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# Prevalence of overweight, obesity, and early adiposity rebound in nursery school children in southeastern France

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## ABSTRACT

**Background:** The aim of the present study was to assess the prevalence of overweight, obesity, and early adiposity rebound in nursery school children aged 3.5–4.5 years and to evaluate associations with deprivation.

**Methods:** A cross-sectional study was conducted in the Bouches-du-Rhône department in southeastern France. Data for all nursery school children aged 3.5–4.5 years were collected during systematic medical examinations. The prevalence of overweight and obesity was determined using French, International Obesity Task Force (IOTF), and World Health Organization reference values. A French ecological deprivation index was used to assess associations with deprivation.

**Results:** Among 19,295 children included in the study, the prevalence of overweight (IOTF-25 < BMI < IOTF-30) was 9.1% and the prevalence of obesity (BMI > IOTF-30) was 2.6%. Children attending nursery schools in the most disadvantaged areas were 4.3 times more likely to be affected by obesity than those from schools in the most advantaged areas (OR: 4.32; 95% CI: 2.98–6.25,  $p < 0.001$ ), after adjusting for gender, age group, and school status. Early adiposity rebound was observed in 2131 of 9872 children (21.6%).

**Conclusion:** Programs to prevent childhood overweight and obesity in France should be intensified and take account of major persistent social inequalities. Medical practitioners should learn to systematically assess BMI curve dynamics and early adiposity rebound.

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## 1. Introduction

Obesity and overweight represent an ongoing global public health challenge, which is evolving differently across the world and between developed and developing countries [1,2]. In 2018, 5.9% or 40 million children under 5 years old worldwide were overweight or obese [3]. In Europe in 2016, approximately 17.9% of children aged 2–7 years were affected by overweight or obesity, and 5.3% of children were affected by obesity [4], although prevalence rates vary considerably between regions. In France, as in most developed countries, it seems that overweight and obesity rates in children have stabilized since the 2000s [5]. Obesity in childhood or adolescence can lead to persistent obesity in adulthood with a corresponding risk of developing chronic diseases [6,7], such as cardiovascular, metabolic (insulin resistance, dyslipidemia, and type 2 diabetes mellitus), and

respiratory diseases (obstructive sleep apnea), musculoskeletal disorders, and certain types of cancer (endometrium, breast, colon) [8–10]. Obesity is also associated with a decreased reported quality of life in children [11]. According to the World Health Organization (WHO), “childhood obesity is one of the most serious public health challenges of the 21st century” [12].

Adiposity rebound (AR), first reported in 1984 by Rolland-Cachera et al., is defined as the increase in BMI that follows the minimum (nadir) BMI that usually occurs between 5 and 7 years of age [13]. There is good evidence that adiposity rebound before the age of 5 years (early AR) is associated with pediatric overweight/obesity, an association that is stronger the younger the rebound adiposity occurs [13–17]. However, the prevalence of obesity/overweight and early AR in preschool children remains poorly studied in France. International studies have reported a strong and inverse socioeconomic gradient for childhood obesity and overweight, and a link with the level of parental education, particularly maternal [18–21]. However, this

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related association has rarely been studied in pre-school children in France [5,22–26].

The aim of this study was therefore to assess the prevalence of overweight, obesity, and early AR based on anthropometric measurements of nursery school children aged 3.5–4.5 years in southeastern France. Associations between deprivation and the prevalence of overweight, obesity, and early AR were also studied.

## 2. Methods

### 2.1. Study design

This was a descriptive cross-sectional study. The data were collected over three school years (September 2017 to June 2020). Under French legislation, ethics committee approval was not required as the data were anonymous and recorded independently of the study [27].

### 2.2. Study population

The study population comprised all children between 3.5 and 4.5 years of age enrolled in the 667 nursery schools in the Bouches-du-Rhône department in southeastern France.

