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Changes in body composition by age and obesity status in preschool aged children: The STEPS study

Tuija Leskinen[a,b], PhD, Aino-Maija Eloranta[c,d], PhD, Tuomo Tompuri[c], MD, PhD, Antti Saari[e], MD, PhD, Helena Ollila[a,f], BSc, Johanna Mäkelä[g], PhD, Harri Niinikoski[h], MD, PhD, Hanna Lagström[a,b], PhD

Affiliations:

[a]Department of Public Health, University of Turku, and Turku University Hospital, Turku, Finland

[b]Centre for Population Health Research, University of Turku, Finland

[c]Institute on Public Health and Clinical Nutrition, School of Medicine, University of Eastern Finland, Kuopio, Finland.

[d]Institute of Biomedicine, School of Medicine, University of Eastern Finland, Kuopio, Finland

[f]Department of Biostatistics, University of Turku, Turku, Finland

[e]Department of Pediatrics, Kuopio University Hospital, and University of Eastern Finland, Kuopio, Finland

[g]Finnish Clinical Biobank Tampere, Pirkanmaa Hospital District and Tampere University Hospital, Tampere, Finland

[h]Department of Pediatrics and Physiology, University of Turku, Turku, Finland

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Corresponding author: Hanna Lagström, Department of Public Health, FI-20014 University of Turku, Finland. Telephone: +358 503001882. E-mail: hanlag@utu.fi

Abstract

Background/Objectives Obesity in early childhood is associated with increased risk of chronic diseases, but studies of body composition at preschool ages are sparse. Therefore, we examined differences in body composition by sex and obesity status in Finnish preschool aged children and within-individual changes in body composition in normal and overweight children.

Subject/Methods Body composition was measured using segmental multifrequency bioimpedance analysis (BIA) in 476 children and in 781 children at age 3 and 5 years, respectively. Of those, 308 had repeated BIA measurements at both ages. BMI-SDS was used for classification of normal weight and overweight children.

Results Sex difference in the amount of lean mass (LM) was already seen at 3 years of age (boys 11.7 kg, girls 11.3 kg; $p<0.001$). At 5 years of age, boys had lower fat mass (FM; 3.6kg vs 3.9 kg, $p<0.001$), lower percent fat mass (%FM; 17.2 % vs. 19.1 %; $p<0.001$), and higher LM (16.0 kg vs. 15.2 kg; $p<0.001$) than girls. Overweight children had higher values in FM, %FM and LM compared to normal weight peers at both ages. Among normal weight children, the increase of LM by age was associated with only minor changes in FM whereas children who were or became overweight both LM and FM was substantially increased between 3 and 5 years of age.

Conclusions BIA-assessed body composition differs by sex and obesity status already at age of 3 years. For children who are or become overweight at very young age, the patterns for the changes in LM and FM by age are different than for normal weight children.

Introduction

The prevalence of children having obesity has increased worldwide. Obesity is defined as excessive accumulation of body fat that associates with increased risk of several chronic diseases [1]. A crude measure of obesity is the body mass index (BMI), a person's weight (in kilograms) divided by the square of his or her height (in metres). Although BMI is known to be only a proxy of body adiposity [2–4], BMI-based measures are widely used to assess obesity also in children[5], because of their simplicity, low cost, and widely accepted reference values in children and adolescents [3,6–8]. BMI has been reported to correlate well with body fat mass in adults and in children having high body fat mass [9,10], but it has had a relatively low precision in estimating body fat mass in children with different body weights [11,12]. In a one Swedish study using air displacement pleythysmography in 4 years old children, BMI was found to have strong associations with both fat mass and fat free mass[13]. Because body adiposity tracks from childhood to adulthood [14], more understanding on the development and screening of body fat mass from early age is needed. Therefore, more information on the usefulness of more precise but feasible and fast methods for measuring body fat mass in epidemiological studies and in primary health care among young children should be available.

One of the indirect methods to estimate the amount of body fat mass and lean mass is bioelectric impedance analysis (BIA) that measures the impedance of electric current of different tissues based on total body water composition with specific eguations[15]. Modern multifrequency segmental BIA devices are designed to be suitable to estimate body composition also in children as young as 3 years of age [16]. Previous studies among school-aged children have reported that boys have lower BIA-assessed fat mass and percentage of body fat and also higher fat free mass than girls, but similar area of visceral fat compared to girls [16–18]. However, sex differences in body composition among preschool aged children are rarely reported[19] and therefore we are lacking reference data on body composition for young children.

Preschool age, between 3 and 5 years, is a period when BMI curve starts to rise after initial decrease [20,21] indicating age-related changes in body size due to adiposity rebound. Preschool years have been suggested to be a critical period for the development of overweight and obesity in later life [22–24]. In a large population-based study, the probability of having overweight or obesity in adolescence was almost 90% for those having obesity at age of 3 years [24]. Also other population-based studies have shown that children having normal weight at early years of life remains normal weight at school age, but those children having overweight develop obesity and those having obesity remains obese[24–26]. However, previous data relies on BMI-measures and similar data on changes in body composition at preschool age are not yet established.

Therefore, in the present study we examined the anthropometric distributions and body composition in a large population-based cohort of Finnish boys and girls at the age of 3 and 5 years. Furthermore, we were able to study the within-individual changes in BIA-assessed measures of body composition by sex and obesity status based on national growth curves among preschool aged children.

Methods

Subjects and study design

All pregnant Finnish or Swedish speaking women (n=9,811) in South-West Finland and Turku University Hospital, Finland between September 2007 and March 2010 were offered the opportunity to participate in a prospective Steps to Healthy Development follow-up study (the STEPS Study) [27]. Altogether 1,797 pregnant women and their spouses (n=1,658) decided to participate the STEPS Study Totally 1,827 children who were born to these families, constituted the STEPS study population. Of this study population, part of the children participated to two study visits at the age of 3 (n=948) and 5 years (n=869). The body composition measurements were overall conducted to 476 children at the age of 3 year and to 781 children at the age of 5 years. For the analyses, we excluded children who were measured more than 2 months before or after their 3rd (n=33) or 5th (n=97) birthday and children born premature (i.e. before 37 gestational weeks, n=20 at 3 year of age and n=28 at the age of 5 years). Thus, the final study sample for this study consisted of 196 boys and 230 girls at 3 years of age, and 333 boys and 327 girls at 5 years of age, and 308 children who had body composition measured at both age points (Figure 1). The parents gave their written informed consent. The study protocol was approved by the Ethics Committee of the Hospital District of South-West Finland in February 2007.

