rapid weight gain after the age of two years, termed catch-up growth, and increased prevalence of chronic diseases in adulthood has been documented (18-23), but we did not find any reports of the association between this path of growth and physical functioning in old age. Here we report on the associations between infant and childhood anthropometric measurements, early growth and the combined effect of birth weight and childhood body mass index on physical functioning assessed at mean age of 61.6 years in 1999 individuals belonging to the Helsinki Birth Cohort Study (HBCS).

MATERIALS AND METHODS

Study population

Helsinki Birth Cohort Study (HBCS) includes 8760 individuals born at the Helsinki University Central Hospital between 1934 and 1944, living in Finland in 1971 when a unique personal identification number was assigned to all Finnish residents (4, 24). All 7079 (80.8%) living members of this epidemiological cohort who resided in Finland in the year 2000 were sent a questionnaire and a total of 4515 (63.8%) responded. Of these, a random sample of 2901 was invited to participate in clinical examinations. Of these, 2003 (69.1%) participated at an average age of 61 years in the examinations conducted between the years 2001 and 2004. The longitudinal data used in the present study include 1999 participants (927 men and 1072 women) with data on physical functioning assessed with a questionnaire at the time of clinical examination. Compared to the 8760 members of the original cohort, the individuals who participated in the clinical examination had 30g higher birth weight (95% CI: 6, 54g, P=0.02) and 0.08 kg/m^2 higher BMI at birth (95% CI; 0.02, 0.14, P=0.02), but their length at birth and length of gestation were similar (25).

Ethics statement

The study complies with the guidelines of the Declaration of Helsinki. The study was approved by the Ethics Committee of Epidemiology and Public Health of the Hospital District of Helsinki and Uusimaa and that of the National Public Health Institute, Helsinki. All participants gave a written informed consent.

Infant and childhood measures

Dates of birth, mothers last menstrual period prior to the pregnancy with the participants and weight and length at birth were retrieved from the hospital birth records. Infancy and childhood weight and height were retrieved from child welfare clinic and school health records. These have been described in detail previously (18, 19, 26). Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Duration of breastfeeding was categorized into not breastfed, breastfed for under 3 months, for 3-6 months and for more than 6 months. Childhood socioeconomic status was evaluated based upon father's occupation indicated by the highest occupational class extracted from the birth and child welfare and school health records. The socioeconomic status was classified into four categories (upper middle class, lower middle class, laborers and unknown occupation) according to the social classification system issued by Statistics of Finland (27).

Adult data collection

The participants were measured for weight and height at the clinical examination at a mean age of 61.6 years. Lean body mass was assessed with bioelectrical impedance using the InBody 3.0 eight-polar tactile electrode system, Biospace CO Ltd, Seoul, Korea (28). Participants' smoking status was assessed with questionnaires at the clinical examination (never smoked, former smoker, smokes currently). Register data from the Finnish Population Register Centre was used to indicate adult socioeconomic status. The highest occupational class at 5-yearly intervals between 1970 and 1995 was categorized into upper middle class, lower middle class, self-employed and laborers (27).

SF-36 physical functioning

At the clinical examination, general health-related physical functioning was assessed with the Finnish validated version of the RAND-36 Item Health Survey 1.0 (Short-Form SF-36) physical functioning scale (29-32). It has been widely used in assessing physical functioning in the older population (33, 34). The SF-36 has been found to be a reliable and valid measure of health-related quality of life in the Finnish population (31). The 10 items included in the SF-36 physical functioning score (herein referred to as SF-36 physical functioning) included vigorous activities (e.g. running or lifting heavy objects), moderate activities (e.g. vacuuming or bowling), lifting or carrying groceries, climbing several flights of stairs, climbing one flight of stairs, bending, kneeling or stooping, walking more than a mile, walking several blocks, walking one block and bathing and dressing oneself. The 10 items were coded into 0=a lot of problems or unable to perform, 50=some problems and 100=no problems, they were then summarized and divided by 10 (29). The scores ranged between 0 and 100, with a median score of 90 for men and 85 for women. Participants with SF-36 physical functioning scores in the lowest gender-specific third of the distribution were classified as having lower physical functioning (cut-off score 85 for men and 75 for women).

