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Relation of maternal birthweight with early pregnancy obesity, gestational diabetes, and offspring macrosomia

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Original Article

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Abstract

This study aimed to investigate how maternal birthweight is related to early pregnancy obesity, gestational diabetes mellitus (GDM), and offspring birthweight. Females born term and singleton in Sweden between 1973 and 1995 (N = 305,893) were studied at their first pregnancy. Information regarding their birthweight, early pregnancy body mass index, and pregnancy complications was retrieved from the Swedish Medical Birth Register, as were data on their mothers and offspring. High maternal birthweights (2–3 standard deviation scores (SDS) and >3 SDS) were associated with greater odds of early pregnancy obesity, odds ratio (OR) 1.52 (95% confidence interval (CI) 1.42–1.63) and OR 2.06 (CI 1.71–2.49), respectively. A low maternal birthweight (<2 SDS) was associated with greater odds of GDM (OR 2.49, CI 2.00–3.12). No association was found between high maternal birthweight and GDM. A maternal birthweight 2–3 SDS was associated with offspring birthweight 2–3 SDS (OR 3.83, CI 3.44–4.26), and >3 SDS (OR 3.55, CI 2.54–4.97). Corresponding ORs for a maternal birthweight >3 SDS were 5.38 (CI 4.12–7.01) and 6.98 (CI 3.57–13.65), respectively. In conclusion, a high maternal birthweight was positively associated with early pregnancy obesity and offspring macrosomia. A low, but not a high maternal birthweight, was associated with GDM.

Introduction

The prevalence of noncommunicable diseases are increasing globally.[1] Risk factors for these conditions are passed on from one generation to another. According to the concept Developmental Origin of Health and Disease, the prenatal environment does not only affect fetal growth, but may also influence adult health.[2]

Common definitions of high birthweight include a birthweight above two standard deviation scores (SDS) or a birthweight above the 90th or 95th percentile. Previous studies have reported associations between a high birthweight and adult obesity as well as metabolic disease,[3-6] while others instead indicate beneficial effects of a high birthweight.[5,7,8] However, few studies on adult health have isolated subjects with a very high birthweight (>3 SDS) from those with a moderately high birthweight (2–3 SDS).[6] This distinction might be of interest since data from our group indicate that subjects with a very high birthweight differ from those with a moderately high birthweight with respect to risk of adult disease.[4]

Excessive body weight during pregnancy is associated with several complications for both the mother and the offspring. A pregnant woman with overweight (body mass index (BMI) ≥25 kg/m^2) or obesity (BMI ≥30 kg/m^2) runs an increased risk for preeclampsia, gestational diabetes mellitus (GDM), instrumental delivery, and cesarian section.[9,10] The offspring of a woman with overweight or obesity has an increased risk for a high birthweight, shoulder dystocia, breathing problems, hypoglycemia, and to be admitted to the neonatal intensive care unit.[11]

GDM strongly affects the fetal environment and increases the risk of having a macrosomic offspring.[12] The prevalence of GDM is increasing, but differs depending on ethnic and socioeconomic background.[13] In Sweden, GDM is reported in 1%–2% of the pregnancies.[14] Gestational diabetes and type 2 diabetes (T2DM) share several risk factors such as increased BMI, increased age, as well as a family history of diabetes.[15,16] Furthermore, a positive association between birthweight and later GDM risk has been reported.[17] In addition, a meta-analysis covering many different ethnic populations reveals a sevenfold increased risk of manifest T2DM after GDM,[16] and a Swedish study reports that 25% of females with GDM develop diabetes, mainly T2DM, within 8–14 years after delivery.[18]

As maternal BMI, GDM, T2DM, and offspring birthweight seem closely related, factors influencing the incidence of these conditions may have long lasting effects on public health. This study aimed to investigate how maternal birthweight is related to early pregnancy obesity,