Assessment of gestational and birth data

Gestational and birth data were obtained from the Finnish national register Longitudinal Census Files. We received data on birth weight, birth length, head circumference, gestational age and mode of delivery. We calculated birth weight standard deviation score (SDS) based on Finnish references [28] and categorized birth weight SDS into three categories [<-2 SDS, small for gestational age (SGA); -2 to 2 SDS, appropriate for gestational age (AGA); >2 SDS, large for gestational age (LGA)]. Delivery was defined as premature if the pregnancy lasted for <37 weeks. Maternal date of birth (to calculate maternal age at delivery) and pre-pregnancy body weight and height were self-reported at the time of recruitment. BMI at birth and maternal pre-pregnancy BMI were calculated as body weight (kg) divided by body length/height squared (m^2). To evaluate the representativeness of our final study sample, the gestational and birth characteristics for children with and without body composition data at the age of 5 are shown in Supplementary Table 1.

Assessment of body composition at the age of 3 and 5 years

The assessment of body composition at 3 and 5 years of age were conducted during the study visits by ~~a~~ one study nurse (A-MP). Body weight was measured to the nearest 0.1 kg with an electronic scale (WB110MA, Tanita Corporation. Tokyo, Japan). Standing height was measured to the nearest 0.1 cm with a wall-mounted Harpenden stadiometer (Holtain, Crymych, UK). BMI was calculated as body weight (kg) divided by body height squared (m^2). SDS for body weight, body height and BMI were calculated based on Finnish growth references [21]. Waist circumference was measured after expiration at mid-distance between the bottom of the rib cage and the top of the iliac crest with a measuring tape. Waist-to-height ratio was calculated by dividing waist circumference by body height. Body fat mass (FM), percentage fat mass (%FM), lean mass (LM) and visceral fat area (VFA) were measured using segmental multifrequency BIA (InBody J10; Biospace Co, Seoul, Korea). The measurements were conducted in empty-bladdered non-fasting state. During the measurements, the children were standing still and quiet in a light clothing without a contact between the torso and the arms or between the thighs. The Finnish growth references, described in details elsewhere [21], were used to determine weight status children at the age of 3 and 5 years of age based on BMI-SDS. BMI percentile curves passing through BMIs 17 and 25 at the age of 18 years were calculated to define limits for underweight, normal weight and overweight (including obesity). [17]

Statistical methods

The differences in birth characteristics and body composition between boys and girls were examined using Student's t-test for normally distributed continuous variables, Wilcoxon signed-rank test for non-normally distributed variables, and the chi-square test for categorical variables. The change of body composition was examined between four weight status groups: normal weight at aged 3 and 5 years (NW-NW), change from normal weight at the age of 3 years to overweight at the 5 years (NW-OW), change from overweight at 3 years to normal weight at the 5 years (OW-NW), and overweight at ages of 3 and 5 years (OW-OW). The differences in body composition changes and in the selected National Birth Register characteristics between the weight status groups were analyzed with one-way analysis of variance (ANOVA). If assumptions for parametric models were not met, data were reanalyzed with Kruskal-Wallis test.

The associations between body compositions and weight status groups were also analyzed with hierarchical linear mixed model. The models included weight status group, mode of delivery, birth weight SDS, mothers pre-pregnancy BMI, time, and weight status group*time interaction as explanatory factors. The models were made separately for boys and girls. Time was treated as a categorical variable. Interaction between weight status groups and time was included in the model to examine whether the mean change over time was different between the weight status groups. An unstructured covariance pattern was used for repeated measures. Normal distribution assumption was checked from studentized residuals. SAS, version 9.4 (SAS Institute, Cary, NC, USA), was used for all the analyses and the level of significance was set at $P<0.05$.

Results

Birth characteristics for the children included in the study at age of 5 years are shown in Table 1. At birth, boys were heavier, taller and had greater head circumference compared to girls.

Table 2 shows the characteristics of body size and composition at age of 3 and 5 years for boys and girls separately. Compared to girls, boys had lower height-SDS (p=0.02), higher BMI (p=0.03), higher waist circumference at age of 3 years (p=0.01), and lower waist-to-height ratio at age of 5 years (p<0.01). Sex difference in the amount of LM was already seen at 3 years of age (boys 11.7 kg, girls 11.3 kg; p<0.001). At 5 years of age, boys had lower FM (3.6kg vs 3.9 kg, p<0.001), lower %FM (17.2 % vs. 19.1 %; p<0.001), and higher LM (16.0 kg vs. 15.2 kg; p<0.001) than girls. VFA was 15 to 17 cm^2 higher in boys than in girls at both ages (p<0.001). According to BMI-SDS, boys were more likely to be overweight than girls at the age of 3 (26% vs. 10%; p<0.001) and 5 years (24% vs. 14%; p<0.002) (Table 2).

We then compared overweight children to normal weight children at both ages. As Figure 2 shows, overweight children had higher values in FM, %FM and LM compared to normal weight peers at both ages (p<0.001 for FM and %FM; p<0.01 for LM). Even though both normal and overweight children on average gained FM and LM between 3 and 5 years of age, the increase was higher in overweight than normal weight girls (LM, group*time p-value=0.02) and boys (FM, group*time p-value=0.02; LM, group*time p-value=0.008).