Statistical analyses

Pearson's chi-square test was used for comparing proportions for categorical variables, Student's *t*-test for comparing means for continuous variables. Individuals, who scored in the lowest third were compared to those who scored in the two highest thirds of the SF-36 physical functioning. All significance tests were performed as two-tailed with significance level set at 0.05. The analyses were first conducted separately for men and women but are presented together while the results were similar for both genders ($P > 0.073$ for interaction).

The association between weight measured at birth, 12 months and 24 months, categorized into five groups (4, 18, 35), and SF-36 physical functioning at age 61.6 years was investigated with multiple logistic regressions. The analyses were first adjusted for gender, chronological age at the time of the clinical examination and length of gestation, second we added into the models lean body mass to control for adult body size and finally the models were adjusted for childhood and adulthood socioeconomic status and smoking status.

To further explore these associations, weight, height and BMI measurements at birth and at 2, 7 and 11 years of age were converted into *z* scores (19, 26). The *z* score represents the difference from the mean value for the whole cohort and is expressed in SDs. Linear regression models were performed to confirm the results using SF-36 physical functioning as a continuous 7-category outcome. The relationship between birth weight and SF-36 physical functioning at age 61.6 years was u-shaped, which is why a quadratic term was added to the linear regression models. Conditional growth was explored with logistic regression models for weight, height and BMI in three periods that have been used in previous analyses on these data (ages 0-2, 2-7 years and 7-11 years) (35) using standardized residuals from linear regression models. In this procedure, body size at each time point was regressed on corresponding measures at earlier time points, creating completely uncorrelated residuals reflecting conditional growth (19, 36). Logistic regression models were performed to investigate the combined effect of birth weight and BMI at 11 years of age on physical functioning at age 61.6 years. Birth weight and BMI were divided into distribution based thirds (19, 20). All these analyses were adjusted first for gender, chronological age and length of gestation and second for childhood and adulthood socioeconomic status, lean body mass and smoking status. The growth analyses were additionally adjusted for duration for breastfeeding. The analyses were carried out with SPSS version 18 software (SPSS Inc., Chicago, IL, USA).

RESULTS

Cohort characteristics

The mean age of the 1999 participants was 61.6 years (range 56.7 to 69.8 years). The level of limitation in SF-36 physical functioning is presented in Table 1. Least limitations were perceived in walking one block (limited at least a little: men 4% and women 6%) and most limitations were reported in vigorous activities such as running and lifting heavy objects (limited at least a little: men 70% and women 80%).

The characteristics of those in the lowest third compared to those in the two highest thirds of the SF-36 physical functioning are described in Table 2. Those with lower SF-36 physical functioning were older, heavier and had a higher lean body mass at age 61.6 years than those in the two highest thirds of physical functioning (Student's *t*-test *P* for trend <0.029). The individuals in the lowest third of SF-36 physical functioning had lower educational attainment (Student's *t*-test *P*<0.001) and belonged more frequently to a lower social class in childhood and adulthood (Pearson's chi-squared test *P*<0.001).

Body size at birth and infancy

Table 3 shows the odds ratios for lower SF-36 physical functioning at age 61.6 years according to birth and infant weight. Low birth weight increased the risk of lower physical functioning. The highest odds were seen for those with birth weight less than 2.5 kg, fully adjusted OR 2.73 (95% CI: 1.57, 4.72) and 2.5 to 3.0 kg OR 1.50 (95% CI: 1.10, 2.04) compared to those weighing 3.0 to 3.5 kg at birth. The finding was further confirm in a linear regression (quadratic term β = -0.071, 95% CI -0.128, -0.014, p=0.015). The association between infant weight and SF-36 physical functioning was parallel. Weighing less than 9.0 kg at 1 year of age increased the odds of SF-36 physical functioning at age 61.6

years compared to those weighing over 12.0 kg after adjusting for adult lean body mass OR 2.02, 95% CI 1.09, 3.73 (linear regression β = 0.120, 95% CI 0.023, 0.216, *P*=0.015). Lower weight at 2 years of age increased the risk for lower SF-36 physical functioning at age 61.6 years (linear regression β = 0.192, 95% CI 0.092, 0.292, *P*<0.001). For example, the odds for lower physical functioning was 3.58 (95% CI: 1.97, 6.51) times higher for those who had weighed less than 11.0 kg at 2 years of age compared to those who had weighed more than 14.0 kg. All these odds were little changed by further adjustment for adulthood physical activity behavior, alcohol consumption and chronic physician-diagnosed diseases including hypertension, heart congestion, angina, diabetes, stroke, depression and asthma. Furthermore, the interaction between birth weight and highest social status in childhood was not significant (*P* for interaction =.73).

