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Association of sport participation in preterm and full term born children and body and fat mass indices from age 3 to 14 years

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Abstract

Objectives

To assess the association of gestational age groups (VP: <32 weeks, MP: 32-33 weeks, LP: 34-36 weeks and FT: ≥37 weeks of gestation) and club sport participation in childhood on body mass index (BMI), fat free mass index (FFMI) and fat mass index (FMI).

Design

Longitudinal, cross sectional.

Methods

BMI (age 3, 5, 7, 11 and 14 years; N=10581 to 14702) and FFMI/FMI (age 7, 11 and 14 years; N=10446 to 12996) and consistent club sport participation at age 5, 7 and 11 years (ranging from never participating to participating at all three ages) were assessed prospectively. These were compared by gestational age and their associations with BMI and FMI were investigated, while controlling for confounders (socio-economic, maternal obesity, child related, diet).

Results

BMI and FFMI was lower in VP or MP until age 7, but no differences were found in BMI, FFMI or FMI after age 11 with regard to gestational age. Consistent club sport participation from age 5 to 11 was unrelated to BMI at ages 3 to 7. However, FT children with club sport participation had lower BMI and FMI at ages 11 and 14; but this association was not found in VP or MP.

Conclusion

During adolescence body composition of VP and MP become similar to FT born peers. Consistent sport participation reduces BMI and FMI in FT only. In VP or MP children

modifying effects of sport on body composition might not be detected due to the catch-up growth in weight, height and fat mass at the same time.

Key words: Millennium Cohort Study; sports; body composition; infant, premature;

Practical implications

- Very and moderately preterm born are leaner than term born children.
- During adolescence differences in body composition of different gestational age groups cease to exist.
- Early and consistent club sport participation is associated with lower BMI and FMI in term born adolescents.
- Club sport participation does not influence body composition of very and moderately preterm born significantly.
- Associations of physical activity and body composition should be analysed separately for different gestational age groups.

Abbreviations

BMI body mass index

MCS Millennium Cohort Study

FMI fat mass index

FFMI fat free mass index

MVPA moderate to vigorous physical activity

CI confidence interval

Introduction

Health care professionals regularly recommend participation in organised sport activities (club or class) during childhood to reduce the risk of obesity or overweight in youth. Data support that in the general population[1] continuous club sport participation can be protective against developing obesity in childhood mainly by reducing fat mass, but less so body mass index (BMI). However, there is paucity of studies on the effect of club sport participation on body composition in preterm born individuals In the UK about 1% of all infants are born very preterm (<32 weeks of gestation), 1% are born moderately preterm (32 to 33 weeks of gestation), 4% are born late preterm (34 to 36 weeks of gestation), while the rest is born at term (≥37 weeks of gestation and above)[2].

Firstly, preterm born individuals may not have comparable body composition to those born at term throughout childhood and into adolescence. Differences in body composition between preterm and term born infants have been described at term equivalent age[3], but there is an ongoing discussion at what age these differences resolve[4, 5]. Body mass index differences between preterm and term born adults are not significant but study results are very heterogenous[6]. Nevertheless, a higher metabolic risk has been described for those born preterm[7]. Longitudinal studies reporting on body composition with repeated measurements are lacking.

Secondly, the effect of physical activity on body composition has seldom been studied in preterm born children[8]. Preterm born children are reported to be smaller and leaner[5], or to have a lower lean body mass[9] than term born children. These supposed differences in body composition might influence the relationship between body composition and club sport participation compared to term born populations. Due to the reported higher metabolic risk associated with preterm birth[7], it is important to know whether club sport participation might be an effective strategy to prevent adiposity in preterm born individuals.

This prospective study addresses the above mentioned gaps in research by firstly, investigating changes in body composition of different gestational age groups across childhood while controlling for socio-economic[10], maternal[11] and child factors[12], as well as diet[13] and sport habits. Secondly, it is investigated whether club sport participation affects body and fat mass index and the effects are the same or differ between preterm and term born children while controlling for potential confounders.

Method

The Millennium Cohort Study (MCS) is a representative longitudinal study of 18 818 infants born in the UK[14] born between September 2000 and January 2002. Over-sampling of ethnic minority and disadvantaged areas was used. Parents were interviewed for the first time when the children were aged 9 months (survey 1) and again at 3 (survey 2), 5 (survey 3), 7 (survey 4), 11 (survey 5) and 14 (survey 6) years. Detailed information was collected on maternal, socio-economic and child related factors. Height and weight were measured at age 3, 5, 7, 11 and 14. Body fat was measured at age 7, 11 and 14. Data of twins and triplets are included in the analysis. Ethical approval and written informed consent was obtained for all surveys (London - Hampstead Research Ethics Committee, REC reference 14/LO/0868).

Outcome variables: In order to measure body composition, cohort participants were barefooted, wearing light indoor clothing with emptied pockets and removed hair accessories during measurements. Weight and body fat measurements to one decimal place were obtained using Tanita BF-522W scales (Tanita UK Ltd, Middlesex, UK). Height was measured using Leicester Height Measure Stadiometers (Seca Ltd, Birmingham, UK) and recorded to the nearest millimetre with the head in the Frankfurt plane. Following formulae were used: Body mass index $BMI = \frac{weight\ (kg)}{squared\ height\ (m)}$, Fat mass index $FMI = \frac{fat\ mass\ (kg)}{squared\ height\ (m)}$, and Fat free mass index $FFMI = \frac{fat\ free\ mass\ (kg)}{squared\ height\ (m)}$.

Gestational age in weeks was calculated using the mother's report of the expected due date, which corresponded well with data in routine hospital records[15]. Gestational age was grouped as very preterm (24+0 to 31+6 weeks of gestation), moderately preterm (32+0 to 33+6 weeks of gestation), late preterm (34+0 to 36+6 weeks of gestation) and term (37+0 weeks of gestation and above).

At age 5, 7 and 11 parents reported on the frequency of physical activity in a club or class. The answer was converted into a bivariate variable with a cut-off at club sport participation determined by median split for each age group in the total sample (5 years= once or more a week; 7 years= twice or more a week; 11 years= twice or more a week). The level of consistency of participation in "club sport" was constructed on whether the parents reported across the 3 assessment points from 5-11 years that their child had never, at one, two or all three assessment points participated more than the median in "club sport".

At age 14, self-reported moderate to vigorous physical activity (present MVPA) was used to assess present sport habits and the answer converted into a bivariate variable by median split (i.e. 5 or more days with 60 min. MVPA).

Socio-economic/maternal factors: *Parental education* (equivalent to high school diploma or lower) was used to assess socio-economic factors. *Maternal obesity* (BMI before pregnancy below versus equal or above 25kg/m^2) was used to assess maternal influencing factors.

Child factors: *Gender*, *z-scores for birth weight*[16] (calculated corrected for gestational age using the LMS method[17]), *overweight or obesity* and *underweight* at age 5 (classified using the UK cut-offs for BMI for the corresponding age and gender[18]) were used to assess child related factors.

Diet: *Breastfeeding* (inquired at 9 months of age and converted into a bivariate variable with a cut-off at less versus equal and more than four months), *long term healthy eating habits* (having eaten breakfast every morning at age 5, 7, 11 and 14) and *short term healthy eating habits* (consuming fast food less than once a week at age 14) were used to assess diet.