### 2.3. Data collection

Data were collected during systematic medical examinations carried out by maternal and child health services in the nursery schools. The data collected included: sex, age, weight, height, school attended, and presence of AR. BMI was calculated as usual:  $\text{weight}(\text{kg})/\text{height}^2(\text{m})$ . Values below  $12 \text{ kg/m}^2$  were considered measurement errors and these children were excluded. BMI z-scores were calculated using WHO references for children under 5 years of age [28].

The children were measured once by health service employees (physicians, nurses, and childcare assistants), without shoes and in light clothing. Weight was measured once using an electronic (two-digit precision) or mechanical (single digit precision) scale and height was measured using a stadiometer. Measurement instruments differed between schools and were not standardized.

### 2.4. Definitions of obesity and overweight

The prevalence rates of overweight and obesity were determined using the International Obesity Task Force (IOTF) [4] cut-offs, French reference values (the Rolland-Cachera classification) [29], and WHO thresholds [30]. We used both French reference values and international classifications for comparison with previous French and international studies.

### 2.5. Adiposity rebound

BMI curves usually increase from birth until the first year of life, then decrease down to a minimum between 5 and 7 years of age. AR corresponds to the subsequent increase in BMI [13].

In this study, early AR was defined as any increase of more than two percentile thresholds in the BMI curve (according to French references) between 1 and 4.5 years of age (maximum age of the children in the study). Personal child health records in France contain BMI curves on which the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th percentile values of the reference population are indicated. AR was only assessed in children whose personal child health record was available and contained at least two previous BMI measurements (such that there were three points on the BMI curve in total).

Children with early AR but classified as thin according to the IOTF threshold (i.e.,  $\text{BMI} < \text{IOTF-18.5}$ ) were excluded from the analysis of

early AR as these were likely cases of catch-up growth in underweight children.

We defined children with a “high risk of persistent obesity” as (a) children with early AR and (b) children with obesity ( $\text{BMI} > \text{IOTF-30}$ ) and uninterrupted BMI increase since birth.

### 2.6. Deprivation index

The French ecological deprivation (FDep) index was used to assess the association between deprivation and the prevalence of overweight, obesity, and early AR [31]. This index is a measure of the socioeconomic makeup of the area where the nursery schools are located, defined as the first component of a principal component analysis of four routinely collected ecological socioeconomic variables: the percentage of high-school graduates, median household income, percentage of blue-collar workers, and unemployment rate. An FDep09 index, based on 2009 French census data, was allocated to each child using the IRIS of their school. IRIS is a French system for dividing the country into units of equal population size (~2000 inhabitants). The sample was divided into quintiles, as recommended by the French health agency, *Santé Publique France* [32]: the first quintile (Q1) is the least disadvantaged quintile and the fifth (Q5), the most disadvantaged.

### 2.7. Statistical analysis

Continuous variables were compared using *t* tests. Categorical variables were compared using chi-square tests. The analyzes were carried out using the software SPSS version 20.0 and SAS version 9.4. The threshold for statistical significance was set to  $p < 0.05$  (two-tailed).

For each outcome ( $\text{BMI} > \text{IOTF-25}$ ;  $\text{BMI} > \text{IOTF-30}$ ), we performed univariate and multivariate multilevel analyzes to assess whether the following factors (sex, age group, school status, FDep09 quintile) were independently associated with overweight and obesity. A multilevel model with the nursery school as a random effect was used to account for the hierarchical structure of the data (children in the same nursery school are more correlated with each other than with children from other schools). For each outcome (overweight, obesity), we performed beforehand an empty multilevel model with a single random effect to determine the variability of the outcome that can be accounted by nursery schools. This empty model allows us to compute the intraclass correlation coefficient (ICC), which indicates how much of the total variation in the probability of having  $\text{BMI} > \text{IOTF-25}$  or  $\text{BMI} > \text{IOTF-30}$  was accounted for by the school, and thus enables validation of the subsequent use of this type of model (multilevel model). The ICC was calculated for each model, indicating how much of the total variation in the probability of having a  $\text{BMI} > \text{IOTF-25}$  or  $\text{BMI} > \text{IOTF-30}$  was accounted for by the school.