Infant and childhood growth

Conditional growth was calculated for age periods of 0-2 years, 2-7 years and 7-11 years (Table 4). The analyses indicate the difference between body size measured at a specific age and body size at that age as predicted by earlier measurements. After adjusting for gender, chronological age and length of gestation, duration of breastfeeding, childhood and adulthood socioeconomic status, lean body mass and smoking status, gain in weight OR 0.84 (95% CI: 0.75, 0.94) and BMI OR 0.88 (95% CI: 0.79, 0.98) from birth to 2 years of age were associated with a decreased risk of lower SF-36 physical functioning at 61.6 years of age. Gain in weight and BMI from 7 to 11 years was associated with an increased risk of lower physical functioning, however adjustment for adult lean body mass attenuated the association.

Birth weight and childhood body mass index

Body mass index at 11 years of age did not correlate with physical functioning at 61.6 years of age (*P* for trend =0.091), but the interaction between birth weight and BMI at 11 years of age was statistically significant (*P* for interaction =0.013). Thus, we investigated the combined effect of birth weight and BMI at 11 years of age, both divided into thirds, on physical functioning at age 61.6 years, presented in Table 5. In the simultaneous regression, the highest odds for lower physical functioning were found among individuals with birth weight in the lowest third and BMI at 11 years of age in the highest third compared to the individuals with birth weight in the mid third and BMI at 11 years of age in the highest third (referent) OR 2.93 (95% CI: 1.80, 4.79). Adjusting the models for adult lean body mass, highest socioeconomic status in childhood and adulthood and smoking status increased the odds ratio to 3.08 (95% CI: 1.83, 5.19) compared to the referent, suggesting negative confounding (37). In addition, the odds were significantly increased for those with BMI at age 11 years in the lowest third and birth weight in the lowest third OR 2.46 (95% CI: 1.51, 4.03) and birth weight in the middle third OR 1.92 (95% CI: 1.25, 2.95), compared to the referent. The odds ratio for lower SF-36 physical functioning was also increased for the individuals with birth weight and BMI at 11 years of age in the highest third compared to the referent OR 1.58 (95% CI: 1.05, 2.38). The results were similar when birth weight and BMI at 7 years were regressed simultaneously on physical functioning at age 61.6 years. However, there was no interaction between birth weight and BMI at 7 years of age.

DISCUSSION

We have shown in this well-characterized birth cohort that lower weight at birth and infancy predicted lower general health-related physical functioning at age 61.6 years. The individuals with lower physical functioning in older age had gained weight slower during infancy. Individuals with low birth weight (<3.0 kg) and later at 11 years of age either high (>17.5) or low (<16.0) BMI were at an especially high risk for poor physical functioning in older age. These associations were independent of childhood socioeconomic status and adulthood lean body mass, socioeconomic status and smoking status. These findings indicate that prenatal and childhood growth set the mark for old age physical functioning.

The association between early size and growth and later life physical performance have been reported so far in two studies which used objectively measured performance tests as outcomes. In the British 1946 born cohort, weight gain until 7 years of age was beneficial for performance at age 53 years among men (8). In the Hertfordshire cohort, lower birth weight correlated with lower physical performance among men with an average age of 68 years, but early size and conditional growth in infancy did not correlate consistently with physical performance (11). Our current findings on health-related physical functioning are in line with these earlier findings, but add new knowledge in terms of analyses on serial measures on weight and height available in our data throughout infancy enabling us to investigate these effects at several time points during early life.

This is the first study to report on the association between a combination of lower birth weight and higher childhood BMI on physical functioning in older age. We cannot compare these findings to other studies, but conclude that they parallel earlier findings on increased incidence of hypertension and coronary heart disease found in this cohort for those with low birth weight and high childhood BMI (18-21, 26, 35, 38).