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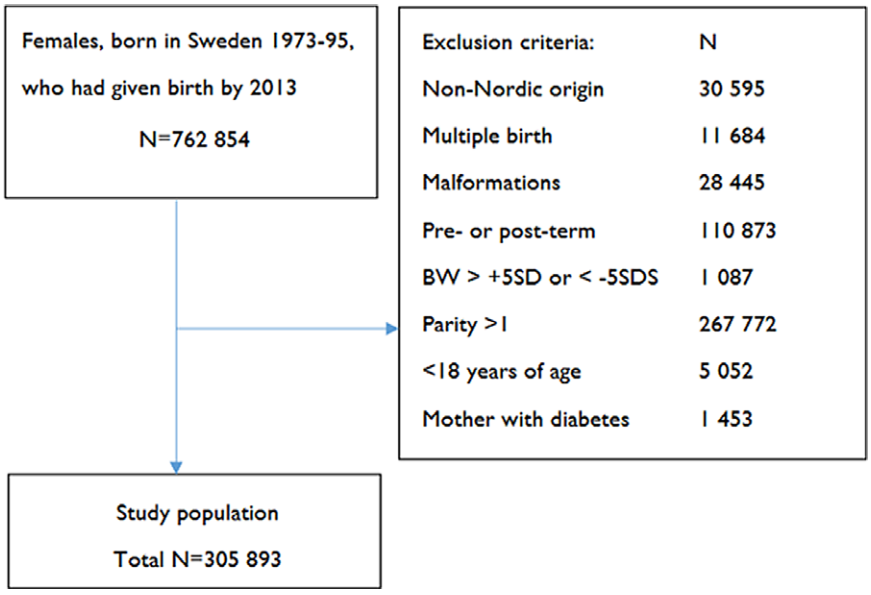

Fig. 1. Description of study cohort and exclusion criteria.

GDM, and offspring birthweight. Particularly, we intended to focus on differences between females with a moderately high (2–3 SDS) and those with a very high (>3 SDS) birthweight.

Materials and methods

Data sources

The Swedish Birth Register, founded in 1973, contains data on more than 99% of all births in Sweden.[19] Information is collected prospectively during the pregnancy, beginning with the first antenatal visit. Data are recorded on maternal demographic factors and reproductive history, as well as on complications during pregnancy, delivery, and the neonatal period. All births and deaths are validated yearly against the Register of the Total Population (kept by Statistics Sweden), using the mother's and the infant's unique individual identification number.

At the first antenatal visit around 10–12 weeks of gestation (95% occurring prior to 15 weeks of gestation), pregnant women are interviewed about current heath, lifestyle, and family history. Weight is measured and height is self-reported or measured. Blood glucose is measured routinely four to six times during the pregnancy since the early 1980s. Women with a blood glucose >8 mmol/l or with risk factors for GDM are offered a 75-g oral glucose tolerance test (OGTT) in order to diagnose possible GDM.[14,20] The main diagnostic criteria for GDM are fasting capillary whole blood glucose >6.1 mmol/l, and/or OGTT 2 h blood glucose >9.0 mmol/l.[14,17]

Study population

The study cohort (Fig. 1) comprised all females born term and singleton in Sweden 1973–1995 by a mother of Nordic origin. Subjects with heredity for diabetes, that is, those whose mothers had a diabetes diagnosis (identified by the International Classification of Disease (ICD) codes 250 (ICD-8) and 648A+W (ICD-9)), were excluded. Subsequently, all subjects who, at the age of 18 years or older, delivered a first born offspring between 1991 and 2013 were extracted (N = 305,893). Data on the cohort, their mothers (born 1924–1976), and their offspring were collected. The study was approved by the Regional Ethical Review Board in Uppsala (Dnr: 2014/104).

Data analysis

Information on birthweight, gestational age, early pregnancy weight and height, smoking habits, as well as maternal and offspring diagnoses was obtained from the Birth Register. Smoker was defined as smoking at the time of registration in maternity care. Maternal age was defined as the age in years at the time of delivery. Maternal data were linked to offspring data through the individual identification number of each Swedish citizen.

Maternal birthweight represented the exposure. It was transformed into SDS according to Niklasson et al.,[21] and classified into four groups: small-for-gestational age (SGA), that is, birthweight < −2 SDS, appropriate for gestational age (AGA), that is, birthweight −2 to +2 SDS, moderately large-for-gestational age (LGA 2–3) with a birthweight 2–3 SDS and very large-for-gestational (LGA >3) with a birthweight >3 SDS.