Between 3 and 5 years of age, 238 children maintained normal weight (NW-NW), 35 children maintained overweight (OW-OW), 22 children became overweight (NW-OW), and 13 children became normal weight from overweight (OW-NW). Those children who remained overweight were heavier (in grams and z-scores) and taller and they had higher BMI-SDS already at birth compared to other weight status groups (Supplementary Table 2). Change of BMI-SDS was the highest for the NW-OW group (Δ0.82) and the lowest for the OW-NW group (Δ-0.54) (Figure 3A), with no differences in Δheight-SDS between the weight status groups (Figure 3B). FM accumulated most in NW-OW group (Δ1.8 kg) compared to other weight status groups (range from Δ-0.2 to 0.7 kg) (Figure 3C), whereas all weight status groups gained LM similarly between 3 and 5 years of age (Figure 3D). Change of %FM was positive for NW-OW group (Δ1.5-%), but negative for other groups (from Δ-6.7 to Δ-3.4 %) (Figure 3E). Decrease of VFA was only minimal for NW-OW group compared to other groups (Figure 3F). Figure 4 shows that among NW-OW children, the more they gained LM between 3 and 5 years of age, the more they gained FM. Correspondingly, among OW-OW, OW-NW and NW-NW children greater gain of LM was associated with minor gain of FM (Figure 3C and 3D, Figure 4). For OW-OW children, the gain in LM was around 5 kg but the change in FM ranged from -4 kg to +4 kg. Among OW-NW children, the gain in LM was compensated with loss of FM. For children maintaining normal weight, the gain in LM between 3 and 5 years of age was associated with only small changes in FM (Figure 4).

Discussion

In this large population based study among Finnish preschool aged children, we found that BIA-assessed body composition differs by sex and obesity status already at age of 3 years. The changes in body composition between 3 and 5 years of age was different for those children who became or remained overweight, so that in addition to gaining LM as normal weight children, they also gained FM.

At birth boys were heavier and taller than girls. Further, the differences in body composition as LM between boys and girls were seen in BIA-measurements at the age of 3 years. At 5 years of age, the sex differences were also seen in FM and %FM. These results are in line with studies on school-aged children showing boys having lower BIA-assessed FM and %FM and higher fat free mass than girls[16–18] . Overall, pre-school aged boys were more likely to be overweight than girls at both ages. Earlier studies have shown that BMI may correlate differently among pre-school aged boys and girls, so that there is a correlation between BMI and fat free mass in boys, but for girls the correlation is stronger between BMI and FM [8,19,29]. The reasons for different growth development and fat distribution between boys and girls remain still unclear, but divergent hormonal status may contribute to the outcome [30].

In the present study, we found that majority of the preschool-aged children remained normal weight between ages 3 and 5 years but also that those children having overweight at age of 3 mainly remained overweight at age of 5. These findings are in line with other population-based studies using BMI-measures[25,26]. Obesity at age of 3 years has been shown to predict overweight or obesity at adolescence[24] and the importance to screen and prevent obesity at preschool age is well acknowledge in other studies[23,24,31]. Therefore, having overweight or obesity at age of 3 should be a sign for the clinicians to consult healthy lifestyle habits and weight management strategies for the family in order to prevent future obesity[24,25].

We found that preschool-aged children who stayed overweight as well as those who became overweight between 3 and 5 years of age gained more both LM and FM as compared to children who stayed normal weight or who changed from overweight to normal weight status. Children who stayed normal weight between ages of 3 and 5 years of old gained LM with minimal concurrent increase in FM. For those children who became normal weight between 3 and 5 years of age, the gain in LM was compensated with loss of FM showing that weight status can also be reversible at very young age[24]. Gain of LM may reflect both with normal growth and minimal increase of FM, and loss of FM reflects improved lifestyle. In fact, lifestyle habits, such as children's high level of TV watching, and maternal BMI has been found to be related to lower probability on normalization of weight status between 5 and 8 years of age[26].

It has earlier been reported that LM consistently increase with BMI percentiles, whereas FM and %FM have more complicated relationships with BMI [13,32]. Our finding adds that those children who remained overweight gained LM but either gained or lost FM. Therefore, the accuracy of BMI-based classification to normal weight or overweight among preschool-aged children could benefit from measurements of body composition, so that positive change (i.e. loss) in body fat mass is not hindered by the gain of lean mass. Therefore following the changes in body fat mass among overweight children during early years of life could be more informative especially if changes in lifestyle are recommended.

Our results thus highlight that for children who are or become overweight at very young age, the patterns for the changes in LM and FM by age are different than for normal weight children. Therefore, BIA-based measurements of body fat mass could be a feasible way to follow body composition in preschool-aged children, who may have an increased risk for obesity-related cardiometabolic morbidity in adulthood [22,23,33].

The results of this study improve our understanding of the development and screening of body composition in preschool-aged children. Strength of this study is a large, population-based sample of Finnish preschool aged children. Instead of self-reporting, all measures of body size and body composition were assessed at study clinic by one research nurse. We used BMI-SDS to study changes in the obesity status between 3 and 5 years of age. Moreover, information on length of gestation and birth data were obtained from national registers.

There are also methodological issues/limitations that should be acknowledge. In earlier studies, it has been reported that BMI can only be used as a predictor of overall adiposity[34,35], but that BMI is a poor predictor for level of adiposity in young obese children[36,37]. We also found a wide range of %BF was associated with given BMI-SDS at individual level, even if the BMI-SDS had a strong correlation with %BF (data not shown). In our study, especially pre-school aged girls with high %BF were often classified as normal weight. A previous, albeit rather small study showed that 6- to 7-year-old children with similar BMI values had a marked variation in total body fat (ranging from 8% to 22%) measured by isotope dilution method [38]. A meta-analysis of children and adolescents found that BMI has a high specificity in identifying pediatric obesity, but only moderate sensitivity, suggesting that over a quarter of children who are not labelled as obese by BMI might indeed have excess adiposity [12]. A recent study reported that BMI-SDS associated more strongly with BF% at higher BMI-SDS levels than in lower BMI-SDS levels [8]. Therefore, the critical level of FM among preschool aged children needs further studies as there are no clear cut-off points for normal %FM among children[16].