The mechanisms and pathways through which birth parameters and early growth are linked to physical functioning in older age are likely to be diverse. One of the underlying reasons might be the suboptimal prenatal environment, reflected in small body size at birth, which may permanently retard developing vital organ structures and functioning of biological mechanisms and cause unfavorable changes in body composition (39, 40). It has been postulated that prenatal development of organs and tissue is hierarchical in nature and that restricted prenatal nutrition might result in an unfavorable trade-off of muscle tissue by the fetus in securing necessary supply to vital organs such as the brain (40). Babies who are born lighter lack muscle (41), supporting this trade-off. Lower birth weight correlates further with lower adult lean body mass (13, 42, 43) and muscle strength in later life (9, 10, 12, 13). Furthermore, rapid weight gain during childhood might result in an imbalance between fat and muscle mass, as there is little replication in muscle tissue after infancy (44, 45). Second, lower birth weight increases the incidence of chronic diseases such as diabetes, coronary heart disease and stroke (5, 20, 26), which further increase the prevalence of old age disability (46, 47).

Suboptimal early body size and growth might render the individual more susceptible to the negative effects of an unfavorable social environment (21), which has been linked with poor physical functioning in later life (48). However, the interactions between childhood socioeconomic status and weight and growth in infancy and childhood were not statistically significant, indicating that these effects were independent of childhood socioeconomic status.

Strengths and limitations

The strengths of our study include the well-characterized sample and serial measures of body size during infancy and childhood collected from reliable medical records. We were also able to use register-based data on socioeconomic status in adulthood. Some limitations of the study should be recognized. The individuals in this study had been born in Helsinki University Central Hospital and the majority went to school in Helsinki. They had all attended voluntary child-welfare clinics that were free of charge. Thus, the participants may not represent the entire population living in Finland. However, at birth, childhood social class as indicated by fathers highest occupational status did not differ from that of the population living in the city of Helsinki at that time (4). In this historical cohort, most individuals were born or grew up during the Second World War, a time during which families might have suffered from food shortages in Finland. This must be considered when generalizing these results to current settings. Furthermore, survivor bias might cause some underestimation in terms of the results while the participants had to live to be about 60 years of age and to be able to participate in the clinic exams. Small size at birth predicts premature death and several chronic diseases (4, 5, 49), causing individuals to drop-out from the follow-ups of studies more frequently. The data on physical functioning was self-reported which might yield possible reporting bias, however, high correlations between subjective and objectively measured physical performance have been reported (50). The SF-36 physical functioning scores in this study corresponded to the scores reported for 59- to 72-year-old men and women belonging to the Hertfordshire Cohort Study (50).

Conclusion

In conclusion, we found that lower physical functioning at age 61.6 years was associated with lower weight as well as slower weight gain during infancy. Furthermore, low birth weight combined with either high or low BMI in childhood yielded the highest risks for lower physical functioning in older age. This piece of information is important while the number of obese individuals in all age groups increase and BMI tends to track through adolescence into adulthood and further increase the risk for old age disability (51-53). These results offer new insights in terms of the effects of pre- and postnatal environment on older age physical functioning and are in line with other findings on the relation between early life parameters and health-related outcomes in adulthood.

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Competing interests:

The authors have declared that no competing interests exist.

REFERENCES

1. Fried TR, Bradley EH, Williams CS, et al. Functional disability and health care expenditures for older persons. *Arch Intern Med.* 2001;161(21):2602-2607.

2. Guralnik JM, LaCroix AZ, Abbott RD, et al. Maintaining mobility in late life. I. Demographic characteristics and chronic conditions. *Am J Epidemiol.* 1993;137(8):845-857.

3. Ben-Shlomo Y, Kuh D. A life course approach to chronic disease epidemiology: Conceptual models, empirical challenges and interdisciplinary perspectives. *Int J Epidemiol.* 2002;31(2):285-293.

4. Eriksson JG, Forsen T, Tuomilehto J, et al. Early growth and coronary heart disease in later life: Longitudinal study. *BMJ.* 2001;322(7292):949-953.

5. Lithell HO, McKeigue PM, Berglund L, et al. Relation of size at birth to non-insulin dependent diabetes and insulin concentrations in men aged 50-60 years. *BMJ.* 1996;312(7028):406-410.

6. Frankel S, Elwood P, Sweetnam P, et al. Birthweight, body-mass index in middle age, and incident coronary heart disease. *Lancet.* 1996;348(9040):1478-1480.

7. Guralnik JM, Ferrucci L, Simonsick EM, et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med.* 1995;332(9):556-561.