Main outcomes were early pregnancy BMI (25.0–29.9 and ≥30.0), GDM (identified by ICD codes 648W (ICD-9) and O24.4 (ICD-10)), and offspring birthweight (2–3 SDS and ≥3 SDS). In addition, we performed analyses on the relation between maternal birthweight and offspring birthweight classified by sex. BMI was calculated as kg/m^2 and categorized as underweight (BMI <18.5), overweight (BMI ≥25.0), and obesity (BMI ≥30.0) according to WHO criteria.[22]

During the study period, three versions of ICD were used in Sweden. From study start until 1986, ICD-8 was in use, followed by ICD-9 from 1987 to 1996, and ICD-10 from 1997 and forward. The majority of the subjects (96%) had their first offspring in 1997 or later, that is, after introduction of ICD-10. The ICD-8 and ICD-9 do not define the type of diabetes in pregnancy (coded as 250 (ICD-8) and 648A+W (ICD-9)). The ICD-10 contains the following diabetes diagnoses: GDM (O24.4), type 1 diabetes mellitus (E10 or O24.0), T2DM (E11 or O24.1), and unspecified diabetes (E12–14 or O24.9). Pregnant women with diabetes before or during pregnancy (250 (ICD-8), 648A+W (ICD-9), and E10, E11, and O24.0–9 (ICD-10)) were excluded from the analyses evaluating gestational diabetes and offspring macrosomia. In the analysis

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Table 1. Prevalence and likelihood of overweight and obesity in early pregnancy in relation to subject birthweight

		BMI 25–29.9	BMI 25–29.9		BMI ≥30	BMI ≥30
	BMI 25–29.9	OR (95% CI)		BMI ≥30	OR (95% CI)	
Birthweight (SDS)	N (%)	Unadjusted	Adjusted[a]	N (%)	Unadjusted	Adjusted[a]
<−2	1320 (18.9)	0.96 (0.90–1.02)	0.95 (0.90–1.01)	594 (8.5)	0.95 (0.88–1.04)	0.934 (0.86–1.02)
−2–2	57,655 (19.8)	1.00*	1.00*	25,884 (8.9)	1.00*	1.00*
2–3	1738 (24.2)	1.31 (1.24–1.38)	1.30 (1.23–1.38)	927 (12.9)	1.52 (1.42–1.63)	1.52 (1.42–1.63)
>3	212 (26.9)	1.49 (1.27–1.74)	1.46 (1.25–1.72)	133 (16.9)	2.08 (1.73–2.51)	2.06 (1.71–2.49)

Data are presented as odds ratios (OR) with 95% confidence intervals (CI).
BMI, body mass index; SDS, standard deviation score.
*ref.
[a]Adjustments were made for maternal age and smoking.

evaluating offspring macrosomia, pregnancies with multiple fetuses (1.2%) as well as pre- and post-term births were also excluded.

Statistical analyses were performed in IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA) and SAS 9.3 (SAS Institute Inc., Cary, NC, USA). A two-sided *P* value of <0.05 was considered indicating statistical significance. Multiple logistic regression models were used to evaluate the associations of maternal birthweight with early pregnancy BMI, GDM, and offspring birthweight. Adjustments were made for early pregnancy BMI, maternal age, and smoking status at first antenatal visit. The results were expressed as odds ratios (OR) with 95% confidence intervals (CI).

Results

Mean maternal birthweight was 3 459 ± 465 g. The birthweights were distributed as follows: 2.3% SGA, 95.1% AGA, 2.3% LGA 2–3, and 0.3% LGA >3. Mean age of the subjects at the time of delivery was 26.5 ± 4.3 years. At the first antenatal care visit, 2.8% of the females were underweight, 65.2% normal weight, 22.1% overweight, and 10.0% obese. The mean BMI of the cohort was 24.2 ± 4.4 kg/m^2 and the prevalence of GDM was 0.5%.

Maternal birthweight in relation to early pregnancy BMI

As seen in Table 1, a maternal birthweight between 2–3 SDS was associated with 30% greater odds of overweight (OR 1.30, CI 1.23–1.38) and 52% greater odds of obesity (OR 1.52, CI 1.42–1.63) in early pregnancy compared with a normal birthweight. For subjects with a birthweight >3 SDS, the odds were even higher (OR 1.46, CI 1.25–1.72 for overweight, and OR 2.06, CI 1.71–2.49 for obesity).