The completeness of the sample was calculated by comparing the size of the study group with the average number of children born per year in Bouches-du Rhône in the period 2013–2015.

## 3. Results

### 3.1. Descriptive analysis

Data were obtained for 19,347 children, with a mean age of  $4.1 \pm 0.2$  years, from 667 nursery schools. This represents 72.9% of the estimated population aged 3.5–4.5 years in the Bouches-du-Rhône department. A total of 52 children with a BMI below  $12 \text{ kg/m}^2$  were excluded (0.3% of eligible children). The study group consisted of 9366 girls (48.5%) and 9929 boys (51.5%). The boys' average BMI z-score was significantly higher than the girls' ( $0.3 \pm 1.1 \text{ kg/m}^2$  vs.  $0.2 \pm 1.0 \text{ kg/m}^2$ ,  $p < 0.001$ ).

### 3.1.1. Prevalence (n = 19,295)

The distributions of the study group in terms of IOTF and Rolland-Cachera classes are presented in Fig. 1. The prevalence rates of overweight and obesity were similar as defined by IOTF and WHO thresholds, respectively, 8.9% (1708) versus 9.1% (1747) for overweight and 2.6% (509) versus 2.6% (498) for obesity.

The prevalence of overweight according to IOTF cut-offs differed significantly between girls and boys (10.2% [959] vs. 7.9% [788],  $p < 0.001$ ) and in the prevalence of overweight and obesity according to French reference values (7.5% [707] vs. 6.7% [663],  $p = 0.019$ ). The difference between girls and boys in the prevalence of obesity according to IOTF cut-offs was of borderline significance ( $p = 0.08$ ).

### 3.1.2. Early adiposity rebound (n = 9872)

The data required to evaluate AR were available for 51.2% of the children (n = 9872). The prevalence rates of early AR are presented in Fig. 2. Early AR was observed in 21.6% (2131) of this group, in 19.5% (992) of boys and 23.7% (1139) of girls ( $p < 0.001$ ). Of the children with a normal BMI (IOTF-17 < BMI < IOTF-25), 17.0% (1402) had early AR. Among children with obesity (BMI > IOTF-30), 16.2% (44) had BMI trajectories of constant increase since birth. The prevalence rates of AR and of children with a high risk of persistent obesity in the FDep quintiles are presented in Table 1.

### 3.1.3. Deprivation

Table 1 and Fig. 3 show that the prevalence rates of overweight, obesity, and of children at a high risk of persistent obesity were all higher the more deprived the school area was.

Indeed, the prevalence of obesity increases from 1.1% in the least disadvantaged areas (Q1) to 4.6% in the most disadvantaged areas (Q5). As for overweight, the prevalence increases from 7.6% (Q1) to 10.9% (Q5). However, the prevalence of high risk of persistent obesity, defined as those with early AR and those with a constantly increasing

BMI curve since birth, seems to increase much more moderately with social disadvantage, with a maximum reached at the 4th quintile.

### 3.2. Factors associated with overweight and obesity

The results of the two multilevel multifactorial regression analyzes, the first for overweight including obesity, the second for obesity only, are summarized in Table 2. After adjusting for gender, age group, and school status, children from nursery schools in the most disadvantaged areas were twice as likely to be affected by overweight or obesity than those from the most advantaged areas (odds ratio [OR]: 2.0; 95% confidence interval [CI]: 1.7–2.4,  $p < 0.001$ ). Similarly, the odds of being affected by obesity, adjusted for gender, age group, and school status, were 4.3 times higher for children in the most deprived areas compared with those from the most advantaged (OR: 4.3; 95% CI: 3.0–6.3,  $p < 0.001$ ).

## 4. Discussion

To our knowledge, this is the first time in France that such a large study has identified a significant association between deprivation and the risk of being affected by obesity or overweight in pre-school children. The results are consistent with those of a previous more limited study of the same population and with the recent French Obepi report, where obesity prevalence remained high in the most socially deprived or less educated individuals [22,33].