8. Kuh D, Hardy R, Butterworth S, et al. Developmental origins of midlife physical performance: Evidence from a British birth cohort. *Am J Epidemiol.* 2006;164(2):110-121.

9. Kuh D, Hardy R, Butterworth S, et al. Developmental origins of midlife grip strength: Findings from a birth cohort study. *J Gerontol A Biol Sci Med Sci.* 2006;61(7):702-706.

10. Kuh D, Bassey J, Hardy R, et al. Birth weight, childhood size, and muscle strength in adult life: Evidence from a birth cohort study. *Am J Epidemiol.* 2002;156(7):627-633.

11. Martin HJ, Syddall HE, Dennison EM, et al. Physical performance and physical activity in older people: Are developmental influences important? *Gerontology.* 2009;55(2):186-193.

12. Sayer AA, Cooper C, Evans JR, et al. Are rates of ageing determined in utero? *Age Ageing.* 1998;27(5):579-583.

13. Ylihärsilä H, Kajantie E, Osmond C, et al. Birth size, adult body composition and muscle strength in later life. *Int J Obes (Lond).* 2007;31(9):1392-1399.

14. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q Health Soc.* 1976;54(4):439-467.

15. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38(1):1-14.

16. Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. *JAMA.* 1999;281(6):558-560.

17. Rantanen T, Masaki K, He Q, et al. Midlife muscle strength and human longevity up to age 100 years: A 44-year prospective study among a decedent cohort. *Age (Dordr).* E published ahead of print May 4, 2011.

18. Eriksson JG, Forsen T, Tuomilehto J, et al. Catch-up growth in childhood and death from coronary heart disease: Longitudinal study. *BMJ.* 1999;318(7181):427-431.

19. Barker DJ, Osmond C, Forsen TJ, et al. Trajectories of growth among children who have coronary events as adults. *N Engl J Med.* 2005;353(17):1802-1809.

20. Eriksson JG, Forsen TJ, Osmond C, et al. Pathways of infant and childhood growth that lead to type 2 diabetes. *Diabetes Care.* 2003;2611):3006-3010.

21. Barker DJ, Osmond C, Kajantie E, et al. Growth and chronic disease: Findings in the Helsinki Birth Cohort. *Ann Hum Biol.* 2009;36(5):445-458.

22. Ong KK, Ahmed ML, Emmett PM, et al. Association between postnatal catch-up growth and obesity in childhood: Prospective cohort study. *BMJ.* 2000;320(7240):967-971.

23. Eriksson JG, Osmond C, Kajantie E, et al. Patterns of growth among children who later develop type 2 diabetes or its risk factors. *Diabetologia.* 2006;49(12):2853-2858.

24. Forsen T, Eriksson JG, Tuomilehto J, et al. Mother's weight in pregnancy and coronary heart disease in a cohort of Finnish men: Follow up study. *BMJ.* 1997;315(7112):837-840.

25. Kajantie E, Barker DJ, Osmond C, et al. Growth before 2 years of age and serum lipids 60 years later: The Helsinki Birth Cohort Study. *Int J Epidemiol.* 2008;37(2):280-289.

26. Osmond C, Kajantie E, Forsen TJ, et al. Infant growth and stroke in adult life: The Helsinki Birth Cohort Study. *Stroke.* 2007;38(2):264-270.

27. Central Statistical Office of Finland. Classification of socioeconomic groups: Handbooks 17. Helsinki, Finland: Central Statistical Office of Finland; 1989.

28. Bedogni G, Malavolti M, Severi S, et al. Accuracy of an eight-point tactile-electrode impedance method in the assessment of total body water. *Eur J Clin Nutr.* 2002;56(11):1143-1148.

29. Hays RD, Sherbourne CD, Mazel RM. The RAND 36-item health survey 1.0. *Health Econ.* 1993;2(3):217-227.

30. Ware JE,Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. conceptual framework and item selection. *Med Care.* 1992;30(6):473-483.

31. Aalto, AM, Aro, AR, Teperi, J. RAND-36 as a measure of helath-related quality of life. Reliability, construct validity and reference values in the Finnish general population. Helsinki, Finland: Stakes; 1999.

32. Aalto, AM, Aro, S, Aro, AR, et al. RAND 36-item Health Survey 1.0. Finnish version on the health-related quality of life questionnaire. Helsinki, Finland: Stakes; 1995.