The use of indirect method to measure body composition among preschool-aged children is a limitation of this study. Despite the fact that all body composition measurements for clinical use are indirect methods, BIA is valuable method to assess growth and possible obesity in children[5], even it measures total body water and only estimates FM and LM. The clinical evaluation of excess body fat depends markedly on the methods and criteria used [16], but BIA has previously been shown to be a practical method to estimate %FM in children and adolescents [7,39], even body composition measurements in children are inherently challenging[5,19]. Another limitation of this study is that children were measured in a non-fasting state as BIA methodology is highly susceptible of hydration status of the subject. A higher fluid volume in the body in a non-fasting state than in a fasting state may have overestimated LM and underestimated FM in our sample. Finally, the differences in gestational age, birth weight, birth length and mother's age between children with and without complete data on body composition can limit the generalizability of our findings. Families who were willing to participate in the body composition measurements had slightly lower prematurity rate compared to families who were not willing to participate.

We conclude that boys have a higher lean mass and lower body fat mass than girls already at 3 years of age, and these sex differences become more pronounced by the age of 5 years. Overweight children have higher FM, %FM and LM compared to normal weight peers at both ages. Especially among children who became overweight between 3 and 5 years of age, the increase in LM was accompanied by the gain in FM. Therefore, the low-cost, quick and easy measurements of body composition at very young age can be recommended for routine clinical evaluation of body composition. Among children, especially obese, measure of the body composition is important for monitoring health outcomes for example after interventions.

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Author Disclosure Statement

AME, TL and HL conceptualized the study in accordance with all other authors (TT, AS, JM and HN) and drafted the initial manuscript for submission. All authors were involved in literature search. HO was responsible for statistical analysis. All authors reviewed, revised and approved the submission of this manuscript for peer review.

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Table 1. National Birth Register characteristics of the children and the mothers. Comparison between boys and girls with body composition information (n=787) at the age of 5 years of age. Comparison information based on the chi-square test and % for categorical variables and t-test and mean (SD) for numerical variables.

Birth characteristic	Boys (n=398)	Girls (n=383)	P-value
Gestational age (days at birth)	280 (10)	280 (10)	0.82[f]
Birth weight (g)	3621 (502)	3480 (484)	<0.001
Birth length (cm)	51.4 (2.0)	50.4 (2.4)	<0.001
Head circumference (cm)	35.5 (1.4)	34.8 (1.4)	<0.001
Body mass index at birth (kg/m^2)	13.7 (1.3)	13.7 (1.4)	0.99
Premature birth (<37 gw weeks), % (n)	3.5 (14)	3.6 (14)	0.92
Birth weight Z-score[a]	-0.003 (1.125)	-0.082 (1.179)	0.34
SGA, % (n)	2.0 (8)	3.1 (12)	0.32
AGA, % (n)	94.8 (379)	93.8 (363)	0.65
LGA,% (n)	2.3 (9)	1.8 (7)	0.67
Mother's age at birth, years	31.3 (4.3)	31.3 (4.4)	0.97
Mother's body mass index[b]	24.1 (4.5)	24.1 (4.8)	0.65[c]
Mother's gestational diabetes, % (n)	6.8 (27)	9.3 (36)	0.18

SGA small for gestational age, AGA appropriate for gestational age, LGA= large for gestational age

[a] According to Finnish population-based references for birth weight and length

Table 2. Characteristics of body size and composition of children with complete body composition information at the age of 3 and 5 years. The significance of difference between boys and girls based on the Chi-Square test and % (n) for categorical variables and t-test and mean (SD) for numerical variables. From the analyses were excluded premature children as well as if growth and body composition data were measured more than 2 months before or after 3rd or 5th birthday.

Measurement age	3 years (n=426)			5 years (n=660)		
Characteristic	Boys (n=196)	Girls (n=230)	*P*-value	Boys (n=333)	Girls (n=327)	*P*-value
Body weight, kg	15.6 (1.8)	15.1 (1.5)	0.01	20.4 (2.6)	19.8 (2.5)	0.003
Body weight, SDS	0.09 (1.1)	0.24 (0.85)	0.11	0.15 (0.96)	0.09 (0.90)	0.45
Body height, cm	97.5 (3.8)	96.9 (3.4)	0.12	112.1 (4.7)	110.5 (4.3)	<0.001
Body height, SDS	-0.09 (1.11)	0.14 (0.98)	0.02	-0.04 (1.11)	-0.14 (0.98)	0.24
BMI, kg/m^2	16.3 (1.2)	16.1 (1.1)	0.03	16.2 (1.3)	16.2 (1.5)	0.88
BMI-SDS	0.16 (0.93)	0.11 (0.88)	0.53	0.26 (0.86)	0.24 (0.88)	0.56
WC, cm	50.4 (3.2)	49.7 (3.1)	0.01	54.7 (4.7)	54.9 (4.4)	0.53
Waist-to-height ratio	0.52 (0.03)	0.51 (0.03)	0.10	0.49 (0.04)	0.50 (0.04)	<0.001[c]
FM, kg	3.2 (1.2)	3.3 (1.1)	0.66	3.6 (1.3)	3.9 (1.4)	0.005
%FM	20.6 (6.2)	21.6 (6.4)	0.09	17.2 (4.6)	19.1 (4.7)	<0.001
LM, kg	11.7 (1.4)	11.3 (1.3)	<0.001	16.0 (1.8)	15.2 (1.6)	<0.001
VFA, cm^2	27.9 (5.5)	10.5 (5.0)	<0.001[c]	21.5 (5.1)	6.8 (3.0)	<0.001[c]
[a] Overweight, % (n)	25.5 (50)	10.0 (23)	<0.001	23.7 (79)	14.4 (47)	0.002
[a,b] Obesity, % (n)	4.6 (9)	0.9 (2)	0.02	5.7 (19)	0.9 (3)	<0.001

BMI body mass index

WC waist circumference

BMI-SDS Standard deviation score for body mass index, *FM* fat mass, *%FM* percent fat mass, *LM* lean mass, *VFA* visceral fat area

[a] According to the Finnish Growth References for Children BMI-SDS criteria

[b] The proportion of overweight children includes also obese children

[c] Wilcoxon Rank-Sum Test was used because of the exception of normal distribution

Figure Legends

Figure 1. Flowchart summarizing exclusion and inclusion criteria for present study samples from the STEPS Study**.**

Figure 2. Change of percent fat mass (%FM), fat mass (FM), lean mass (LM) and visceral fat area (VFA) from 3 to 5 years of under and normal weight and overweight including obese separately of boys (left column) and girls (right column) as means ± quartiles. Classification is based on BMI-SDS (normal weight limit < 1.1629 for girls and < 0.7784 for boys). The effect of BMI class to body composition were tested with hierarchical linear mixed model. The models includes also mode of delivery, birth weight SDS, mothers pre-pregnancy BMI, time and BMI class*time interaction as explanatory factors. Group effect p-value indicates whether body composition was different depending on BMI-SDS class. Group*time p-value indicates whether mean change of body composition was significantly different depending on weight status groups. From the analyses were excluded premature children (n=28) as well as if growth and body composition data were measured more than 2 months before or after 3rd or 5th birthday.

