Original Article

Association between lifestyle habits and adiposity values among children exposed and unexposed to gestational diabetes mellitus *in utero*☆

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ABSTRACT

Aims: The objectives of this study were to assess the profile of lifestyle habits among children exposed (GDM+) or unexposed (GDM-) to GDM and to assess whether a healthy lifestyle profile is associated with lower adiposity values among these children.

Methods: A total of 105 GDM+ and 38 GDM- children aged 2—14 years were included. Vegetables and fruit intakes were collected using two 24-h dietary recalls. Physical activity and sedentary time were measured with accelerometers. Screen and sleep time were assessed using questionnaires. Weight, height and waist circumference were measured. Body composition was assessed by absorptiometry.

Results: GDM+ children had lower moderate-to-vigorous physical activity practice (p = 0.043) and fruit intake (p = 0.020) than GDM- children. Among children with an unhealthy lifestyle (meeting 0—2 lifestyle recommendations), GDM+ children had greater percentage of fat mass (p = 0.021) and android fat mass (p = 0.020) than GDM- children. Moreover, among GDM+ children, children with a healthy lifestyle (meeting 3—4 lifestyle recommendations) tended to have lower percentage of fat mass (p = 0.053) and android fat mass (p = 0.071) than those with an unhealthy lifestyle.

Conclusion: Improving lifestyle habits among GDM+ children could represent a promising approach to prevent deteriorated adiposity values.

1. Introduction

Gestational diabetes mellitus (GDM) is defined as hyperglycemia with onset or first recognition during pregnancy [1]. Children exposed to GDM *in utero* (GDM+) are at high risk of developing obesity later in life [2]. More specifically, these children tend to develop central adiposity [3—5], associated with a less favorable cardiometabolic profile which can lead to the development of chronic diseases [6]. Lifestyle habits, including diet [7] and movement behaviors (i.e. physical activity, sedentary time, screen time and sleep) [8], are recognized as important risk factors of obesity among children in the general population [9]. Indeed, an energy-dense, high-fat, low-fiber diet characterized by low consumption of vegetables and fruit is positively associated with increased adiposity among children [7]. Moreover, children practicing less physical activity, sleeping less or engaging in more screen time than the movement guidelines [10,11] are at increased risk for obesity

and central obesity [8]. Given that childhood is an important period during which lifestyle habits shape and track into adulthood [12], the adoption of a healthy lifestyle by GDM+ children may represent a promising avenue to prevent long-term adverse outcomes like obesity and central fat accumulation.

The prevalence of GDM increases worldwide [13], hence the importance of studying this population. However, lifestyle habits of GDM+ children are poorly studied. The use of subjective lifestyle habits measurements [3,14–17] and the inclusion of children with a very limited age range [2,15,16,18] or exposed to other types of diabetes [14,18] represent important methodological issues among previous studies. We have already shown that a better diet quality is associated with better health outcomes among GDM+ children [19]. However, the role of movement behaviors has not been investigated in this population. To our knowledge, no studies have explored the synergistic impact of diet and movement behaviors on children's health [8,20] among this specific population. To address these gaps, the objective of this study was to: 1) assess diet, sleep duration, physical activity, sedentary time and screen time among GDM+ children and children unexposed to GDM *in utero* (GDM-); and 2) assess whether a healthy lifestyle profile is associated with better adiposity values among GDM+ and GDM- children.