33. Bohannon RW, DePasquale L. Physical functioning scale of the Short-Form (SF) 36: Internal consistency and validity with older adults. *J Geriatr Phys Ther.* 2010;33(1):16-18.

34. Brazier JE, Harper R, Jones NM, et al. Validating the SF-36 health survey questionnaire: New outcome measure for primary care. *BMJ.* 1992;305(6846):160-164.

35. Eriksson JG, Forsen TJ, Kajantie E, et al. Childhood growth and hypertension in later life. *Hypertension.* 2007;49(6):1415-1421.

36. De Stavola BL, Nitsch D, dos Santos Silva I, et al. Statistical issues in life course epidemiology. *Am J Epidemiol.* 2006;163(1):84-96.

37. Mehio-Sibai A, Feinleib M, Sibai TA, et al. A positive or a negative confounding variable? A simple teaching aid for clinicians and students. *Ann Epidemiol.* 2005;15(6):421-423.

38. Bhargava SK, Sachdev HS, Fall CH, et al. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *N Engl J Med.* 2004;350(9):865-875.

39. Barker DJ. Developmental origins of adult health and disease. *J Epidemiol Community Health.* 2004;58(2):114-115.

40. Hales CN, Barker DJ. Type 2 (non-insulin-dependent) diabetes mellitus: The thrifty phenotype hypothesis. *Diabetologia.* 1992;35(7):595-601.

41. Koo WW, Walters JC, Hockman EM. Body composition in human infants at birth and postnatally. *J Nutr.* 2000;130(9):2188-2194.

42. Rogers I, EURO-BLCS Study Group. The influence of birthweight and intrauterine environment on adiposity and fat distribution in later life. *Int J Obes Relat Metab Disord.* 2003;27(7):755-777.

43. Singhal A, Wells J, Cole TJ, et al. Programming of lean body mass: A link between birth weight, obesity, and cardiovascular disease? *Am J Clin Nutr.* 2003;77(3):726-730.

44. Gollnick PD, Timson BF, Moore RL, et al. Muscular enlargement and number of fibers in skeletal muscles of rats. *J Appl Physiol.* 1981;50(5):936-943.

45. McMillen IC, Robinson JS. Developmental origins of the metabolic syndrome: Prediction, plasticity, and programming. *Physiol Rev.* 2005;85(2):571-633.

46. Gregg EW, Mangione CM, Cauley JA, et al. Diabetes and incidence of functional disability in older women. *Diabetes Care.* 2002;25(1):61-67.

47. Pinsky JL, Jette AM, Branch LG, et al The Framingham disability study: Relationship of various coronary heart disease manifestations to disability in older persons living in the community. *Am J Public Health.* 1990;80(11):1363-1367.

48. Birnie K, Cooper R, Martin RM, et al. Childhood socioeconomic position and objectively measured physical capability levels in adulthood: A systematic review and meta-analysis. *PLoS One.* 2011;6(1):e15564.

49. Kajantie E, Osmond C, Barker DJ, et al. Size at birth as a predictor of mortality in adulthood: A follow-up of 350 000 person-years. *Int J Epidemiol.* 2005(3);34:655-663.

50. Syddall HE, Martin HJ, Harwood RH, et al. The SF-36: A simple, effective measure of mobility-disability for epidemiological studies. *J Nutr Health Aging.* 2009;13(1):57-62.

51. Vanhala M, Vanhala P, Kumpusalo E, et al. Relation between obesity from childhood to adulthood and the metabolic syndrome: Population based study. *BMJ.* 1998;317(7154):319.

52. Alley DE, Chang VW. The changing relationship of obesity and disability, 1988-2004. *JAMA.* 2007;298(17):2020-2027.

53. Stenholm S, Rantanen T, Alanen E, et al. Obesity history as a predictor of walking limitation at old age. *Obesity (Silver Spring).* 2007;15(4):929-938.