Figure 3. Change of (A) BMI-SDS, (B) height-SDS, (C) fat mass (kg), (D) lean mass (kg), (E) body fat as percentage and (F) visceral fat area in four different BMI class groups: a) stayed normal weight at aged 3 and 5 years (NW-NW; n=238); b) change weight group from normal weight at the age of 3 years to overweight at the 5 years (NW-OW; n=22); c) change weight group from overweight 3 years to overweight at the 5 years (OW-NW; n=13) and d) stayed overweight at both ages of 3 and 5 years (OW-OW; n=35). Classification is based on BMI-SDS (normal weight limit < 1.1629 for girls and < 0.7784 for boys). The significance of difference between weight status groups is based on One-way Anova. P-

value for %FM and VFA was checked whit Kruskal-Wallis test because of the exception of normal distribution.

Figure 4. Change of ΔLM/ΔFM in four different BMI class groups: a) stayed normal weight at aged 3 and 5 years (NW-NW; n=220); b) change weight group from normal weight at the age of 3 years to overweight at the 5 years (NW-OW; n=21); c) change weight group from overweight 3 years to overweight at the 5 years (OW-NW; n=12) and d) stayed overweight at both ages of 3 and 5 years (OW-OW; n=32) without outliers. Classification is based on BMI-SDS (normal weight limit < 1.1629 for girls and < 0.7784 for boys). The significance of difference between BMI-SDS classes is based on Fisher transformation test.

Figure 1.