### 4.1. Prevalence

We measured the prevalence of overweight and obesity using both French reference values and the IOTF classification, for comparison with previous French and international studies. Note that the

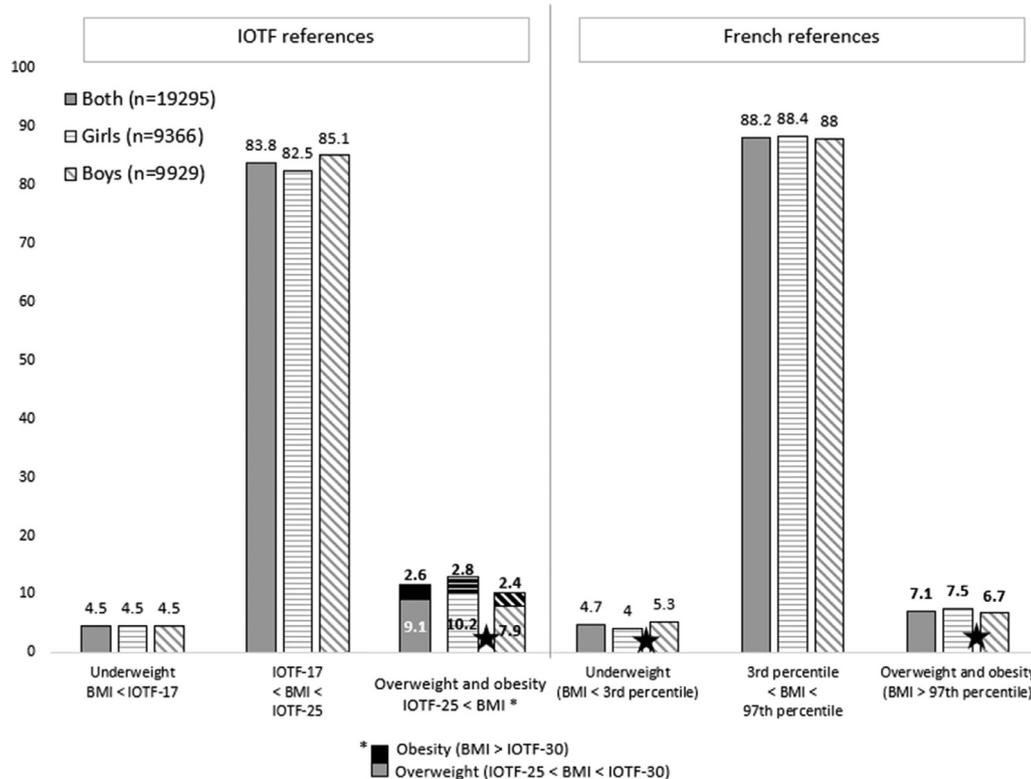
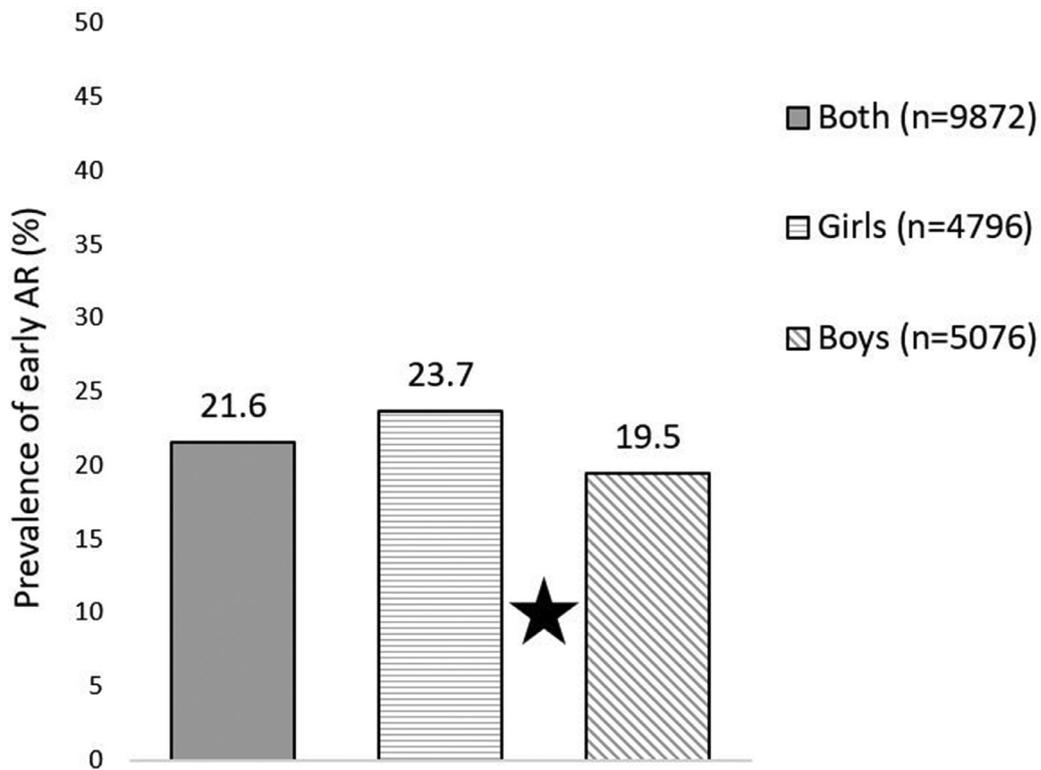
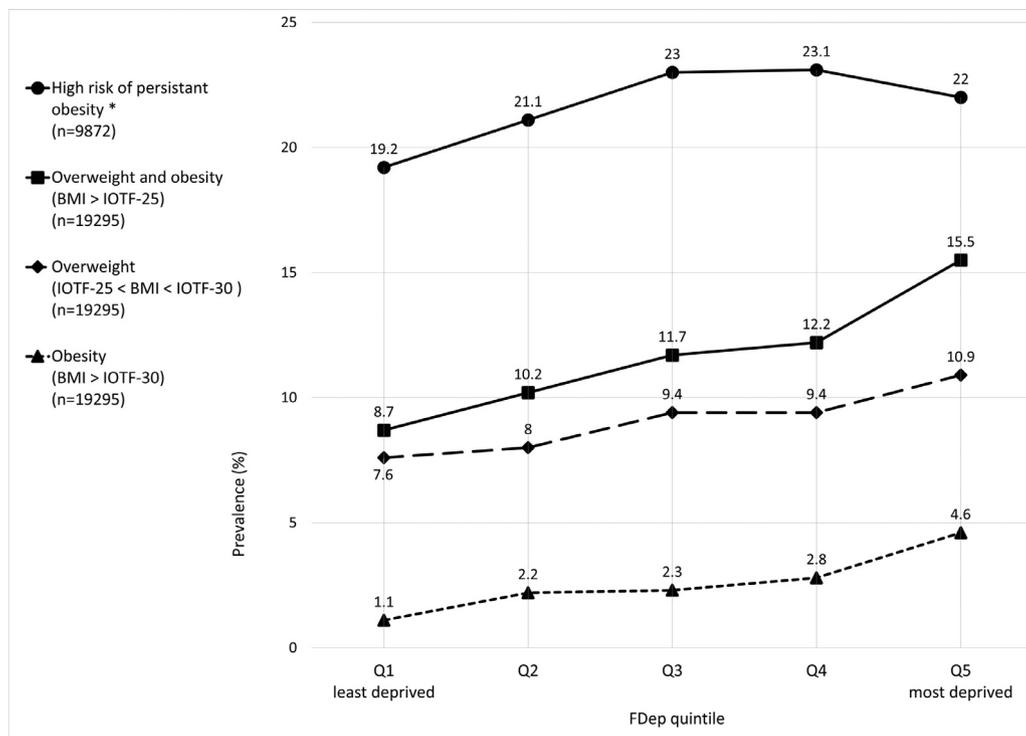


Fig. 1. Distribution of the study group (n = 19,295) according to the International Obesity Task Force (IOTF) classification and with respect to French reference values (Rolland-Cachera classification). ★  $p < 0.05$  (chi-square test of the difference in prevalence between girls and boys). BMI: body mass index.