Table 1 Physical Functioning (Percent and Mean Score) at Mean Age of 61.6 Years Among 927 Men and 1072 Women Belonging to Helsinki Birth Cohort

	Men n=927				Women n=1072			
SF-36 Physical functioning scale	Not limited %	Limited a little %	Limited a lot %	Mean score (SD)	Not limited %	Limited a little %	Limited a lot %	Mean score (SD)
Vigorous activities (running, lifting heavy objects)	30.5	43.3	26.2	52.2 (37.6)	19.6	48.1	32.1	43.8 (35.5)
Moderate activities (moving a table, vacuuming, bowling)	80.2	16.8	3.0	88.7 (24.2)	62.4	30.9	6.7	78.1 (30.6)
Lifting or carrying groceries	87.4	10.2	2.4	92.6 (20.7)	58.6	34.7	6.7	76.1 (30.8)
Climbing several flights of stairs	64.3	28.4	7.2	78.7 (31.0)	43.9	44.8	11.3	66.5 (33.2)
Climbing one flight of stairs	90.5	7.4	1.9	94.5 (18.2)	82.3	13.7	4.0	89.6 (24.3)
Bending, kneeling or stooping	59.2	32.8	8.1	75.6 (32.0)	48.3	41.9	9.8	69.4 (32.8)
Walking more than a mile	79.3	15.0	5.7	87.0 (27.5)	74.1	81.2	7.7	83.5 (30.4)
Walking several blocks	90.6	6.8	2.6	94.1 (19.6)	87.2	9.6	3.2	92.3 (21.7)
Walking one block	95.6	3.3	1.1	97.4 (13.2)	93.6	4.6	1.8	96.1 (16.1)
Bathing or dressing oneself	93.1	5.7	1.2	96.0 (15.7)	90.7	7.6	1.7	94.7 (17.7)

Table 2 Cohort Characteristics According to Physical Functioning at 61.6 Years of Age According to SF-36 Physical Functioning Score

		Top and middle thirds[†]	Lowest third[†]	
Measurement[*]	n	Mean (SD)	Mean (SD)	P-value
Adult characteristics				
Age (years)	1999	61.41 (2.8)	61.83 (3.1)	0.006
Men				
Weight (kg)	927	84.31 (12.2)	91.27 (17.8)	<0.001
Height (cm)	926	176.98 (6.1)	176.38 (5.8)	0.171
Lean body mass (kg)	885	64.67 (7.4)	65.97 (9.0)	0.029
Women				
Weight (kg)	1071	71.44 (11.9)	79.35 (16.2)	<0.001
Height (cm)	1071	163.50 (5.6)	162.42 (5.8)	0.004
Lean body mass (kg)	1029	47.43 (5.4)	48.75 (6.2)	0.001
Length of education (yrs)	1952	12.64 (3.7)	11.20 (3.3)	<0.001
	n	%	%	
Smoking status	1983			<0.001
Never smoked		44.8	35.7	
Former smoker		34.2	33.0	
Current smoker		20.9	31.3	
Physical activity	1994	46.3	39.5	0.005
Drinks alcohol weekly	1994	53.6	44.8	<0.001
Fathers highest social class in childhood	2003			<0.001
Upper middle		19.2	12.0	
Lower middle		23.3	21.0	
Laborer		56.9	66.1	
Unknown		0.6	0.9	
Highest social class in adulthood	2002			<0.001
Upper middle		53.3	36.2	
Lower middle		36.2	42.9	
Self-employed		2.8	5.2	
Laborer		7.7	15.7	

Physical activity=at least moderately active 3≥ times/week

[*]Comparison for categorical variables performed with Chi-square test and for continuous variables with Student's *t*-test

[†]SF-36 score top and middle thirds vs. lowest third (cut-off at 85 for men and 75 women)

Table 3 Odds Ratios and 95% Confidence Intervals for Lower SF-36 Physical Functioning at Age 61.6 Years According to Weight Measured at Birth and in Infancy