Participants: Of the 18852 families participating in the MCS we excluded 253 families with missing gestational age[19]. Datasets of twins and triplets were included in the analysis.

Statistical analysis: SPSS version 24 (IBM, Armonk, New York) was used. Descriptive data for BMI, FFMI and FMI were analysed controlling for attrition by using complex sample analysis with the non-response weights provided by the study centre[20]. Results were adjusted in the general linear model for known confounders (gender[21], z-score of birth weight[13], maternal obesity and parental education[22]) and analysed at each age separately. Data for very, moderate and late preterm were compared to term born children using t-test. A p-value <0.05 (Bonferroni adjusted) was regarded significant.

BMI from age 3 to 14 years, FMI and FFMI from age 7 to 14 years, BMI increase from age 3 to 11 years, FMI increase from age 7 to 11 years were compared with regard to "club sport" using complex sample analysis[20]. Results were adjusted in the general linear model for known confounders (gender[21], z-score of birth weight[13], maternal obesity and parental education[22]) at each age and in the very, moderately, late preterm and the term born group separately. Significant differences were analysed using t- test, a p-value <0.05 (Bonferroni adjusted) was regarded significant.

Linear regression analysis was used to analyse whether there were differences with regard to preterm birth of predictors on BMI and FMI at age 14. Despite the large overall sample, numbers of very and moderately preterm born was small. Thus these two gestational age groups were analysed together. Linear regression analysis was performed with known socio-economic/maternal (parental education, maternal obesity) and child factors (gender, z-Score birth weight, overweight or obesity and underweight at age 5), diet (breastfeeding, long and short term healthy eating habits) as well as sport habits ("club sport" and present MVPA)[1, 10, 23]. Unadjusted Coefficient (β), 95% confidence intervals (CI) and adjusted r^2 of the respective variable on BMI/FMI are shown for term, late preterm and very to moderately preterm born adolescents. For each group of variables (socio-economic/maternal, child factors, diet and sport habits) adjusted r^2 was determined. Adjusted β (CI) for the model including all variables and adjusted r^2 are given separately for term, late preterm and very to moderately preterm born adolescents.

To test sensitivity of the linear regression models mentioned above the full models were repeated after multiple imputation of missing data with 5 iterations using SPSS' automatic imputation method. The linear regression models were repeated for the last (fifths) iteration.

Results

Participation rates have been described elsewhere in detail and found that families with lower socio-economic status were more likely to drop-out[14]. BMI data were available for 13758 (74%) (age 3), 14702 (79%) (age 5), 13175 (71%) (age 7), 12433 (67%) (age 11) and 10581 (57%) (age 14). FMI data were available for 12996 (70%) (age 7), 12292 (66%) (age 11) and 10446 (56%) (age 14). A flow chart of participation at the different ages can be found in the Appendix (Figure A1). The distribution of gestational age groups included in the MCS is representative of preterm birth rates in the UK[2].

Very preterm born children had a lower BMI, FFMI and FMI (figure 1) until age 7 compared to term born peers (Appendix table A1). Between age 7 and 14 very preterm born children showed the highest increase in BMI, FFMI and FMI so that differences compared to term born adolescents disappeared (Appendix table A1). Differences in BMI, FFMI and FMI between moderately preterm and term born children were significant in the first 7 years of life. The increase in BMI, FFMI and FMI was comparable to term born peers. Late preterm did not differ significantly in any body measurement in comparison to term born peers.

Term born children did not differ in BMI at age 3, 5 and 7 and FMI at age 7 with regard to their consistency in club sport participation between 5 to 11 years (Appendix table A2). However, BMI and FMI of term born children was lower at age 11 and 14 in those that had engaged more consistently in club sport. Late preterm born children that consistently engaged in club sport had a lower FMI at age 11 compared to those late preterm that did not engage in sport. No other comparisons were significant. BMI and FMI were not significantly related to club sport participation in the very and moderately preterm born groups. The lowest FMI, though not significant, was seen in very and moderately preterm born that had either never or always engaged in club sport.

Accordingly, the increase in BMI from age 3 to 11 and the increase in FMI from age 7 to 11 was lower in term born children engaging more in club sport between age 5 to 11. Late preterm born engaging in club sport had a lower increase in BMI from age 3 to 11, but there were no significant differences for any of the other preterm groups (figure 2, Appendix table A2).

BMI at age 14 (Appendix, Table A3) was lower in term, late preterm and very to moderately preterm born adolescents of higher educated parents and increased with maternal obesity. Female gender was associated with a higher BMI in all gestational groups, while a higher z-score of birth weight was associated with increased BMI at age 14 only in term born. Being overweight at age 5 was associated with higher BMI at age 14 and underweight at age 5 was associated with a lower BMI at age 14. Sport habits (club sport and MVPA at age 14) explained 2% of the variance of BMI in term and late preterm but none in very to moderately preterm born adolescents.

Sport explained 4% of the variance of FMI (Appendix, Table A4) in term, 3% in late preterm and 5% in very to moderately preterm born adolescents. After controlling for socio-economic/maternal, child related factors and diet higher consistency of club sport participation was associated with lower BMI and FMI in term born only (Table 1).

Frequencies of the analysed variables before and after imputation of missing values were comparable (Appendix, Table A5). Sensitivity analysis after imputing missing values revealed similar results for BMI and FMI in term and preterm born adolescents (Appendix, Table A6).

Discussion

This large UK cohort study provides evidence of how body composition changes in term and preterm born individuals from early childhood into adolescence. BMI and FFMI were lower in very and moderately preterm born children in childhood, but they caught up in BMI and FFMI by age 11 and 14 after controlling for known confounders. Findings on FMI from the MCS are comparable at age 11 to a previous UK cohort[5]. While at age 7 very preterm born had the leanest body composition, their FMI at age 14 was higher than those born at term indicating the importance of longitudinal follow-up to capture changing body composition with advancing age in preterm born cohorts.

Similar to previous studies up to 23% of variance in BMI and FMI at age 14 were explained by maternal obesity, gender[11, 22] and early childhood weight development[12], i.e. factors that cannot be modified in middle childhood or adolescence anymore. On the other hand, factors that are modifiable like diet and sport had only a small impact on BMI and FMI. Participation in club sport during childhood, particularly participation over years, had a small but positive influence in reducing FMI and to a lesser extent BMI in term born children. This is consistent with a meta-analysis on the influence of club sport participation[24] on FMI. In contrast, the influence of club sport on BMI according to a recent systematic review is inconclusive[25]. However, few previous studies utilised a longitudinal design and controlled for confounders[25].

During early childhood BMI did not differ in the MCS in children with regard to later consistency of club sport participation. However, differences emerged soon after starting club sport with the greatest, albeit small effect for consistent participation. A dose response relationship between the children's consistency in club sport participation and a lower BMI and FMI was found. The more consistent term born children participated in sport the lower was the increase in BMI from age 3, and FMI from age 7 to age 11. A previous longitudinal study in children suggested that obesity is leading to subsequent inactivity in children[26]. In our study we controlled for known early childhood confounders and the findings suggest that club sport participation influences later body composition over and above starting BMI or

FMI. Our data support that club sport should be encouraged at pre-school age already and participation needs to be maintained across childhood to have significant effects on body composition in childhood and adolescence.

