# Growth Trajectories of Body Mass Index during Childhood: Associated Factors and Health Outcome at Adulthood

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**Objective** To identify body mass index (BMI) trajectories from birth to age 10 years and to assess their association with child and parental characteristics and with adult nutritional status and metabolic risk factors.

**Study design** Retrospective cohort study with 1188 subjects aged 20-60 years. Childhood growth was assessed using measured weight and height data collected retrospectively from health booklets, which also provided information on gestational age, birth weight, and early nutrition. Height, weight, waist circumference, fasting blood glucose, lipids profile, and blood pressure were measured at adulthood. Participants self-reported parental silhouette based on a 9-figural scale. Group-based modeling was applied to identify BMI trajectories. Associations were assessed using ANOVA and multiple logistic regression.

**Results** Five growth trajectories following or crossing BMI percentiles emerged: stable-25th (15.3% of the sample), stable-50th (35.9%), stable-75th (28.0%), ascending-75th (19.2%), and ascending-obesity (1.6%). Overall, associated factors from early life were mother's corpulence (higher in the ascending-obesity group), gestational age (higher in the stable-50th, stable-75th, and in the ascending-obesity groups), and birth weight (higher in the ascending-obesity group) (all $P < .05$). Childhood trajectories were associated with adult BMI and waist circumference (higher in the stable-75th and in the ascending groups) (all $P < .0001$).

**Conclusions** This study shows heterogeneity in patterns of growth trajectories. Specific trajectories were associated with greater BMI and waist circumference during adulthood. Monitoring growth trajectories may improve chronic disease prevention. *(J Pediatr 2017;186:64-71).*

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Associations between early-life growth factors, in particular adiposity (measured by the body mass index [BMI]) and adult body weight[1] and health,[2] have generated substantial interest in the literature. However, the static assessment of BMI in childhood as a factor that relates with health outcomes at adult age ignores the dynamic of BMI variation over time. One promising approach considering both the intensity and the developmental pattern of adiposity has emerged through the analysis of BMI trajectories, which allows establishing sequences of transitions from one state to another over time.

Growth characteristics were shown to relate to health outcomes in adulthood, including the BMI trajectory of subjects who had been thin in infancy and, thereafter, rapidly gained weight,[3-5] and showed variations in growth velocity[6] and age at adiposity rebound.[5,7]

Multiple pathways leading to adult obesity probably exist. Few studies have examined the development of BMI or BMI z score trajectories in childhood using group-based trajectory modeling; this is a statistical technique that assumes that the data include latent distinct groups (trajectories), which best summarize the complex developmental information collected over a life course.[8] These studies have identified 3-7 growth trajectory groups.[9-21]

Consequences of the heterogeneity in these trajectories remain largely unexplored. Few studies have examined the association between trajectories (using group-based trajectory modeling) and nutritional status in childhood or adolescence,[16] metabolic outcomes,[16,17] mortality,[21] or the association with nutritional status and metabolic risk factors in adulthood.

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| BMI | Body mass index |
| CECA | Child Growth and Metabolic Outcome at Adulthood |
| EPICES | Evaluation of Deprivation and Inequalities of Health in Healthcare Centers |
| HDL | High-density lipoprotein |
| LDL | Low-density lipoprotein |

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The authors declare no conflicts of interest.


http://dx.doi.org10.1016/j.jpeds.2017.02.010

We hypothesized that growth trajectories may be related to parental and early life characteristics and that different patterns of growth may correlate with specific metabolic outcomes in adult life. This study aimed to explore BMI growth trajectories from birth to 10 years of age, to verify child and parental characteristics associated with distinct BMI trajectories, and to determine whether these trajectories are associated with nutritional status and metabolic risk factors at adulthood.

## Methods

The sample was selected from the pool of 24 574 adults attending one of the health examination centers in the central/western part of France (parts of 3 regions: Centre, Pays de la Loire, and Normandie) from September 2008 to July 2009. All individuals affiliated with the French national health insurance system (corresponding to about 85% of the French population) are able to benefit from a free medical and laboratory check-up every 5 years. The population is generally aware of this benefit; practical information is publicly available. All adults attending the health centers traditionally complete a set of questionnaires that focus on diet, physical activity, lifestyle, socioeconomic conditions, and health status. In addition, a clinical examination and blood sampling was performed. Subjects participating in the Child Growth and Metabolic Outcome at Adulthood (CECA) study were asked to complete an additional growth questionnaire that included information on parental silhouette, nutrition in early life, and weight and height data during childhood, and to bring their health booklets containing growth data to the medical check-up. To be included in the study, subjects had to bring the health booklet to the examination and complete the growth questionnaire. Data collection by the examination centers was approved by the *Comité National Informatique et Liberté* (CNIL number26674).