**Fig. 2.** Prevalence of early adiposity rebound (among 9872/19,295 with an assessable BMI curve). ★ $p < 0.05$  (chi-square test of the difference in prevalence between girls and boys). BMI: body mass index; AR: adiposity rebound.



**Fig. 3.** Prevalence of obesity and overweight in the study group ( $n = 19,295$ ), and of children with a high risk of persistent obesity (among 9872 with an assessable BMI curve) in quintiles defined by the level of deprivation (FDep index) of the area around their nursery school. Children at high risk of persistent obesity were defined as those with early adiposity rebound and those with a constantly increasing BMI curve since birth.

BMI: body mass index; FDep: French deprivation index; IOTF: International Obesity Task Force.

**Table 1**

Prevalence of early adiposity rebound and children at high risk of persistent obesity in deprivation quintiles.

FDep quintile	Q1 (n = 1755) Least deprived	Q2 (n = 1780)	Q3 (n = 2127)	Q4 (n = 2133)	Q5 (n = 2077) Most deprived	Total (n = 9872)
Early AR	19.1 (335)	21.0 (373)	22.9 (487)	22.7 (484)	21.8 (452)	21.6 (2131)
Obesity with uninterrupted BMI increase since birth	0.1 (2)	0.1 (2)	0.1 (3)	0.4 (8)	1.4 (29)	0.4 (44)
High risk of persistent obesity*	19.2 (337)	21.1 (375)	23.0 (490)	23.1 (492)	23.2 (481)	22.0 (2175)

AR: adiposity rebound; FDep: French ecological deprivation index; BMI: body mass index.

Values are percentage (number) of patients.

\* High risk of persistent obesity was defined as early AR or obesity with uninterrupted BMI increase since birth.

definitions of overweight and obesity in the IOTF classification lead to higher prevalence estimates than the French reference values do.

The results of this study are consistent with those of previous investigations of children in France published over the past 20 years. The prevalence of overweight, excluding obesity (IOTF-25 < BMI < IOTF-30), was 9.1%, slightly higher than observed in three other French studies of 3- to 6-year-olds: 8.2% [22], 8.4% [34], and 8% [15]. The prevalence of obesity (BMI > IOTF-30) measured in the present study (2.6%) is marginally higher than reported in two of these studies (2.1% [22] and 2% [15]), but lower than found for children 1 year older than in our study (3.5%) [34]. The prevalence of overweight and obesity according to French reference values was 7.1%, which is lower than was found in a 2012 study of children living in the same area but 1 year older than those in our study (10.5%) [35]. Our results are in agreement with those of a recent systematic review of the prevalence of overweight and obesity in pre-school children (2–7 years) in Europe [36], which places France as one of the countries with the lowest prevalence of overweight and/or obesity in Europe (overweight and obesity 11%, 95% CI: 7.7–15.4%, obesity alone 2.3%, 95% CI: 1.8–2.7%).

It therefore seems that the prevalence of overweight and obesity has stabilized over the past 20 years. This was noted previously for high-income countries in 2015 and 2017, although a recent report emphasized a significantly increasing linear trends of obesity in young French adults between 2013 and 2016 [1,5,33]

#### 4.2. Deprivation

In spite of this leveling off in the prevalence of overweight and obesity, this study highlights the persistence of significant social inequalities in health, which are all the more worrying as they are present from an early age, the children in this study being only 3.5–4.5 years old.