2. Methods

2.1. Study design

Children were recruited between 2012 and 2017 as part of the cohort study *GDM2* whose objective was to evaluate the impact of GDM exposure during pregnancy as well as lifestyle behaviors during the postnatal period on metabolic alterations in the offspring. Details on the study design have been previously described [21]. Briefly, women with or without a history of GDM and their children were recruited in Quebec City. Recruitment was made using contact information of participants from a previous project conducted by our research team among women with and without a history of GDM [22]. Participants were also recruited through medical records of two hospitals with a neonatal care unit in Quebec City (*Hôpital Saint-François d'Assise, Centre Hospitalier de l'Université Laval*), data from the provincial health plan registry (*Régie de l'assurance maladie du Québec*), emails sent to Laval University community, and posts on healthcare websites and social networks. GDM+ children had to be born from a mother with a history of GDM, but without a history of type 1 or type 2 diabetes. GDM- children had to be born from a mother without a history of GDM, type 1 or type 2 diabetes. Children came to the Institute of Nutrition and Functional Foods (INAF) of Laval University (Québec, Canada), accompanied by their mother, for a single 1-h visit. Written consents were obtained from all participants and ethical approval was obtained from the Laval University Ethics Committee (2011-196-A-4 R-3) and from the *Centre Hospitalier Universitaire de Québec* Ethics Committee (2015–2031). This cohort study was registered in the Clinical Trials.gov registry (NCT01340924).

2.2. Data collection

2.2.1. Lifestyle habits
2.2.1.1. Sleep. Mothers were asked to complete a physical activity log for their child over 7 consecutive days. They recorded the time their child spent doing various activities, such as napping (e.g. "nap from 1:00 p.m. to 2:00 p.m."), and reported their child's nocturnal bed time and wake up time. Valid sleep data was defined as a minimum of three nights over the week [23,24]. After exclusion of children with missing data (n = 41) or non-valid data (n = 6), mean nocturnal sleep duration and mean nap duration was calculated for each child. For children younger than 5 years, consistent with national recommendations [11], mean nocturnal sleep duration was combined with mean nap duration. According to the Canadian Society for Exercise Physiology (CSEP) 24-Hour Movement Guidelines for the Early Years [11] and for Children and Youth [10], children aged 1–2 years sleeping at least 11 h per day (including naps), children aged 3–4 years sleeping at least 10 h per day (including naps), children aged 5–13 years sleeping at least 9 h per day and children aged 14–17 years sleeping at least 8 h per day were categorized as meeting the sleep recommendation.

2.2.1.2. Physical activity and sedentary time. Physical activity and sedentary time were objectively assessed by ActiGraph GT3X triaxial accelerometers (ActiGraph, Pensacola, FL). Participants were instructed to wear it over the hip on an elasticized belt during 7 consecutive days continuously and for 24 h per day. They were asked to remove the accelerometer only during water-based activities (e.g. swimming, showering, bathing, etc.). Accelerometer data were collected in 1-min epochs and extracted with Actilife Software version 6.13.3. The level of movement intensity was derived in counts per minute per day according to Evenson cut-points: sedentary (≤100 counts), light (>100 to ≤2296 counts), moderate (≥2296 to <4012 counts) and vigorous (≥4012 counts) intensity activity [25]. Nonwear time was defined as a period of zero counts for at least 60 min consecutively, with allowance for a maximum of 2 min between 1 and 100 counts [26]. Sleep periods according to physical activity log were also defined as nonwear time. Valid day was defined as a minimum of 10 h of wear time, and valid week as a minimum of four valid days [27]. Children with missing data (n = 36) or non-valid data (n = 22) were excluded from physical activity analysis. According to the CSEP guidelines [10,11], children aged 1–2 years practicing at least 180 min of light-to-vigorous physical activity (LVPA), children aged 3–4 years practicing at least both 180 min of LVPA per day and 60 min of moderate-to-vigorous physical activity (MVPA) per day and children aged 5–17 years practicing at least 60 min of MVPA per day were categorized as meeting the physical activity recommendation. No quantified recommendation existed for sedentary time [10,11].