While in term born children club sport influenced body composition positively, this relationship was more complex in very and moderately preterm born children. Those very and moderately preterm born children with the least and those with the most consistent club sport participation had the lowest BMI and FMI at age 7 and 11. This finding indicates that lean very and moderately preterm born children might miss out on club sport. Similarly, a Finnish cohort reported a lower body fat percentage in physically inactive preterm born young adults[27]. Therefore, the association between club sport and body composition seems to be bidirectional in very and moderately preterm born children. The age range analysed for the influence of club sport on body composition in this study overlaps with the period of "catch-up" growth in very and moderately preterm compared to term born children, as shown above. From age 11 to 14 those previously lean, very preterm born children that never participated in club sport showed the highest increase in BMI and FMI. Further follow-up is needed to differentiate whether this increase represents "delayed catch-up growth", earlier "growth spurt of puberty"[28] or the beginning of adiposity. Therefore, early and consistent club sport participation might still have a moderating effect on body composition for very and moderately preterm born children. We need prospective, longitudinal studies inquiring type, duration and intensity of club sport combined with objective measurements of physical activity to determine a possible dose relationship. On available data early and consistent participation in club sport should be advised in preterm born children as well. However, effects of club sport participation on body composition may not be immediate in the preterm population but preventive in transition to adolescence.

Strengths of this study are the prospective longitudinal design that allowed for analysis of BMI and FMI repeatedly across childhood into adolescence. The sample size of preterm children is large and exceeds those of most neonatal cohort studies[29]. Complex sample analysis allowed controlling for attrition and analysis was adjusted for numerous potential confounders. The first 1000 days have been identified as a crucial period for the origins of childhood obesity. Several risk factors have been consistently associated with later obesity and include high maternal BMI, smoking during pregnancy, high infant birth weight and accelerated infant weight gain[30] and we were able to control our data for these risk factors.

There are also limitations. The Millennium Cohort study is a population based sample and probably represents a group of preterm born children with less impairment. For example, a previous study[31] found that rates of severe motor impairment were lower than expected for the gestational age groups[32]. Participation in physical activity was analysed before and no difference were found across the gestational age groups[31]. Even though the cohort is large, numbers of extremely preterm were very low and thus statistical power insufficient for further separate analysis. Detailed information of neonatal complications was not available and we could not control for frequent complications of prematurity associated with lower BMI during childhood, such as Bronchopulmonary Dysplasia. FMI was first assessed at age 7 and may have already been influenced by club sport participation in some children. The different gestational age groups might differ in the preferred type or the intensity of the club sport training, but these data were not assessed in the MCS. The Millennium Cohort used the chronological and not the corrected age for their surveys, therefore very preterm born are about 2 1/2 months, moderate preterm born about 2 months and late preterm born about 1 month younger than term born peers at each survey. While we were able to control for attrition using complex sample design we were unable to control for repeated measurements (generalizing estimating equations) at the same time.

Conclusion

During early childhood BMI and FFMI was lower in very and moderately preterm born children than term born children. However, these differences according to gestational age disappeared from 11 years onwards.

Child factors like gender and early childhood weight best explained BMI and FMI in all gestational age groups. Parental education and maternal obesity had an additional small impact on body composition in very to moderately preterm born adolescents. Early and consistent sport club participation had a very small influence on BMI and FMI in term born children only. Very and moderately preterm born children have a different development of body composition compared to term born peers. Modifying effects of club sport participation on body composition in very and moderately preterm born might not be detected due to the catch-up growth in weight, height and fat mass at the same time. However, as a modifiable factor, club sport should be encouraged in both, term and preterm born children.

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Table 1: Sport habits associated with body and fat mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

Linear regression analysis, dependent variable is the body mass index (kg weight/height in m^2) and fat mass index (kg fat/height in m^2), the models are controlled for socio-economic factors (parental education, maternal obesity during pregnancy), child related factors (gender, z-score of birth weight, over- or underweight at age 5) and dietary factors (breast feeding, long and short term healthy eating habits) (full model and unadjusted β (95%CI) shown in Appendix table A3 and A4)

Table A1: Body mass index, Fat mass index and Fat free mass index for different gestational age groups and ages

BMI: body mass index, FMI: fat mass index, FFMI fat free mass index. VP: very preterm, MP: moderately preterm, LP: late preterm, FT: full term born. Mean and 95% confidence interval adjusted for gender, z-score of birth weight, maternal obesity during pregnancy and parental education are given. P-values are given for the comparison to full term born children.

Table A2: Fat mass index and body mass index for different gestational age groups and ages with regard to sport club participation

BMI: body mass index, FMI: fat mass index. Mean and 95% confidence interval adjusted for gender, z-score of birth weight, maternal obesity during pregnancy and parental education are given. Significant group differences ($p<0.05$) are highlighted in bold.

Table A3: Factors associated with body mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

Linear regression analysis, dependent variable is the body mass index (kg weight/height in m2), adj. r2 for the group of socio-economic/maternal, child factors, diet and sport are given in the according grey row

Table A4: Factors associated with fat mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

Linear regression analysis, dependent variable is the fat mass index (kg body fat/height in m^2), adj. r^2 for the group of socio-economic/maternal, child factors, diet and sport are given in the according grey row

Table A5: Comparison of data before and after imputation of missing data

Table A6: Factors associated with **body and fat mass index** for term, late preterm and very to moderately preterm born adolescents at age 14 after imputations of missing data

Dependent variable is the body mass index (kg weight/height in m^2) and fat mass index (kg body fat/height in m^2)

Figure 1: Mean BMI from age 3 to 14 and FFMI and FMI from age 7 to 14 for different gestational age groups after controlling for attrition (complex sample analysis), gender, z-score of birth weight, maternal obesity and parental education. VP vs. FT born children had a lower BMI at age 3 ($p<0.001$), 5 ($p=0.04$) and 7 ($p<0.01$), MP vs. FT born children had a lower BMI at age 3 ($p<0.001$), 5 ($p=0.01$), 7 ($p=0.01$) and 11 ($p=0.03$), BMI of LP never differed from FT born at any age. VP vs. FT born children had a lower FFMI at age 7 ($p<0.001$), MP vs. FT born children had a lower FFMI at age 7 ($p<0.01$) and 11 ($p=0.01$). Group differences for FMI were not significant at any age.

BMI: Body mass index, FFMI: fat free mass index, FMI: fat mass index. VP: very preterm, MP: moderately preterm, LP: late preterm, FT: term born.

Figure 2: Increase in BMI (kg/m2) from age 3 to 11 and FMI (kg/m2) from age 7 to age 11 with regard to participation in club sport between age 5 to 11 more than average after controlling for attrition by complex sample analysis as well as parental education, maternal obesity, gender and z-score of birth weight. * $p<0.05$, ** $p<0.001$; VP: very preterm, MP: moderately preterm, LP: late preterm, FT: term born.