	OR (95% CI)		
Weight (kg)	Model 1	Model 2	Model 3
Birth			
< 2.5	2.39 (1.42-4.02)	2.70 (1.59-4.58)	2.73 (1.57-4.72)
- 3.0	1.42 (1.06-1.89)	1.48 (1.09-2.00)	1.50 (1.10-2.04)
- 3.5	1	1	1
- 4.0	1.10 (0.86-1.40)	1.02 (0.80-1.32)	1.07 (0.82-1.38)
> 4.0	1.34 (0.95-1.90)	1.17 (0.81-1.69)	1.17 (0.80-1.71)
	P for trend = 0.005	*P* for trend = 0.001	*P* for trend = 0.002
1 years			
< 9.0	1.54 (0.86-2.77)	2.02 (1.09-3.73)	1.98 (1.06-3.73)
- 10.0	1.47 (0.86-2.54)	1.73 (0.98-3.05)	1.71 (0.95-3.06)
- 11.0	1.33 (0.77-2.77)	1.53 (0.87-2.67)	1.50 (0.85-2.67)
- 12.0	1.36 (0.77-2.40)	1.46 (0.82-2.61)	1.44 (0.79-2.61)
> 12.0	1	1	1
	P for trend = 0.60	*P* for trend = 0.18	*P* for trend = 0.22
2 years			
< 11.0	2.63 (1.51-4.56)	3.71 (2.07-6.65)	3.58 (1.97-6.51)
- 12.0	2.30 (1.37-3.88)	2.84 (1.65-4.90)	2.65 (1.52-4.63)
- 13.0	2.27 (1.35-3.82)	2.69 (1.58-4.60)	2.65 (1.53-4.59)
- 14.0	2.28 (1.31-3.97)	2.43 (1.38-4.29)	2.32 (1.30-4.15)
> 14.0	1	1	1
	P for trend = 0.018	*P* for trend = 0.001	*P* for trend = 0.001

SF-36 score top and middle thirds vs. lowest third (cut-off at 85 for men and 75 women).
Model 1=adjusted for gender, chronological age and length of gestation.
Model 2=Model 1+ adult lean body mass.
Model 3=adjusted for Model 2 + highest social class in childhood and adulthood and smoking status.

Table 4 Odds for Lower SF-36 Physical Functioning at Age 61.6 Years for 1-SD Increase in Conditional Growth from Birth to 11 Years of Age

	OR (95% CI)	
	Model 1*	Model 2†
Weight‡		
0-2 years	0.89 (0.80-0.98)	0.84 (0.75-0.94)
2-7 years	1.06 (0.95-1.18)	0.99 (0.88-1.12)
7-11 years	1.11 (1.01-1.23)	1.07 (0.96-1.19)
Height‡		
0-2 years	0.97 (0.88-1.08)	0.91 (0.81-1.02)
2-7 years	0.98 (0.88-1.09)	0.93 (0.83-1.05)
7-11 years	0.99 (0.89-1.09)	0.97 (0.87-1.09)
BMI‡		
0-2 years	0.89 (0.80-0.98)	0.88 (0.79-0.98)
2-7 years	1.08 (0.97-1.20)	1.05 (0.94-1.17)
7-11 years	1.13 (1.02-1.25)	1.07 (0.96-1.19)

SF-36 score top and middle thirds vs. lowest third (cut-off at 85 for men and 75 women).
BMI= body mass index.
*Adjusted for gender, chronological age, length of gestation.
†Adjusted for gender, chronological age, length of gestation, duration of breastfeeding, adult lean body mass, highest social class in childhood and adulthood and smoking status.
‡Measure at age 7-11 years is the standardized residual of the measure at age 11 years regressed on same measures at birth and ages two and seven years. The conditional measures are adjusted for all earlier values.

Table 5 Odds Ratios for Lower SF-36 Physical Functioning at Age 61.6 Years According to Birth Weight and Body Mass Index at 11 Years of Age

	Odds ratio (95% confidence interval)		
Birth weight (kg)	Body mass index (kg/m^2) at 11 years of age		
	<16	16-17.5	>17.5
<3.0	1.93 (1.21-3.06)[*] / 2.46 (1.51-4.03)[†]	1.46 (0.85-2.51)[*] / 1.57 (0.88-2.80)[†]	2.93 (1.80-4.79)[*] / 3.08 (1.83-5.19)[†]
3.0-3.5	1.67 (1.12-2.50)[*] / 1.92 (1.25-2.95)[†]	1.22 (0.81-1.84)[*] / 1.25 (0.80-1.93)[†]	1.00
>3.5	1.56 (1.00-2.43)[*] / 1.58 (0.98-2.55)[†]	1.29 (0.87-1.93)[*] / 1.37 (0.90-2.09)[†]	1.74 (1.19-2.56)[*] / 1.58 (1.05-2.38)[†]

SF-36 score top and middle thirds vs. lowest third (cut-off at 85 for men and 75 women).
Values for birth weight and body mass index were divided into three equal sized groups.
[*]Adjusted for gender, chronological age and length of gestation
[†]Adjusted for gender, chronological age, length of gestation, adult lean body mass, highest social class in childhood and adulthood and smoking status