The association between parental socioeconomic variables and overweight/obesity has been demonstrated many times in studies of children, using individual indicators such as socioeconomic status or educational level [5,18,19,22–25]. However, the mechanisms underlying the relationship between socioeconomic status and obesity or overweight remain unclear [37,38]. According to Mech's systematic review in 2016, factors that help to explain the association between socioeconomic status and overweight or obesity act at three levels: that of the children (extensive TV time, breastfeeding [early weaning], poor eating habits, and birth weight), their parents (extensive TV time, smoking, and overweight), and the household (ethnicity and less child-care attendance) [37]. Furthermore, it has been observed that children raised in environments with high levels of cognitive stimulation are the least likely to develop obesity and are more likely to be physically active [39–41].

Regardless of the mechanisms involved, these disparities in the prevalence of overweight or obesity between the most and least deprived school areas should be considered when implementing prevention policies. According to a 2014 French expert report on social inequalities in health outcomes related to diet and physical activity, interventions focusing on individual responsibility, such as nutrition education or information campaigns, are likely to increase social inequalities in health [42]. According to the authors, there is a need for policies and interventions whose intensity is proportional to the needs of different groups in the population, a concept developed by the WHO as early as 2008 [43]. This is one of the principles underlying the French Nutritional Health Program for 2019–2023 [44], developed in response to evidence that between 2006 and 2015, the prevalence of overweight (including obesity) among 6- to 17-year-olds had remained higher among children from the least educated backgrounds and that this difference had even increased for boys in that period [5].

#### 4.3. Early adiposity rebound

Early AR (i.e., AR before the age of 6 years) is associated with the development of overweight and obesity later on in life, and the earlier it occurs, the greater the level of overweight [13–17].

Early AR was observed in 21.6% of assessable children in the study group, with a significantly higher prevalence in girls than in boys (23.7% vs. 19.5%,  $p < 0.001$ ). This suggests that just over one in five

**Table 2**

Multilevel multifactorial regression models for overweight- and obesity-associated factors.

<b>Model for factors associated with overweight (including obesity)*</b>			
<b>ICC=6%</b>			
	OR	95% CI	p
Gender			
Girls vs. boys	1.31	1.20–1.43	< 0.001
Age group			
[4, 4.5] years vs. [3.5, 4] years	1.11	1.01–1.23	0.0226
School status			
Private vs. public	0.89	0.73–1.08	0.2439
FDep quintile			
Q1 (least deprived)	Ref	-	-
Q2	1.23	1.02–1.48	0.0306
Q3	1.42	1.18–1.70	< 0.001
Q4	1.47	1.23–1.76	< 0.001
Q5 (most deprived)	1.97	1.65–2.35	< 0.001
<b>Model for factors associated with obesity*</b>			
<b>ICC=12%</b>			
	OR	95% CI	p
Gender			
Girls vs. boys	1.18	0.98–1.41	0.0767
Age group			
[4, 4.5] years vs. [3.5, 4] years	1.34	1.11–1.62	0.0023
School status	0.78	0.52–1.16	0.2241
Private vs. public			
FDep quintile	Ref	-	-
Q1 (least deprived)	2.03	1.36–3.02	< 0.001
Q2	2.08	1.40–3.09	< 0.001
Q3	2.50	1.70–3.69	< 0.001
Q4	4.32	2.98–6.25	< 0.001
Q5 (most deprived)			

CI: confidence interval; FDep: French ecological deprivation index; ICC: intraclass correlation coefficient; OR: odds ratio.

\* Overweight and obesity defined according to International Obesity Task Force (IOTF) cut-offs.

children in the Bouches-du-Rhône department have an increased risk of developing obesity later in life, which is very worrying. This estimate of the prevalence of early AR is slightly higher than the rate reported by Roche et al. in a French cohort of 1055 children (16.3%) [15]. In their study, early AR was defined by the position of the BMI minimum relative to the median of the sample; type A early AR (16.3% of sample) was associated with an increased risk of developing overweight/obesity at 6–8 years of age.