2.2.1.3. Screen time. Through a self-administered questionnaire adapted from the Canadian Community Health Survey, mothers were asked two questions about their child's habitual engagement in screen-based behaviors (television, computer, video game console, iPod, smartphone, and tablet) per day. For children under 5 years of age, mothers were asked the following questions: "On average, how many time a day your child …" 1) "… use the computer or play video games (including consoles, iPod, tablet, smartphone, etc.)?" and 2) "… watch television?". These questions were open-ended (i.e. answers given in hours:minutes). For children aged between 5 and 11 years, mothers were asked the following questions: "On average, how many hours a day does your child …" 1) "… watch television or videos or play video games?" and 2) "… spend on a computer (doing work, playing games, sending and receiving messages, chatting or surfing the Internet)?". The following responses were possible: 0, <1 h, 1–2 h, 3–4 h, 5–6 h, ≥7 h. No questions about screen-based behaviors were asked for children aged 12 years or older. The daily screen time was calculated by combining either the two open-ended questions in young children or the two closed-ended questions in older children by using the mid-points of the categories previously detailed (0, 0.5, 1.5, 3.5, 5.5 and 7 h, respectively) [8]. Children with missing data (n = 6) were excluded from screen time analysis. According to the CSEP guidelines [10,11], children aged 2–4 years engaging in no more than 1 h of screen time per day and children aged 5–17 years engaging in no more than 2 h of screen time per day were

categorized as meeting the screen time recommendation.

2.2.1.4. Diet. Dietary intakes of children were assessed by a trained dietician with two 24-h dietary recalls using the validated Multiple-Pass Method [28]. During the visit to the research center, a first recall was administered to the mother if the child was younger than 10 years or directly to the child if older; both the mother and the child were always present to add details if needed. The second recall was administered by phone within 7—10 days after the visit. Children with missing diet data (n = 1) were excluded from diet analysis. Considering that vegetables and fruit consumption is a significant component of a healthy diet [29,30] often used as a proxy measure to assess children diet quality [31], number of vegetable and fruit servings per day was measured according to national reference serving size [32] by calculating mean intakes from the two recalls. According to Eating Well with Canada's Food Guide [32], children aged 2—3 years, 4—8 years, 9—13 years or 14—18 years eating at least 4, 5, 6 or 7—8 (i.e. 7 for girls or 8 for boys) servings of vegetables and fruit per day, respectively, were categorized as meeting the diet recommendation.

2.2.2. Lifestyle profile

Children were classified as meeting a healthy or unhealthy lifestyle. For lifestyle habits with quantified recommendations (i.e. diet, sleep, physical activity and screen time), children meeting 3 to 4 lifestyle habits recommendations were classified as adopting a healthy lifestyle and children meeting 0 to 2 lifestyle habits recommendations were classified as adopting an unhealthy lifestyle. Children with missing data and insufficient data to assign them into a category (n = 47) were excluded from this classification. For example, a child meeting recommendations about diet and screen time with missing physical activity and sleep data was excluded. However, children with missing data but sufficient data to assign them into a category were included. For example, a child not meeting recommendations about diet and screen time, meeting recommendation about sleep and with missing physical activity data was included in the unhealthy lifestyle category.

2.2.3. Adiposity measurements

During the visit at the research center, children's weight and height were measured, in light clothes without shoes, with a calibrated balance (Tanita BC-418, Tanita Corporation of America Inc., Arlington Heights, IL, USA) to the nearest 0.1 kg and with a stadiometer to the nearest millimeter, respectively. Waist circumference at the umbilical level was measured twice, without clothes, at the nearest millimeter. Body mass index (BMI) z score was calculated with WHO AnthroPlus software (version 1.0.4, World Health Organization, Geneva, Switzerland). Children's body composition and fat distribution was also measured using a dual-energy X-ray absorptiometry scanner (DXA, GE Lunar Prodigy Bone Densitometer, GE Healthcare Lunar, Madison, WI, USA). Non-valid DXA data was defined as a blurred image, identified by two independent trained professionals [4]. After exclusion of children with missing data (n = 44) or non-valid data (n = 6), DXA data was extracted with the Lunar enCORE software version 13.40 and 14.1. More details about this method can be found elsewhere [4]. Different variables were considered: total fat mass (%), android fat mass (%), gynoid fat mass (%) and visceral fat mass (g). Android-to-gynoid fat mass percentage ratio (i.e. android fat mass percentage/gynoid fat mass percentage) was also calculated.

2.2.4. Mother characteristics

Sociodemographic characteristics, such as annual family income and maternal education level, were obtained from self-administered questionnaires filled by mothers. Maternal weight and height were measured according to the method used with children and current BMI was calculated (kg/m^2).