Figure A1: Flow chart of study participation and exclusions. Percentages are of the original sample at 9 months with valid gestational age n=18 565. Club sport: participation in organised physical activity age 5 to 11. FMI: Fat mass index. BMI: body mass index

Table 1: Sport habits associated with body and fat mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

		Term Adjusted β (95%CI)	Late preterm Adjusted β (95%CI)	Very and moderately preterm adjusted β (95%CI)
BMI				
	once	-0.16 (-0.39 to 0.08)	-0.16 (-1.34 to 0.81)	-0.38 (-1.74 to 0.98)
Club sport	twice	**-0.15 (-0.27 to -0.03)**	-0.04 (-0.52 to 0.45)	0.41 (-0.31 to 1.12)
	always	**-0.26 (-0.50 to -0.02)**	-0.29 (-1.28 to 0.71)	0.24 (-1.49 to 1.98)
MPVA age 14 > average		**-0.56 (-0.72 to -0.40)**	-0.69 (-1.38 to 0.01)	-0.29 (-1.49 to 0.92)
N (adjusted r^2)		7377 (0.32)	435 (0.30)	163 (0.28)
FMI				
	once	**-0.20 (-0.36 to -0.04)**	-0.17 (-0.90 to 0.55)	-0.43 (-1.73 to 0.46)
Club sport	twice	**-0.16 (-0.24 to -0.08)**	-0.08 (-0.44 to 0.28)	0.06 (-1.33 to 0.65)
	always	**-0.35 (-0.52 to -0.18)**	-0.61 (-1.35 to 0.13)	-0.09 (-1.22 to 1.04)
MPVA age 14 > average		**-0.50 (-0.61 to -0.39)**	-0.34 (-0.85 to 0.17)	-0.44 (-1.22 to 0.35)
N (adjusted r^2)		7293 (0.39)	430 (0.33)	162 (0.42)

Linear regression analysis, dependent variable is the body mass index (kg weight/height in m^2) and fat mass index (kg fat/height in m^2), the models are controlled for socio-economic factors (parental education, maternal obesity during pregnancy), child related factors (gender, z-score of birth weight, over- or underweight at age 5) and dietary factors (breast feeding, long and short term healthy eating habits) (full model and unadjusted β (95%CI) shown in Appendix table A3 and A4)

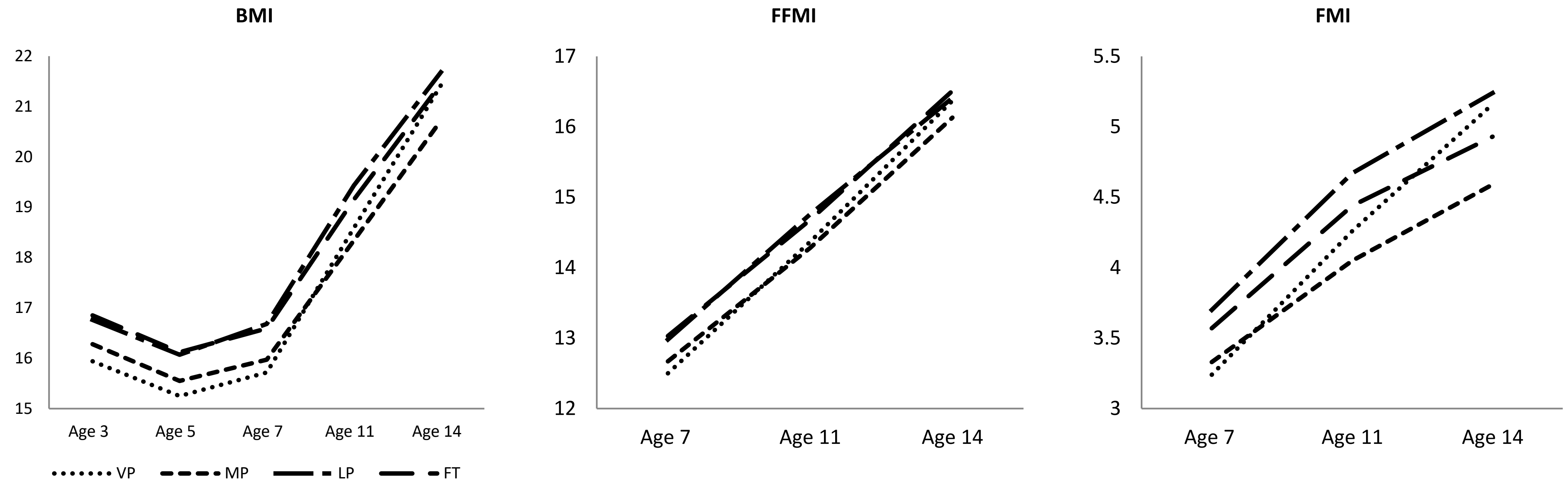

Figure 1: Mean BMI from age 3 to 14 and FFMI and FMI from age 7 to 14 for different gestational age groups after controlling for attrition (complex sample analysis), gender, z-score of birth weight, maternal obesity and parental education. VP vs. FT born children had a lower BMI at age 3 ($p<0.001$), 5 ($p=0.04$) and 7 ($p<0.01$), MP vs. FT born children had a lower BMI at age 3 ($p<0.001$), 5 ($p=0.01$), 7 ($p=0.01$) and 11 ($p=0.03$), BMI of LP never differed from FT born at any age. VP vs. FT born children had a lower FFMI at age 7 ($p<0.001$), MP vs. FT born children had a lower FFMI at age 7 ($p<0.01$) and 11 ($p=0.01$). Group differences for FMI were not significant at any age.

BMI: Body mass index, FFMI: fat free mass index, FMI: fat mass index. VP: very preterm, MP: moderately preterm, LP: late preterm, FT: term born.

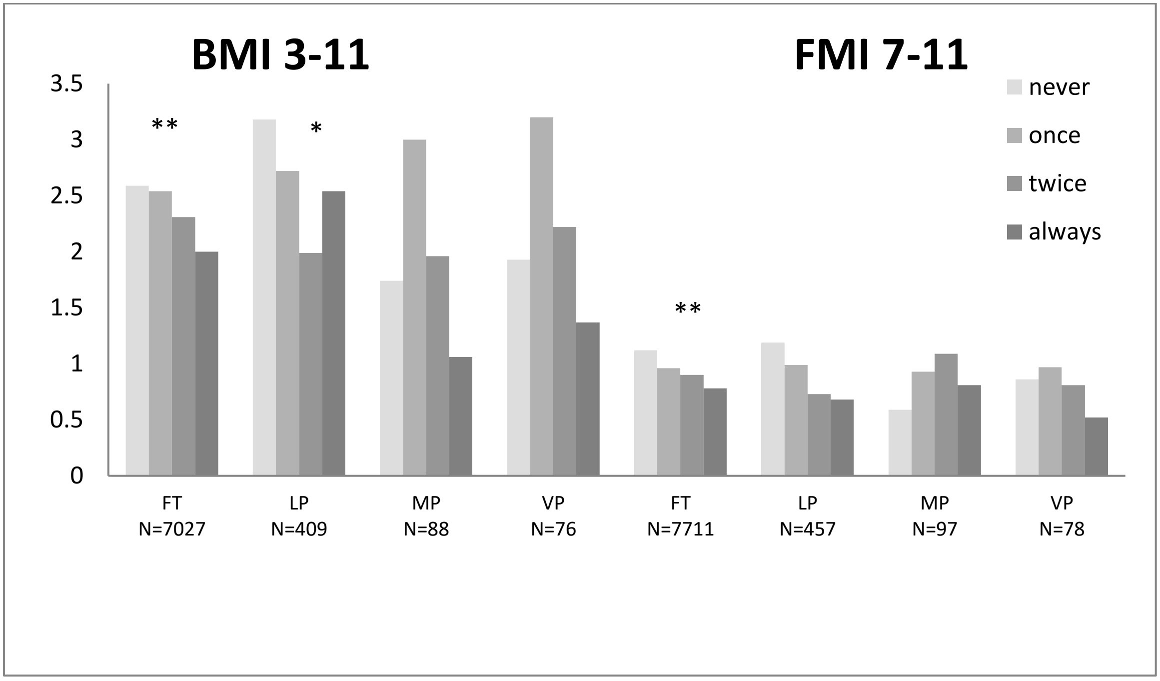

Figure 2: Increase in BMI (kg/m^2) from age 3 to 11 and FMI (kg/m^2) from age 7 to age 11 with regard to participation in club sport between age 5 to 11 more than average after controlling for attrition by complex sample analysis as well as parental education, maternal obesity, gender and z-score of birth weight. * $p<0.05$, ** $p<0.001$; VP: very preterm, MP: moderately preterm, LP: late preterm, FT: term born.