Self-administered questionnaires were completed by participants and verified by the physician performing the health examination interview. Sex, age, physical activity (≤30 minutes/day, 30-60 minutes/day, >60 minutes/day), and occupational category (managerial staff, intermediate profession, employee or manual worker, unemployed, never employed, and retired) were provided. The deprivation level of each participant was assessed using the Evaluation of Deprivation and Inequalities of Health in Healthcare Centers (EPICES) score.[22] The EPICES score is calculated based on answers to 11 questions, and varies from 0 to 100, from the least deprived to the most deprived situation. Gestational age (months), birth weight (g), and nutrition when leaving the maternity ward (exclusive or partial breastfeeding, formula feeding) were collected using data from the health booklets when available. Parental silhouette was estimated using 9-figural scale.[23] Subjects were asked to choose the silhouettes that most closely resembled that of their mothers and fathers at the maximal BMI attained during their lifetime.

Individuals were asked to report growth data from childhood that were recorded in their health booklet. Health booklets have been distributed to parents of all newborns in France since 1945 by the Ministry of Health. They are intended to record anthropometry (measured by health practitioners) and health events during childhood beginning at birth. Subjects included in our study were asked to report weight and height data at birth and at specific periods during childhood extracted from their health booklet: 1 measurement of weight and length/height at approximately at 1, 3, 6, and 9 months of age; 2 measurements between 1 and 2 years of age, between 2 and 3 years of age, and between 3 and 4 years of age; and finally, 1 measurement at around 5, 6, 7, 8, 9, and 10 years of age. Subjects were also asked to report the exact date and/or age at each reported measurement. All weight and height measures were verified by nurses dedicated to this specific study to avoid potential errors. Then, BMI (weight in kilograms divided by squared height in meters) was calculated for each data point. Individual growth curves were constructed. Age at adiposity rebound was visually estimated[24] as described previously.[25] Prevalence of overweight (including obesity) during infancy was assessed according to the International Obesity Task Force BMI cut-offs.[26]

Weight, height, and waist circumferences in adulthood were measured by trained nurses, with participants wearing only underwear, according to standardized procedures.[27] Waist circumference was measured by the physician at the smallest horizontal circumference between the costal margin and the iliac crests. Waist circumference was measured to the nearest 0.5 cm. Height was measured to the nearest 0.1 cm with a Seca stadiometer (Seca GmbH and Co KG, Hamburg, Germany). Weight was measured to the nearest 0.1 kg with a Seca scale (Seca GmbH and Co). Sitting diastolic and systolic blood pressures were measured in subjects who had been lying down for at least 5 minutes, using an OMRON automatic tensiometer (Omron HEM-705CP; Omron Healthcare/DuPont Medical, Frouard, France). Blood samples were collected in the morning after at least 8 hours of fasting. All samples were assayed using a C8000 Architect Abbott analyzer (Architect Abbott, Rungis, France). Plasma glucose was assayed by the hexokinase procedure (Architect Abbott). High-density lipoprotein (HDL)-cholesterol and triglycerides were assayed by an enzymatic method (Architect Abbott). Total cholesterol concentration was assessed by a peroxidase, anti-peroxidase antibody method (Architect Abbott). Low-density lipoprotein (LDL)-cholesterol concentration was calculated with the Friedewald equation in which LDL-cholesterol = (total cholesterol – HDL-cholesterol – triglycerides)/5.[28]

### Statistical Analyses

All analyses were performed using SAS software v 9.3 (SAS Institute Inc, Cary, North Carolina). BMI z scores were calculated according to World Health Organization growth standards.[29] Identification of BMI z score trajectories from birth to 10 years of age was made by performing the exploratory method of group-based trajectory modeling (also referred to as a semiparametric mixture model),[8] using a PROC TRAJ macro in SAS (SAS Institute Inc).[30,31] We estimated each possible combination of trajectory shapes (linear, quadratic, cubic, or quartic) in 4, 5, and 6 trajectory models. To determine trajectory shape and number, we considered several factors,