2.3. Statistical analyses

Children' characteristics according to GDM exposure were compared using Chi-square tests for categorical variables, Student t-tests for continuous variables, and ANOVA adjusted for age and sex for lifestyle habits. Chi-square tests were used to compare the proportion of children meeting each lifestyle habit recommendation and the proportion of children adopting a healthy or an unhealthy lifestyle between GDM+ and GDM- children. Children were assigned into four groups: HGDM+ (GDM+ children adopting a healthy lifestyle), HGDM- (GDM- children adopting a healthy lifestyle), UGDM+ (GDM+ adopting an unhealthy lifestyle) and UGDM- (GDM- children adopting an unhealthy lifestyle). Adiposity values were compared between four groups using ANOVA adjusted for age and sex (except for BMI z score). Variables non-normally distributed were transformed according to Box-Cox procedure when needed. Statistical significance was set to $p < 0.05$. The statistical software *SAS Studio* was used for analyses.

3. Results

A total of 143 children (105 GDM+ and 38 GDM-) were included in the present study. Participants' characteristics according to GDM exposure status are presented in Table 1. GDM+ children were younger than GDM- children (p = 0.026). GDM+ and GDM- children came from families with similar socioeconomic status, measured by annual family income (p = 0.369) and maternal education level (p = 0.730).

To compare lifestyle habits of GDM+ and GDM- children, we first compared mean values of each lifestyle habit between the two groups. As shown in Table 2, GDM+ children practiced less MVPA than GDM- children (p = 0.043). Other movement behaviors (i.e. sedentary time, screen time and sleep) were similar between the two groups (p > 0.05). Regarding diet, GDM+ children consumed less fruit servings than GDM- children (p = 0.020). We compared the proportion of children meeting each lifestyle recommendation in the two groups and found that the proportions were similar for each lifestyle habit (p > 0.05). We also compared the proportion of children adopting a healthy or an unhealthy lifestyle: GDM+

Table 1
Participant's characteristics according to GDM exposure status.

Participant's characteristics	GDM+(n = 105)	GDM-(n = 38)	p
Age (years)	5.9 ± 2.5	6.8 ± 2.3	0.026
Sex			
Boys	53 (50.5)	16 (42.1)	0.376
Pubertal onset[a]	16 (15.8)	5 (13.2)	0.694
Annual family income (CAD$/year)[b]			
0—39,999	11 (13.10)	7 (22.58)	0.369
40,000—79,999	24 (28.57)	9 (29.03)	
80,000—99,999	22 (26.19)	4 (12.90)	
≥100,000	27 (32.14)	11 (35.48)	
Maternal education level[c]			
High school or less	17 (18.28)	4 (12.50)	0.730
College	18 (19.35)	6 (18.75)	
University	58 (62.37)	22 (68.75)	
Maternal current BMI (kg m^{-2})	26.5 ± 6.2	23.9 ± 4.1	0.032

Results are expressed as raw means ± standard deviations or n (%).
GDM+: children exposed to gestational diabetes *in utero*; GDM−: children unexposed to gestational diabetes *in utero*.
[a] n = 101 for GDM+; n = 38 for GDM-.
[b] n = 84 for GDM+; n = 31 for GDM-.
[c] n = 93 for GDM+; n = 32 for GDM-.

Table 2
Participant's lifestyle habits according to GDM exposure status.