Appendix:

Table A1: Body mass index, Fat mass index and Fat free mass index for different gestational age groups and ages

	VP		MP		LP		FT
BMI		p		p		p	
Age 3	15.9 (15.6-16.2)	<0.001	16.3 (16.0-16.6)	<0.001	16.8 (16.5-17.0)	1.0	16.8 (16.8-16.9)
Age 5	15.3 (14.6-15.9)	0.04	15.5 (15.2-16.9)	0.01	16.1 (15.9-16.3)	1.0	16.1 (16.1-16.2)
Age 7	15.7 (15.2-16.2)	0.003	16.0 (15.6-16.4)	0.01	16.7 (16.4-16.9)	1.0	16.6 (16.5-16.6)
Age 11	18.6 (17.7-19.5)	0.64	18.3 (17.7-19.0)	0.03	19.4 (19.0-19.8)	0.54	19.1 (19.1-19.2)
Age 14	21.4 (19.8-23.0)	1.0	20.7 (19.8-21.6)	0.34	21.7 (21.2-22.1)	1.0	21.4 (21.3-21.6)
FMI							
Age 7	3.2 (2.9-3.6)	0.11	3.3 (3.0-3.6)	0.26	3.7 (3.5-3.9)	0.44	3.6 (3.5-3.6)
Age 11	4.3 (3.8-4.8)	1.0	4.1 (3.7-4.4)	0.15	4.7 (4.4-4.9)	0.34	4.4 (4.4-4.5)
Age 14	5.2 (4.1-6.2)	1.0	4.6 (4.0-5.2)	0.75	5.2 (4.9-5.6)	0.21	4.9 (4.8-5.0)
FFMI							
Age 7	12.5 (12.2-12.8)	<0.001	12.7 (12.5-12.9)	0.002	13.0 (12.9-13.1)	0.83	13.0 (13.0-13.1)
Age 11	14.4 (14.0-14.8)	0.41	14.3 (14.0-14.5)	0.01	14.8 (14.6-14.9)	1.0	14.7 (14.6-14.7)
Age 14	16.4 (15.8-16.9)	1.0	16.1 (15.7-16.5)	0.18	16.4 (16.2-16.6)	1.0	16.5 (16.5-16.6)

BMI: body mass index, FMI: fat mass index, FFMI fat free mass index. VP: very preterm, MP: moderately preterm, LP: late preterm, FT: full term born. Mean and 95% confidence interval adjusted for gender, z-score of birth weight, maternal obesity during pregnancy and parental education are given. P-values are given for the comparison to full term born children.

Table A2: Fat mass index and body mass index for different gestational age groups and ages with regard to sport club participation

		VP	MP	LP	FT
BMI					
	Never	15.9 (15.1-16.7)	16.2 (15.8-16.7)	17.0 (16.4-17.6)	16.8 (16.7-16.9)
	Once	16.2 (15.6-16.8)	15.8 (15.3-16.3)	16.8 (16.0-17.7)	16.8 (16.7-16.9)
Age 3	Twice	16.1 (15.4-16.8)	16.6 (15.7-17.6)	16.5 (16.2-16.9)	16.9 (16.8-16.9)
	Always	15.5 (14.7-16.2)	16.5 (15.9-17.1)	16.6 (16.3-17.0)	16.9 (16.8-17.0)
		N=93	N=98	N=489	N=8217
	Never	16.1 (14.8-17.4)	15.9 (15.2-16.5)	16.4 (16.1-16.8)	16.1 (15.9-16.2)
	Once	14.8 (1.9-16.8)	15.3 (14.9-15.8)	16.1 (15.6-16.6)	16.2 (16.1-16.3)
Age 5	Twice	15.4 (14.4-16.4)	16.2 (14.8-17.6)	16.0 (15.6-16.3)	16.3 (16.2-16.3)
	Always	15.2 (14.3-16.2)	15.8 (15.1-16.5)	16.1 (15.7-16.6)	16.2 (16.1-16.3)
		N=103	N=112	N=575	N=9442
	Never	15.9 (14.9-16.8)	15.8 (15.1-16.6)	17.0 (16.4-17.6)	16.5 (16.4-16.6)
	Once	16.4 (15.2-17.6)	15.6 (14.9-16.3)	16.8 (16.3-17.4)	16.7 (16.6-16.8)
Age 7	Twice	15.9 (14.8-17.0)	16.5 (15.4-17.5)	16.3 (15.9-16.7)	16.5 (16.4-16.6)
	Always	14.6 (13.3-15.8)	15.7 (15.0-16.3)	16.5 (16.1-16.9)	16.5 (16.4-16.6)
		N=100	N=112	N=568	N=9340
	Never	17.8 (14.4-17.2)	18.0(17.0-19.0)	20.1 (19.2-21.0)	**19.3 (19.1-19.6)**
	Once	19.3 (17.7-20.9)	18.0 (16.8-19.2)	19.3 (18.5-20.0)	**19.3 (19.1-19.5)**
Age 11	Twice	18.5 (17.2-19.9)	19.3 (17.8-20.9)	18.9 (18.3-19.5)	**19.0 (18.9-19.2)**
	Always	17.0 (15.4-18.5)	17.7 (16.2-19.1)	19.2 (18.5-19.9)	**18.8 (18.7-19.0)**
		N=99	N=111	N=559	**N=9181**
	Never	20.9 (18.7-23.1)	20.1 (18.9-21.3)	22.1 (20.8-23.3)	**21.6 (21.3-22.0)**
	Once	20.7 (19.4-22.1)	20.8 (19.6-22.0)	22.2 (21.2-23.1)	**21.5 (21.3-21.8)**
Age 14	Twice	20.9 (19.4-22.3)	22.2 (20.1-24.4)	21.4 (20.6-22.2)	**21.3 (21.1-21.5)**
	Always	18.6 (16.7-20.5)	20.1 (17.6-22.6)	21.4 (20.7-22.1)	**21.2 (21.05-21.3)**
		N=76	N=96	N=458	**N=7721**
FMI					
	Never	3.2 (2.6-3.8)	3.1 (2.7-3.6)	3.9 (3.4-4.4)	3.6 (3.5-3.7)
	Once	3.8 (2.9-4.7)	3.3 (2.9-3.7)	3.8 (3.4-4.3)	3.6 (3.5-3.7)
Age 7	Twice	3.3 (2.6-4.0)	3.6 (2.9-4.35)	3.4 (3.1-3.6)	3.5 (3.5-3.6)
	Always	2.8 (2.1-3.5)	2.8 (2.3-3.4)	3.6 (3.3-3.8)	3.5 (3.4-3.5)
		N=83	N=100	N=474	N=7963
	Never	4.1 (2.9-5.2)	3.7 (2.9-4.5)	**5.1 (4.4-5.8)**	**4.7 (4.5-4.8)**
	Once	4.8 (3.5-6.0)	4.3 (3.4-5.1)	**4.9 (4.3-5.4)**	**4.6 (4.4-4.7)**
Age 11	Twice	4.2 (3.2-5.2)	4.7 (3.6-5.8)	**4.1 (3.7-4.5)**	**4.4 (4.3-4.5)**
	Always	3.3 (2.4-4.2)	3.6 (2.7-4.6)	**4.2 (3.8-4.6)**	**4.2 (4.1-4.3)**
		N=79	N=97	**N=464**	N=7893
	Never	5.0 (3.6-6.4)	4.4 (3.5-5.3)	5.5 (4.7-6.3)	**5.2 (5.0-5.4)**
	Once	4.1 (3.5-4.8)	4.9 (4.2-5.7)	5.7 (5.0-6.4)	**5.1 (4.9-5.2)**
Age 14	Twice	4.8 (3.8-5.8)	5.7 (4.4-6.9)	5.0 (4.5-5.6)	**4.8 (4.7-5.0)**
	Always	3.0 (1.8-4.1)	4.3 (2.5-6.1)	4.7 (4.2-5.1)	**4.7 (4.5-4.8)**
		N=75	N=96	N=453	N=7631