Maternal birthweight in relation to GDM

A low maternal birthweight (<−2 SDS) was associated with an increased likelihood of GDM (OR 2.49, CI 2.00–3.12), compared with a normal birthweight. There was no association between a high birthweight and GDM (Table 2). In addition, there was a positive association between early pregnancy BMI and the likelihood of GDM, which was doubled for overweight subjects (OR 2.13, CI 1.87–2.42), and almost sevenfold increased for obese subjects (OR 6.71, CI 5.97–7.54) (Table 2). Increased maternal age and smoking were also associated with an increased likelihood of GDM (Table 2).

Maternal birthweight in relation to offspring birthweight

Offspring birthweights, in subjects with singleton, term pregnancies and no diagnosis of diabetes in pregnancy, were distributed as follows: 1.6% SGA, 96.3% AGA, 1.9% LGA 2–3, and 0.2% LGA >3 SDS.

A high maternal birthweight was associated with greater odds of a high offspring birthweight (Table 3). Subjects with a birthweight 2–3 SDS had almost a fourfold increased likelihood of an offspring birthweight 2–3 SDS (OR 3.83, CI 3.44–4.26), compared with mothers with a normal birthweight. The odds of having an offspring with a birthweight >3 SDS in this group were 3.55 (CI 2.54–4.97) (Table 3). Corresponding figures for subjects with a birthweight >3 SDS were 5.38 (CI 4.12–7.01) and 6.98 (CI 3.57–13.65), respectively (Table 3).

The analyses evaluating maternal birthweight in relation to offspring birthweight classified by sex showed higher odds of LGA among males compared with females (Supplementary Tables 1 and 2).

There was also an association of early pregnancy BMI with offspring birthweight. The risk of having an infant with a birthweight >3 SDS was almost seven times higher for obese subjects (OR 6.78, CI 5.41–8.51), compared with normal weight mothers (Table 3). The effect of age was modest with lowest risk for high offspring birthweight in subjects who were 30–34 years old (Table 3).

Discussion

This large population based register study demonstrated a positive and independent association of maternal birthweight with early pregnancy BMI and offspring birthweight. In addition, subjects with a low birthweight had greater odds of developing GDM.

Our results showed that the mother's own birthweight was positively associated with early pregnancy BMI, which is in line with previously reported data.[23] In our cohort, 22.1% of the mothers were overweight in early pregnancy and 10.0% were obese. These figures are lower compared with those of other populations.[24,25] However, the proportion of overweight and obese women entering pregnancy is escalating in Sweden.[23] Consequences of rising maternal weights include increasing prevalence of GDM and offspring macrosomia.[26]

We found that a low maternal birthweight was associated with greater odds of GDM. This is consistent with data of a previous study reporting a twofold increased likelihood of GDM in mothers who themselves had a birthweight <10th percentile compared with

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Table 2. Prevalence and likelihood of gestational diabetes (GDM) in relation to maternal birthweight, early pregnancy BMI, maternal age, and smoking

		GDM	GDM
	GDM	OR (95% CI)	
Maternal characteristics	N (%)	Unadjusted	Adjusted
Birthweight (SDS)			
<−2	87 (1.3)	2.42 (1.95–3.01)	2.49 (2.00–3.12)
−2–2	1506 (0.5)	1.00*	1.00*
2–3	32 (0.4)	0.86 (0.61–1.22)	0.77 (0.54–1.10)
>3	5 (0.6)	1.23 (0.51–2.98)	1.02 (0.42–2.47)
BMI (kg/m^2)			
<18.5	27 (0.4)	1.11 (0.76–1.64)	1.15 (0.78–1.71)
18.5–24.9	514 (0.3)	1.00*	1.00*
25–29.9	396 (0.7)	2.08 (1.84–2.36)	2.13 (1.87–2.42)
≥30	548 (2.0)	6.47 (5.77–7.25)	6.71 (5.97–7.54)
Age (years)			
18–24	449 (0.4)	0.81 (0.72–0.91)	0.74 (0.65–0.84)
25–29	669 (0.5)	1.00*	1.00*
30–34	422 (0.6)	1.17 (1.04–1.32)	1.24 (1.10–1.41)
≥35	90 (0.9)	1.71 (1.37–2.14)	1.49 (1.18–1.88)
Smoking			
No	1382 (0.5)	1.00*	1.00*
Yes	181 (0.6)	1.20 (1.02–1.40)	1.22 (1.04–1.43)