Lifestyle habits	GDM+	GDM-	P
Moderate-to-vigorous physical activity (minutes d^{-1})[a]	37.6 ± 17.7	46.1 ± 17.0	0.043[†]
Sedentary time (minutes d^{-1})[a]	368 ± 71	364 ± 66	0.258[†]
Screen time (hours d^{-1})[b]	2.0 ± 1.4	1.9 ± 1.3	0.229[†]
Sleep (hours d^{-1})[c]	10.4 ± 0.8	10.5 ± 0.6	0.236[†]
Vegetables and fruit (number of servings d^{-1})[d]	4.7 ± 2.5	5.4 ± 2.6	0.076[†]
Vegetables (number of servings d^{-1})	2.0 ± 1.5	2.2 ± 1.5	0.769[†]
Fruit (number of servings d^{-1})	2.6 ± 1.9	3.2 ± 1.7	0.020[†]
Proportion of participants meeting lifestyle recommendations according to GDM exposure status			
Physical activity	6 (10.3)	5 (18.5)	0.315
Screen time	65 (65.7)	27 (71.1)	0.547
Sleep	64 (95.5)	29 (100.0)	0.551
Vegetables and fruit	44 (42.3)	19 (50.0)	0.414
Proportion of participants adopting a healthy or an unhealthy lifestyle according to GDM exposure status			
Healthy lifestyle	16 (23.2)	11 (39.3)	0.109
Unhealthy lifestyle	53 (76.8)	17 (60.7)	

Results are expressed as raw means ± standard deviations or n (%).
GDM+: children exposed to gestational diabetes *in utero*; GDM−: children unexposed to gestational diabetes *in utero*.
[†]Adjustments for age and sex.
  [a] n = 58 for GDM+; n = 27 for GDM-.
  [b] n = 99 for GDM+; n = 38 for GDM-.
  [c] n = 67 for GDM+; n = 29 for GDM-.
  [d] n = 104 for GDM+; n = 38 for GDM-.

children tended to adopt an unhealthy lifestyle in a larger proportion than GDM- children (p = 0.109).

To investigate the effect of lifestyle habits on the association between GDM exposure and adiposity measurements, we compared adiposity values between GDM+ and GDM- children according to the lifestyle profile. Children excluded from this lifestyle profile analysis (n = 47) were not different than children included in relation to age, sex, anthropometric profile, body composition and socioeconomic status (data not shown). As shown in Table 3, we observed that among children with an unhealthy lifestyle, GDM+ children had greater percentage of fat mass and android fat mass (p = 0.021 and p = 0.020, respectively) than GDM- children. Furthermore, among GDM+ children, children with a healthy lifestyle tended to have lower percentage of fat mass and android fat mass (p = 0.053 and p = 0.071, respectively) than children with an unhealthy lifestyle. We also observed that GDM- children adopting a healthy lifestyle had lower visceral fat mass (p = 0.007) than GDM+ children adopting an unhealthy lifestyle.

4. Discussion

Results of this study showed that GDM+ children present a suboptimal lifestyle profile compared to GDM- children. Indeed, they practiced less physical activity and consumed less fruits compared to GDM- children. More importantly, among all children with an unhealthy lifestyle profile, GDM+ children had altered adiposity values including greater proportion of total and abdominal fat mass compared to GDM- children whereas among GDM+ children specifically, children with a healthy lifestyle profile tended to have better adiposity values than those with an unhealthy lifestyle.

We observed that, among children with an unhealthy lifestyle, GDM+ children had an altered fat distribution compared with GDM- children. Moreover, among GDM+ children specifically, children adopting a healthy lifestyle tended to have a better fat distribution compared with children adopting an unhealthy lifestyle, suggesting that healthy lifestyle habits can potentially

Table 3
Adiposity values by lifestyle group according to GDM exposure status.

Adiposity values	HGDM+ (n = 16)	HGDM-(n = 11)	UGDM+(n = 53)	UGDM-(n = 17)	p
Anthropometric profile					
BMI z-score	0.14 ± 1.06	0.01 ± 0.68	0.26 ± 1.14	0.16 ± 0.81	0.893
Waist circumference (cm)	55.8 ± 6.6	52.8 ± 3.7	55.9 ± 8.0	57.0 ± 6.8	0.090[†]
Body composition [1]					
Fat mass (%)	23.9 ± 8.3[a]	24.8 ± 3.9	27.5 ± 5.9[b]	25.2 ± 4.9	0.049[†]
Android fat mass (%)	15.8 ± 10.2[c]	16.7 ± 5.6	20.7 ± 9.6[d]	18.0 ± 7.5	0.049[†]
Gynoid fat mass (%)	27.8 ± 9.8	29.8 ± 5.7	32.5 ± 6.8	30.1 ± 5.5	0.063[†]
Android-to-gynoid fat mass ratio	0.55 ± 0.17	0.55 ± 0.01	0.61 ± 0.18	0.58 ± 0.16	0.183[†]
Visceral fat mass (g)	46.1 ± 50.0	26.2 ± 15.8[e]	79.4 ± 84.3	62.9 ± 63.7	0.037[†]