BMI: body mass index, FMI: fat mass index. Mean and 95% confidence interval adjusted for gender, z-score of birth weight, maternal obesity during pregnancy and parental education are given. Significant group differences (p<0.05) are highlighted in bold.

Table A3: Factors associated with body mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

		Term			Late preterm			Very and moderately preterm		
		unadjusted β (95%CI)	Adj. r^2	Adjusted β (95%CI)	unadjusted β (95%CI)	Adj. r^2	Adjusted β (95%CI)	unadjusted β (95%CI)	Adj. r^2	adjusted β (95%CI)
Socio-economic/maternal			**0.074**			**0.054**			**0.122**	
Higher parental education		**-0.93 (-1.11 to -0.76)**	**0.013**	**-0.42 (-0.58 to -0.25)**	**-1.36 (-2.09 to -0.62)**	**0.024**	**-1.21 (-1.94 to -0.47)**	**-1.22 (-2.29 to -0.16)**	**0.021**	**-1.28 (-2.42 to -0.13)**
Maternal obesity		**2.25 (2.06 to 2.44)**	**0.064**	**1.55 (1.37 to 1.72)**	**1.58 (0.75 to 2.42)**	**0.027**	**0.86 (0.12 to 1.59)**	**3.00 (1.68 to 4.32)**	**0.100**	**2.20 (0.91 to 3.49)**
Child			**0.258**			**0.259**			**0.203**	
Gender female		**1.00 (0.83 to 1.17)**	**0.015**	**0.67 (0.52 to 0.83)**	**0.85 (0.11 to 1.59)**	**0.008**	0.25 (-0.46 to 0.95)	**1.67 (0.61 to 2.73)**	**0.043**	**1.30 (1.24 to 2.37)**
Birth weight z-score		**0.23 (0.14 to 0.32)**	**0.003**	-0.02 (-0.11 to 0.07)	0.35 (0.02 to 0.69)	0.007	0.17 (-0.15 to 0.49)	0.20 (-0.23 to 0.63)	0.000	-0.09 (-0.54 to 0.36)
Overweight at age 5		**4.92 (4.73 to 5.11)**	**0.233**	**4.41 (4.21 to 4.60)**	**5.15 (4.34 to 5.96)**	**0.238**	**4.29 (3.43 to 5.16)**	**3.51 (1.87 to 5.15)**	**0.080**	**2.46 (0.73 to 4.20)**
Underweight at age 5		**-2.89 (-3.31 to -2.47)**	**0.021**	**-2.43 (-2.87 to -2.00)**	**-3.27 (-4.80 to -1.75)**	**0.033**	**-2.22 (-3.60 to -0.84)**	**-4.10 (-5.64 to -2.56)**	**0.121**	**-3.09 (-4.75 to -1.43)**
Diet			**0.035**			**0.027**			0.004	
Breast feeding		**-0.74 (-0.92 to -0.56)**	**0.007**	**-0.24 (-0.41 to -0.07)**	-0.82 (-1.66 to 0.03)	**0.005**	-0.40 (-1.22 to 0.43)	-0.22 (-1.49 to 1.05)	0.000	0.20 (-1.10 to 1.49)
Long term healthy eating habits		**-1.36 (-1.54 to -1.19)**	**0.028**	**-0.73 (-0.89 to -0.57)**	**-0.98 (-1.71 to -0.25)**	**0.012**	-0.56 (-1.27 to 0.16)	-0.61 (-1.72 to 0.50)	0.001	-0.14 (-1.21 to 0.93)
Short term healthy eating habits		-0.27 (-0.47 to 0.07)	0.001	**-0.48 (-0.66 to -0.30)**	-0.72 (-1.52 to 0.09)	0.004	**-0.99 (-1.78 to -0.21)**	-0.93 (-2.20 to 0.33)	0.006	-0.36 (-1.70 to 0.98)
Sport			**0.018**			**0.022**			0.001	
	once	-0.18 (-0.43 to 0.08)		-0.16 (-0.39 to 0.08)	0.22 (-0.84 to 1.28)		-0.16 (-1.34 to 0.81)	-0.25 (-1.66 to 1.16)		-0.38 (-1.74 to 0.98)
Club sport	twice	**-0.28 (-0.41 to -0.15)**	**0.006**	**-0.15 (-0.27 to -0.03)**	-0.41 (-0.92 to 0.11)	0.010	-0.04 (-0.52 to 0.45)	0.18 (-0.58 to 0.94)	0.000	0.41 (-0.31 to 1.12)
	always	**-0.81 (-1.07 to -0.56)**		**-0.26 (-0.50 to -0.02)**	-1.02 (-2.10 to 0.05)		-0.29 (-1.28 to 0.71)	-0.05 (-1.74 to 1.64)		0.24 (-1.49 to 1.98)
MPVA age 14 > average		**-1.04 (-1.22 to -0.86)**	**0.015**	**-0.56 (-0.72 to -0.40)**	**-1.23 (-1.97 to -0.49)**	**0.019**	-0.69 (-1.38 to 0.01)	-1.07 (-2.22 to 0.08)	0.012	-0.29 (-1.49 to 0.92)
N (adjusted r^2)				7377 (0.32)			435 (0.30)			163 (0.28)

Linear regression analysis, dependent variable is the body mass index (kg weight/height in m^2), adj. r^2 for the group of socio-economic/maternal, child factors, diet and sport are given in the according grey row

Table A4: Factors associated with fat mass index at age 14 for term, late preterm and very to moderately preterm born adolescents