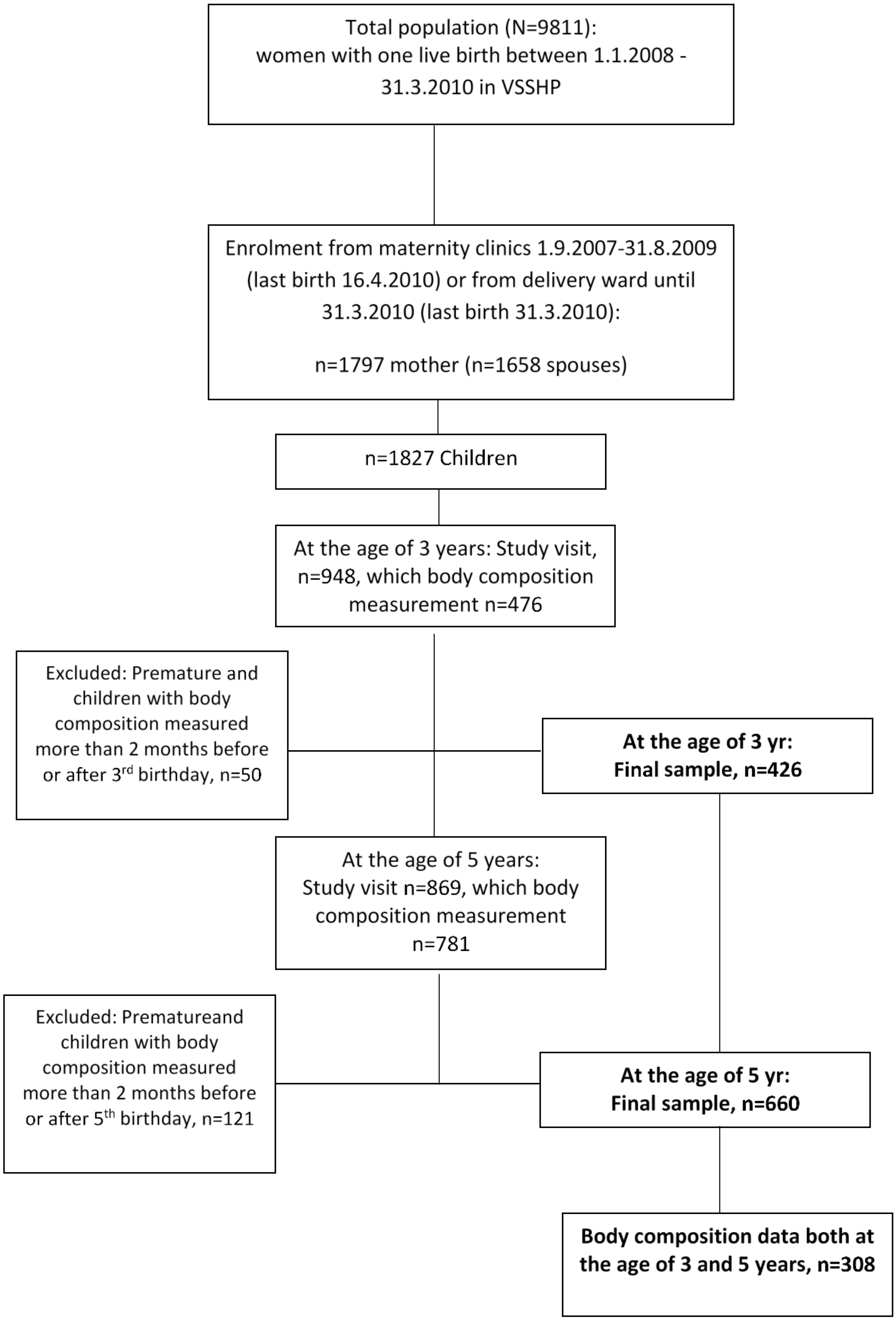
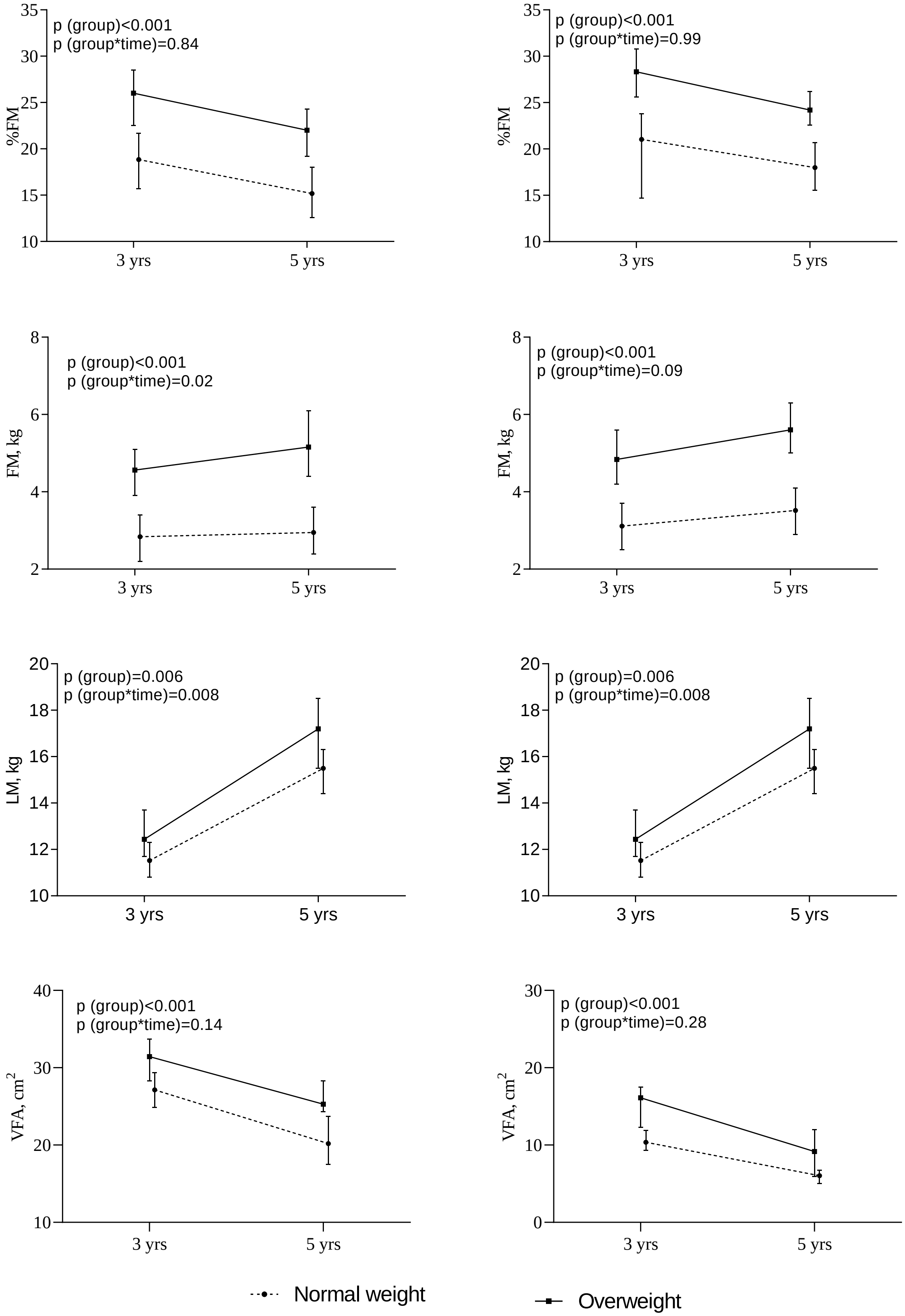
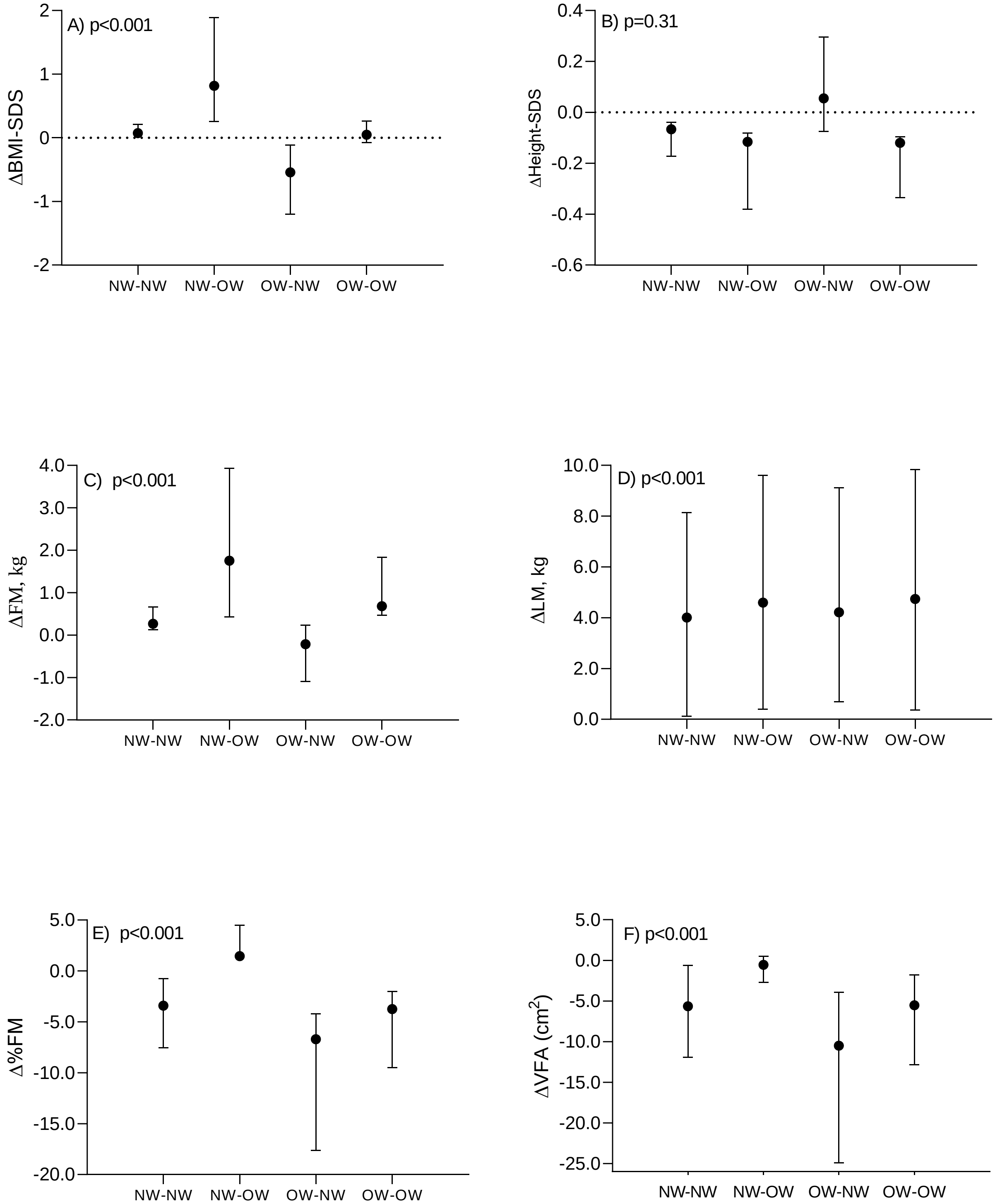