Among the children with a normal BMI (IOTF 17–25) in the study, 17.0% (1402) had early AR. Péneau et al. observed similarly in 2009 that most adolescents with obesity had a normal BMI at the time of AR [45]. Williams and Goulding found in their longitudinal study that children with early AR were the subgroup with the lowest BMI at age 3 years [46]. Early AR is thus predictive of excessive weight gain before it can be noticed by parents or health professionals, even in children who are not affected by overweight or obesity. Medical supervision is warranted for these children at greater risk of developing obesity, and recommendations should be provided to their parents. Several French studies have found that early AR is only investigated by 35–71% of general practitioners, which is insufficient [47–51]. As a reminder, the parents' BMI should also be assessed to categorize the child in a population at risk of developing overweight or obesity.

Among children with obesity (BMI > IOTF-30), 16.2% had a BMI curve that had risen continuously since birth, which is suggestive of genetic obesity (monogenic or syndromic) and should prompt investigations [52]. Children with a constantly rising BMI curve were grouped together with those with early AR because both groups have a high risk of persistent obesity and require follow-up, and in some cases management needs to be initiated quickly.

The effect of deprivation on the prevalence of early AR is less important than for obesity and overweight, and no longer seems to exist from the 3rd deprivation quintile. It suggests that early AR should be accorded the same importance regardless of children's socioeconomic backgrounds.

#### 4.4. Strengths and limitations of the study

To our knowledge, this is the first study in France to involve such a large group of children ( $n = 19,295$ ) at such a young age (3.5–4.5 years). The study sample included about three quarters of all children of this age in the Bouches-du-Rhône department and was therefore close to exhaustive. AR was assessed for 9872 children, which again had not been done before in France. Despite a lack of individual-level socioeconomic data, the prevalence of overweight/obesity was found to be associated with the level of disadvantage of the school's area using the FDep index.

The limitations of the study include the fact that the children were measured and weighed using non-standardized equipment, which may have introduced measurement bias. Furthermore, it was not possible to know whether the three BMI measurements in the health record used to assess the BMI curve and the presence of early AR were performed with the same equipment. Another limitation is that the FDep index was used as a proxy for individual socioeconomic variables, based on the hypothesis that an individual's socioeconomic level is close to the average level of the area where they live, which introduces ecological bias [32]. However, the use of this index at the smallest possible geographic scale (IRIS unit) tends to minimize ecological bias [53]. Although this approach can be useful for documenting and monitoring health inequalities, it is then difficult to distinguish between contextual and individual effects in the measurement of a health event [54,55]. Nevertheless, this index allows the individual socioeconomic level to be approached in studies where collecting individual socioeconomic data is not feasible, as was the case in this large study ( $n = 19,531$ ). A further limitation is that the analysis of deprivation considered the area around the children's

nursery school rather than the area around their home. However, children in France typically attend schools in their catchment area, although this is not necessarily the case if the parents request it.

## 5. Conclusion

This study reported a stabilized prevalence of overweight (IOTF-25 < BMI < IOTF-30) and obesity (BMI > IOTF-30), respectively, of 9.1% and 2.6% among 19,295 nursery school children aged 3.5–4.5 years. However, one in five of these children developed early AR and obesity prevalence remained high in the most socially deprived. Programs against childhood overweight and obesity should be continued and even intensified in France in the hope of reducing prevalence from a very young age. Medical practitioners should be better informed of the importance of plotting children's BMI curves, of systematically following the dynamics of these curve, and of the detection early AR [52]. Thanks to this screening, the practitioner could then support the parents and their child toward lifestyle changes without feeling guilty and with a proper appreciation of their personal context.

In the maternal and child protection service (PMI), the implementation of prevention, referral, and management actions for overweight and obesity in children is required, including a training plan with reference teams in the region, the setting up of multidisciplinary meetings for complex cases and, a good understanding of the offer of references and expertise in the field, both for professionals and families.

Implementing these measures right now and from the earliest age is crucial to limit the development and societal impact of obesity and chronic diseases in adulthood.

## Declaration of Competing Interest

None.

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