		Term			Late preterm			Very and moderately preterm		
		unadjusted β (95%CI)	Adj. r^2	Adjusted β (95%CI)	unadjusted β (95%CI)	Adj. r^2	Adjusted β (95%CI)	unadjusted β (95%CI)	Adj. r^2	adjusted β (95%CI)
Socio-economic/maternal			**0.059**			**0.049**			**0.117**	
Higher parental education		**-0.72 (-0.85 to -0.59)**	**0.014**	**-0.29 (-0.41 to -0.17)**	**-1.01 (-1.57 to -0.45)**	**0.023**	**-0.92 (-1.46 to -0.37)**	**-0.83 (-1.58 to -0.08)**	**0.019**	**-0.87 (-1.61 to -0.12)**
Maternal obesity		**1.45 (1.31 to 1.59)**	**0.049**	**1.01 (0.89 to 1.13)**	**1.03 (0.39 to 1.67)**	**0.019**	**0.67 (0.13 to 1.22)**	**2.07 (1.10 to 3.03)**	**0.090**	**1.46 (0.62 to 2.31)**
Child			**0.334**			**0.301**			**0.355**	
Gender female		**2.39 (2.28 to 2.51)**	**0.160**	**2.15 (2.04 to 2.26)**	**2.29 (1.77 to 2.82)**	**0.129**	**1.86 (1.34 to 2.38)**	**2.80 (2.15 to 3.46)**	**0.269**	**2.36 (1.65 to 3.06)**
Birth weight z-score		-0.07 (-0.14 to 0.01)	0.000	-0.06 (-0.12 to 0.003)	0.04 (-0.22 to 0.29)	0.000	0.04 (-0.20 to 0.28)	0.03 (-0.28 to 0.33)	0.000	-0.05 (-0.34 to 0.25)
Overweight at age 5		**3.16 (3.02 to 3.31)**	**0.178**	**2.77 (2.64 to 2.91)**	**3.45 (2.80 to 4.09)**	**0.183**	**2.89 (2.25 to 3.53)**	**2.71 (1.54 to 3.88)**	**0.095**	**1.72 (0.57 to 2.87)**
Underweight at age 5		**-1.50 (-1.81 to -1.18)**	**0.010**	**-1.16 (-1.47 to -0.86)**	**-1.89 (-3.07 to -0.70)**	**0.018**	**-1.19 (-2.22 to -0.15))**	**-1.99 (-3.12 to -0.87)**	**0.056**	**-1.33 (-2.42 to -0.25)**
Diet			**0.048**			**0.034**			0.006	
Breast feeding		**-0.53 (-0.66 to -0.39)**	**0.007**	**-0.18 (-0.30 to -0.07)**	-0.42 (-1.06 to 0.22)	0.001	-0.06 (-0.67 to 0.56)	-0.29 (-1.18 to 0.61)	0.000	0.16 (-0.68 to 1.00)
Long term healthy eating habits		**-1.24 (-1.37 to -1.11)**	**0.042**	**-0.52 (-0.63 to -0.41)**	**-1.08 (-1.63 to -0.53)**	**0.028**	-0.37 (-0.90 to 0.16)	-0.40 (-1.20 to 0.40)	0.000	-0.15 (-0.85 to 0.55)
Short term healthy eating habits		-0.12 (-0.27 to 0.02)	0.000	**-0.25 (-0.38 to -0.13)**	-0.25 (-0.97 to 0.26)	0.001	**-0.63 (-1.20 to -0.05)**	-0.63 (-1.54 to 0.28)	0.005	-0.27 (-1.14 to 0.61)
Sport			**0.040**			**0.031**			**0.045**	
	once	**-0.23 (-0.42 to -0.04)**		**-0.20 (-0.36 to -0.04)**	0.11 (-0.69 to 0.92)		-0.17 (-0.90 to 0.55)	-0.53 (-1.53 to 0.47)		-0.43 (-1.73 to 0.46)
Club sport	twice	**-0.29 (-0.38 to -0.19)**	**0.010**	**-0.16 (-0.24 to -0.08)**	-0.30 (-0.70 to 0.09)	**0.020**	-0.08 (-0.44 to 0.28)	0.02 (-0.52 to 0.56)	0.000	0.06 (-1.33 to 0.65)
	always	**-0.83 (-1.02 to -0.64)**		**-0.35 (-0.52 to -0.18)**	**-1.17 (-1.99 to -0.35)**		-0.61 (-1.35 to 0.13)	-0.53 (-1.72 to 0.66)		-0.09 (-1.22 to 1.04)
MPVA age 14 > average		**-1.15 (-1.28 to -1.02)**	**0.035**	**-0.50 (-0.61 to -0.39)**	**-0.96 (-1.52 to -0.40)**	**0.021**	-0.34 (-0.85 to 0.17)	**-1.36 (-2.16 to -0.57)**	**0.052**	-0.44 (-1.22 to 0.35)
N (adjusted r^2)				7293 (0.39)			430 (0.33)			162 (0.42)

Linear regression analysis, dependent variable is the fat mass index (kg body fat/height in m^2), adj. r^2 for the group of socio-economic/maternal, child factors, diet and sport are given in the according grey row

Table A5: Comparison of data before and after imputation of missing data

	Body mass index		Fat mass index	
		imputed		imputed
Socio-economic/maternal				
Higher parental education in %	4780/9003 (53%)	4845/9166 (53%)	4735/8893 (53%)	4797/9052 (53%)
Maternal obesity in %	2460/8486 (29%)	2676/9166 (29%)	2423/8387 (29%)	2635/9052 (29%)
Child				
Gender female in %	4583/9166 (50%)	4583/9166 (50%)	4533/9052 (50%)	4533/9052 (50%)
Overweight at age 5 in %	1817/9094 (20%)	1856/9166 (20%)	1794/8982 (20%)	1832/9052 (20%)
Underweight at age 5 in %	346/9091 (4%)	418/9166 (5%)	340/8979 (4%)	410/9052 (5%)
Diet				
Breast feeding in %	3140/9165 (34%)	3141/9166 (34%)	3113/9051 (34%)	3114/9052 (34%)
Long term healthy eating habits in %	4389/8861 (50%)	4518/9166 (34%)	4337/8750 (50%)	4464/9052 (49%)
Short term healthy eating habits in %	6668/9097 (73%)	6706/9166 (73%)	6590/8986 (73%)	6626/9052 (73%)
Sport				
Club sport Once in %	2486/9166 (27%)	2486/9166 (27%)	2449/9052 (27%)	2449/9052 (27%)
Club sport Twice in %	2451/9166 (27%)	2451/9166 (27%)	2429/9052 (27%)	2429/9052 (27%)
Club sport Always in %	2383/9166 (26%)	2383/9166 (26%)	2362/9052 (26%)	2362/9052 (26%)
MPVA age 14 > average in %	3504/9122 (38%)	3514/9166 (38%)	3461/9009 (38%)	3471/9052 (38%)

Table A6: Factors associated with **body and fat mass index** for term, late preterm and very to moderately preterm born adolescents at age 14 after imputations of missing data