Total population (N=9811):
women with one live birth between 1.1.2008 - 31.3.2010 in VSSHP
Enrolment from maternity clinics 1.9.2007-31.8.2009 (last birth 16.4.2010) or from delivery ward until 31.3.2010 (last birth 31.3.2010):
n=1797 mother (n=1658 spouses)
n=1827 Children
At the age of 3 years: Study visit, n=948, which body composition measurement n=476
Excluded: Premature and children with body composition measured more than 2 months before or after 3rd birthday, n=50
At the age of 3 yr:
Final sample, n=426
At the age of 5 years:
Study visit n=869, which body composition measurement n=781
Excluded: Prematureand children with body composition measured more than 2 months before or after 5th birthday, n=121
At the age of 5 yr:
Final sample, n=660
Body composition data both at the age of 3 and 5 years, n=308

Figure 2.



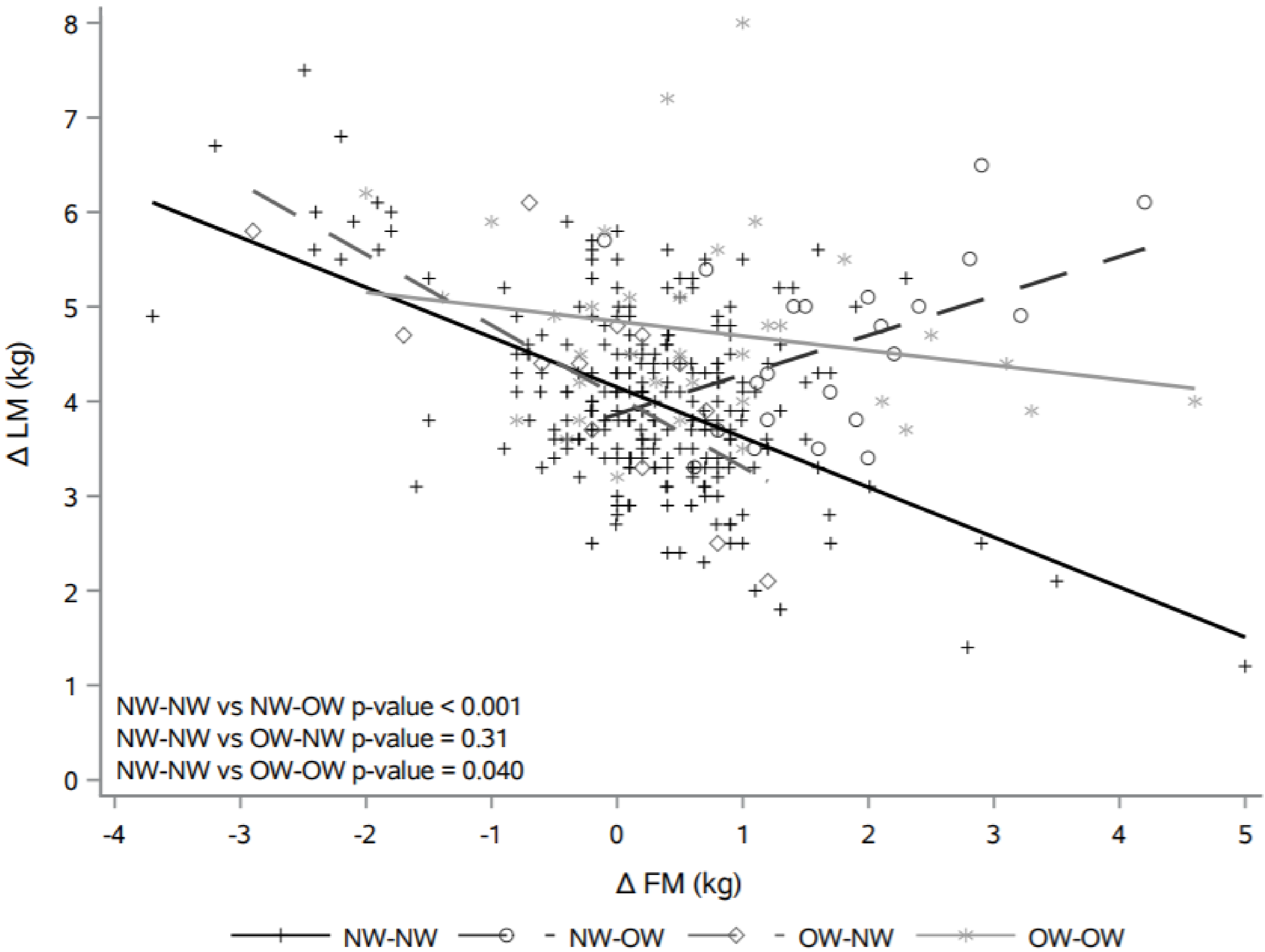
p (group)<0.001
p (group*time)=0.84
%FM
35
30
25
20
15
10
3 yrs
5 yrs
p (group)<0.001
p (group*time)=0.99
%FM
p (group)<0.001
p (group*time)=0.02
FM, kg
8
6
4
2
p (group)<0.001
p (group*time)=0.09
FM, kg
p (group)=0.006
p (group*time)=0.008
LM, kg
20
18
16
14
12
10
p (group)=0.006
p (group*time)=0.008
LM, kg
p (group)<0.001
p (group*time)=0.14
VFA, cm2
40
30
20
10
p (group)<0.001
p (group*time)=0.28
VFA, cm2
30
20
10
0
Normal weight
Overweight