Data are presented as odds ratios (OR) with 95% confidence intervals (CI).
BMI, body mass index; GDM, gestational diabetes mellitus; SDS, standard deviation score.
*ref.
[a]Adjusted for the other variables listed in the table.

those who had a normal or high birthweight.[27] In contrast, others report no correlation between maternal birthweight and later development of GDM.[28] However, the latter study evaluated a supposedly healthy cohort since the women were between 24 and 26 years of age.

In our study, the likelihood of GDM was not increased in mothers with high birthweights compared with those with a normal birthweight. This finding is in contrast with previous studies reporting a U-shaped relation between female birthweight and later development of GDM.[17,29] Hence, according to these studies, women born SGA or LGA (>2 SDS) are more prone to develop GDM compared with those with a normal birthweight.[17] These inconsistent results could possibly be explained by differences in cohort characteristics. For example, we only included nulliparous subjects, whilst Lagerros et al.[17] also included parous women. Nulliparous women are younger and have a lower risk of developing GDM compared with women who are older.[30] Moreover, parous women are heavier and gain more weight during pregnancy compared with nulliparous women.[31] A high body weight and excessive weight gain in pregnancy are well-known risk factors for the development of GDM.[30]

In this study, the low GDM prevalence of 0.5% may be partly explained by the exclusion of groups with a higher risk of GDM, for example, parous women, older women, and women with a non-Nordic origin.[30] Additionally, some cases of GDM might not be captured by the screening.[13,15,32] Since 1998, GDM prevalence has been steady around 0.9%–1.3%. This should be compared to a prevalence of 2.2% in a Swedish region where OGTT was routinely performed in all pregnant women.[14]

We found that a high maternal birthweight was positively associated with offspring birthweight after adjustments for early pregnancy BMI. The likelihood was greatest for women who themselves had a very high birthweight (>3 SDS). Moreover, the ORs were higher for males compared with females. Our results are in good agreement with those of a previous study reporting associations of maternal birthweight with offspring birthweight among mothers who themselves had a normal birthweight or macrosomia.[33] Like our findings, the associations differed depending on offspring sex. Our results also demonstrated an association between early pregnancy BMI and offspring birthweight, which has been reported by other investigators.[6,32,34-36] The increasing prevalence of high birthweights is worrying as it is associated with increased risk of adverse perinatal complications, such as asphyxia, shoulder dystocia, and hypoglycemia, as well as later risk of obesity.[3] A high birthweight also increases the risk of maternal injuries during delivery.[3]

Although being born moderately LGA is associated with adult overweight, some studies indicate advantages of an increased birthweight. Thus, two Danish studies[5,7] demonstrated decreased overall mortality for individuals born with birthweights above the 90th percentile compared with AGA,[5] and for birthweights between 3.7

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Table 3. Likelihood of offspring birthweight between 2–3 SDS or >3 SDS, in relation to maternal birthweight SDS, BMI in early pregnancy (kg/m^2), age (years), and smoking