		Body mass index Term	Late preterm	Very and moderately preterm	Fat mass index Term	Late preterm	Very and moderately preterm
		Adjusted Coefficient B (95%CI)	Adjusted Coefficient B (95%CI)	adjusted Coefficient B (95%CI)	Adjusted Coefficient B (95%CI)	Adjusted Coefficient B (95%CI)	adjusted Coefficient B (95%CI)
Socio-economic/maternal							
Higher parental education		**-0.40 (-0.57 to -0.23)**	**-1.10 (-1.81 to -0.40)**	**-1.19 (-2.26 to -0.13)**	**-0.30 (-0.41 to -0.18)**	**-0.81 (-1.33 to -0.28)**	**-0.83 (-1.51 to -0.15)**
Maternal obesity		**1.38 (1.22 to 1.55)**	**0.58 (-0.18 to 1.15)**	**2.07 (0.68 to 3.45)**	**0.91 (0.79 to 1.03)**	0.48 (-0.05 to 1.00)	**1.22 (0.37 to 2.08)**
Child							
Gender female		**0.65 (0.50 to 0.80)**	0.49 (-0.46 to 0.95)	**1.00 (-0.01 to 2.00)**	**2.13 (2.02 to 2.23)**	**2.01 (1.52 to 2.51)**	**2.32 (1.68 to 2.95)**
Birth weight z-score		0.02 (-0.07 to 0.10)	0.05 (-0.26 to 0.35)	-0.16 (-0.58 to 0.25)	-0.04 (-0.10 to 0.01)	-0.04 (-0.27 to 0.18)	-0.10 (-0.37 to 0.16)
Overweight at age 5		**4.42 (4.22 to 4.61)**	**4.55 (3.71 to 5.38)**	**2.25 (0.57 to 3.93)**	**2.78 (2.64 to 2.91)**	**2.99 (2.38 to 3.61)**	**1.60 (0.53 to 2.68)**
Underweight at age 5		**-1.94 (-3.09 to -0.79)**	**-2.01 (-3.41 to -0.62)**	**-3.68 (-5.18 to -2.18)**	**-0.90 (-1.62 to -0.18)**	**-1.10 (-2.13 to -0.07)**	**-1.56 (-2.51 to -0.62)**
Diet							
Breast feeding		**-0.27 (-0.43 to -0.10)**	-0.23 (-1.02 to 0.55)	0.55 (-0.63 to 1.73)	**-0.19 (-0.30 to -0.08)**	0.04 (-0.54 to 0.62)	0.40 (-0.35 to 1.14)
Long term healthy eating habits		**-0.80 (-0.95 to -0.64)**	-0.39 (-1.08 to 0.31)	-0.44 (-1.45 to 0.57)	**-0.55 (-0.66 to -0.44)**	-0.28 (-0.80 to 0.23)	-0.26 (-0.90 to 0.37)
Short term healthy eating habits		**-0.40 (-0.57 to -0.23)**	**-0.94 (-1.70 to -0.17)**	-0.07 (-1.23 to 1.38)	**-0.19 (-0.31 to -0.07)**	**-0.57 (-1.13 to -0.01)**	0.01 (-0.79 to 0.81)
Sport							
	Once	-0.14 (-0.35 to 0.08)	0.03 (-0.89 to 0.94)	0.05 (-1.18 to 1.28)	**-0.17 (-0.32 to -0.02)**	-0.06 (-0.74 to 0.62)	-0.26 (-1.04 to 0.52)
Club sport	Twice	**-0.16 (-0.27 to -0.05)**	-0.12 (-0.58 to 0.34)	0.41 (-0.23 to 1.09)	**-0.16 (-0.24 to -0.09)**	-0.14 (-0.48 to 0.20)	0.18 (-0.26 to 0.61)
	always	**-0.31 (-0.54 to -0.08)**	-0.44 (-1.41 to 0.53)	0.81 (-0.81 to 2.43)	**-0.38 (-0.54 to -0.22)**	-0.71 (-1.42 to 0.01)	0.15 (-0.88 to 1.18)
MPVA age 14 > average		**-0.58 (-0.74 to -0.43)**	-0.49 (-1.18 to 0.21)	-0.64 (-1.77 to 0.49)	**-0.52 (-0.63 to -0.41)**	-0.20 (-0.71 to 0.32)	-0.57 (-1.29 to 0.14)
N (adjusted r^2)		8471 (0.31)	496 (0.29)	194 (0.25)	8367 (0.38)	488 (0.33)	192 (0.40)

Dependent variable is the body mass index (kg weight/height in m^2) and fat mass index (kg body fat/height in m^2)

Figure A1

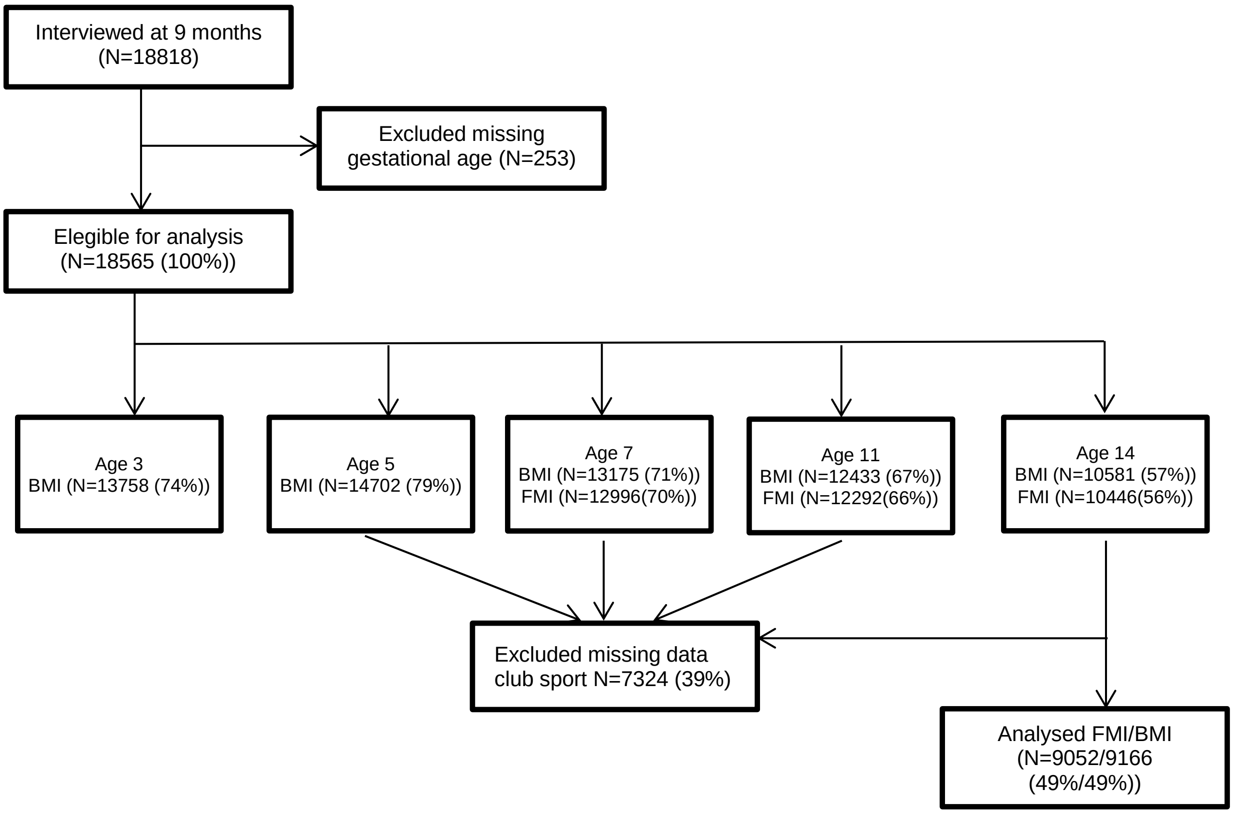

Figure A1: Flow chart of study participation and exclusions. Percentages are of the original sample at 9 months with valid gestational age n=18 565. Club sport: participation in organised physical activity age 5 to 11. FMI: Fat mass index. BMI: body mass index