Figure 3.



A) p<0.001
ΔBMI-SDS
2
1
0
-1
-2
NW-NW
NW-OW
OW-NW
OW-OW
B) p=0.31
ΔHeight-SDS
0.4
0.2
0.0
-0.2
-0.4
-0.6
NW-NW
NW-OW
OW-NW
OW-OW
C) p<0.001
ΔFM, kg
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
NW-NW
NW-OW
OW-NW
OW-OW
D) p<0.001
ΔLM, kg
10.0
8.0
6.0
4.0
2.0
0.0
NW-NW
NW-OW
OW-NW
OW-OW
E) p<0.001
Δ%FM
5.0
0.0
-5.0
-10.0
-15.0
-20.0
NW-NW
NW-OW
OW-NW
OW-OW
F) p<0.001
ΔVFA (cm2)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
NW-NW
NW-OW
OW-NW
OW-OW

Figure 4.



8
7
6
5
4
3
2
1
0
Δ LM (kg)
NW-NW vs NW-OW p-value < 0.001
NW-NW vs OW-NW p-value = 0.31
NW-NW vs OW-OW p-value = 0.040
-4
-3
-2
-1
0
1
2
3
4
5
Δ FM (kg)
NW-NW
NW-OW
OW-NW
OW-OW

Supplementary Material

Supplementary Table 1. National Birth Register characteristics of the children and the mothers. Comparison between children with (n=781) or without (n=1031) body composition information at the age of 5 years of age separately in boys and girls. Comparison between without and with body composition information based on the chi-square test and % for categorical variables and t-test and mean (SD) for numerical variables.

	Boys			Girls		
Birth characteristics	Without (n=546) body composition data	With (n=398) body composition data	P	Without (n=485) body composition data	With (n=383) body composition data	P
Gestational age (days at birth)	277.2 (13.8)	279.6 (10.5)	0.003	276.9 (14.5)	279.6 (9.8)	0.001
Birth weight (g)	3514.4 (594.8)	3621.2 (501.7)	0.003	3399.3 (606.8)	3476.8 (483.3)	0.038
Birth length (cm)	50.8 (2.8)	51.4 (2.0)	<0.001	50.1 (2.5)	50.4 (2.4)	0.065
BMI at birth (kg/m^2)	13.6 (1.4)	13.7 (1.3)	0.17	13.5 (1.5)	13.7 (1.4)	0.21
Birth weight Z-score	-0.250 (1.36)	-0.003 (1.12)	0.003	-0.283 (1.48)	-0.088 (1.18)	0.032
Caesar section, % (n)	14.8 (80)	10.4 (41)	0.048	16.5 (79)	11.6 (44)	0.047
Mother's age at birth, years	30.2 (4.8)	31.3 (4.3)	<0.001	30.3 (4.7)	31.3 (4.4)	0.001
Mother's BMI[2]	24.4 (4.9)	24.1 (4.5)	0.28	24.5 (4.9)	24.1 (4.9)	0.18
Mother's gestational diabetes, % (n)	6.5 (35)	6.9 (27)	0.82	9.4 (45)	9.5 (36)	0.94

Supplementary Table 2. Selected National Birth Register characteristics [mean (SD) or % (n)] of the children and the mothers in four different weight groups based on BMI-SDS (normal weight limit < 1.1629 for girls and < 0.7784 for boys). The significance of difference between BMI-SDS classes is based on One-way Anova. Variable marked with * was checked whit Kruskal-wallis test because of the exception of normal distribution.

BMI-SDS group	NW-NW (n=238)	NW-OW (n=22)	OW-NW (n=13)	OW-OW (n=35)	*P*-value
Birth characteristics					
Gestational age (days at birth)	280 (8)	281 (8)	280 (7)	282 (10)	0.71
Birth weight (g)	3559 (420)	3611 (406)	3635 (372)	3857 (421)	0.002
Birth length (cm)	50.9 (2.0)	51.3 (1.9)	51.9 (2.0)	51.9 (2.1)	0.02
Body mass index at birth (kg/m^2)	13.7 (1.1)	13.7 (1.1)	13.5 (0.9)	14.3 (1.1)	0.01
Birth weight Z-score	0.003 (0.954)	0.107 (0.934)	0.148 (0.832)	0.612 (0.914)	0.006
Caesarean section, % (n)	7.5 (23)	0.6 (2)	0.3 (1)	1.3(4)	0.98*
Mother's age at birth, years	31.6 (4.1)	30.2 (4.9)	32.7 (5.1)	30.6 (4.7)	0.19
Mother's body mass index	23.8 (4.7)	25.5 (6.4)	23.1 (2.6)	25.0 (3.9)	0.19
Mother's gestational diabetes, % (n)	5.9 (18)	1.0 (3)	0.3 (1)	0.7 (2)	0.74*

NW-NW maintained normal weight at 3 and 5 years, *NW-OW* change weight group from normal weight (3 yrs) to overweight (5 yrs), *OW-NW*