Maternal characteristics		Offspring birthweight					
		BW 2–3 SDS	BW 2–3 SDS	BW 2–3 SDS	BW >3 SDS	BW >3 SDS	BW >3 SDS
	N	N (%)	OR (95% CI) Unadjusted	OR (95% CI) Adjusted[a]	N (%)	OR (95% CI) Unadjusted	OR (95% CI) Adjusted[a]
Birthweight (SDS)							
<−2	6977	44 (0.8)	0.43 (0.32–0.58)	0.46 (0.34–0.62)	7 (0.1)	0.76 (0.36–1.61)	0.83 (0.39–1.75)
−2–2	290,953	4324 (1.8)	1.00*	1.00*	395 (0.2)	1.00*	1.00*
2–3	7175	419 (7.0)	4.18 (3.76–4.63)	3.83 (3.44–4.26)	39 (0.6)	4.05 (2.91–5.63)	3.55 (2.54–4.97)
>3	788	66 (10.3)	6.41 (4.96–8.28)	5.38 (4.12–7.01)	9 (1.4)	8.84 (4.54–17.19)	6.98 (3.57–13.65)
BMI (kg/m^2)							
<18.5	7692	33 (0.5)	0.34 (0.24–0.48)	0.36 (0.25–0.50)	3 (0.0)	0.45 (0.14–1.41)	0.49 (0.16–1.54)
18.5–24.9	179,954	2095 (1.4)	1.00*	1.00*	131 (0.1)	1.00*	1.00*
25–29.9	60,925	1337 (2.7)	1.89 (1.77–2.02)	1.88 (1.76–2.01)	125 (0.2)	2.50 (2.00–3.15)	2.52 (1.99–3.19)
≥30	27,538	932 (4.3)	3.12 (2.89–3.37)	3.08 (2.84–3.33)	144 (0.7)	6.75 (5.42–8.41)	6.78 (5.41–8.51)
Missing	29,784						
Age (years)							
18–24	103,686	1773 (2.0)	1.06 (0.99–1.13)	1.10 (1.03–1.18)	161 (0.2)	0.97 (0.79–1.19)	0.93 (0.75–1.16)
25–29	124,910	2000 (1.9)	1.00*	1.00*	198 (0.2)	1.00*	1.00*
30–34	67,441	920 (1.6)	0.86 (0.80–0.93)	0.86 (0.79–0.93)	77 (0.1)	0.73 (0.56–0.95)	0.77 (0.59–1.01)
≥35	9856	160 (2.0)	1.06 (0.90–1.25)	1.02 (0.86–1.20)	14 (0.2)	0.94 (0.55–1.61)	0.90 (0.52–1.55)
Smoking							
No	262,410	4326 (2.0)	1.00*	1.00*	389 (0.2)	1.00*	1.00*
Yes	28,757	320 (1.3)	0.67 (0.60–0.75)	0.60 (0.54–0.68)	42 (0.2)	0.98 (0.72–1.35)	0.87 (0.63–1.20)
Missing	14,726						

Data are presented as odds ratios (OR) with 95% confidence intervals (CI).
BMI, body mass index; BW, birthweight; SDS, standard deviation score.
*ref.
[a]Adjustments were made for early pregnancy BMI, age, and smoking.

and 4.2 kg compared with both higher and lower birthweights.[7] Furthermore, the risk of coronary heart disease has been reported to be lower for individuals with a moderately high birthweight compared with those with birthweights between 3 and 4 kg.[8]

A major strength of this study was the use of a nationwide register with high coverage, making it possible to analyze birthweight subgroups separately. The register also provides a possibility to study intergenerational effects, related to pregnancy and the perinatal period. Since data are forwarded to the register at the time of delivery, recall bias is minimized. Moreover, the homogeneity of the cohort represents another strength. Hence, the results reflect the situation in a Nordic population.

A weakness of this study was the limited possibility to control for genetic factors,[37] due to the incompleteness of grandmother BMI and GDM data. Other limitations include that we did not have access to comprehensive socioeconomic data, or information on maternal weight gain during pregnancy. Yet another possible limitation to this study is that we did not have information on father's size. Paternal birthweight is associated with offspring birthweight,[38,39] whereas there is no association between paternal BMI during pregnancy and birthweight of the offspring.[39]

In conclusion, our study demonstrated that being born with a high birthweight was associated with an increased likelihood of adult overweight and obesity as well as offspring macrosomia. This was most pronounced in subjects with a very high birthweight (>3 SDS). A low, but not a high, birthweight was associated with an increased likelihood of gestational diabetes.

Supplementary materials. For supplementary material for this article, please visit https://doi.org/10.1017/S2040174421000751.

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Conflicts of interest. The authors declare no competing interests.

Ethical standards. The study was approved by the Regional Ethical Review Board in Uppsala (Dnr: 2014/104), and performed in accordance with relevant national and international guidelines for medical research.

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