Results are expressed as raw means ± standard deviations.
HGDM+: children exposed to gestational diabetes *in utero* adopting a healthy lifestyle, HGDM−: children unexposed to gestational diabetes *in utero* adopting a healthy lifestyle, UGDM+: children exposed to gestational diabetes *in utero* adopting an unhealthy lifestyle, UGDM−: children unexposed to gestational diabetes *in utero* adopting an unhealthy lifestyle.
[†]Adjustments for age and sex.
[1] n = 7 for HGDM+; n = 10 for HGDM-; n = 30 for UGDM+; n = 17 for UGDM-.
  [a] p = 0.053 compared to UGDM+.
  [b] p = 0.021 compared to UGDM-.
  [c] p = 0.071 compared to UGDM+.
  [d] p = 0.020 compared to UGDM-.
  [e] p = 0.007 compared to UGDM+.

attenuate the influence of GDM exposure on adiposity profile. To our knowledge, no studies have explored the influence of a healthy lifestyle on adiposity profile among this specific population. However, some authors have analysed the influence of specific unhealthy lifestyle habits on adiposity values among GDM+ children. Zhang and colleagues found a significant positive association between television watching time and central obesity among GDM+ children [33], indicating that this specific screen-based behavior could be associated with an altered adiposity distribution. Moreover, Zhu and colleagues showed that overweight/obesity among GDM+ children appeared more pronounced among those who consumed higher sugar-sweetened beverages, an indicator of an unhealthy diet [34]. On the other hand, some studies observed that the association between exposure to GDM and adiposity values remains unchanged after adjustment for children's lifestyle habits [2,3,35]. Our findings suggest that healthy lifestyle habits during childhood could attenuate the negative influence of *in utero* exposure to GDM on adiposity profile. However, this hypothesis needs to be confirmed in larger studies.

In addition, we observed that GDM+ children practiced approximatively 10 min less of MVPA and consumed 0.6 less fruit servings per day than GDM- children. Of note, fewer fruit servings is not explained by less fruit juice consumption among GDM+ children as fruit juice consumption was similar between the two groups (data not shown). These statistically significant differences across these daily lifestyle habits seem relatively small. However, because every additional 10 min of MVPA per day has been associated with a 3.5% lower fat mass percentage among children [36] and since low fruit consumption has been reported to explain the greater proportion of the variance of unhealthy dietary patterns associated with increased adiposity during childhood [7,37], even small daily differences in lifestyle habits might be important to consider. To our knowledge, this is the first study showing that GDM+ children engage in less physical activity than GDM- children. Previously published studies showed no statistically significant difference in movement behaviors between children exposed or unexposed to GDM [2,3,15—17]. The same studies also showed that different diet markers (e.g. unhealthy diet pattern score, energy intake, energy from fat) were similar between the two groups [2,3,15—17]. However, one study did show that children exposed to GDM or type 1 diabetes were less likely to meet fruit consumption recommendations than those unexposed [14]. In light of these results and those obtained in the present study, fruit consumption could possibly represent a diet marker to target among GDM+ children in order to prevent excess adiposity among these high risk children.

Interestingly, few children adopted a healthy lifestyle in our cohort despite high family income and maternal education level, whereas children from a high socioeconomic status family usually adopt better lifestyle habits [12,38]. From our results, less than 30% of children from the entire cohort adopted a healthy lifestyle (i.e. meet more than two lifestyle habits recommendations out of four) (data not shown). Among GDM+ children specifically, less than 25% of them adopted a healthy lifestyle, approximately 40% of them met the vegetables and fruit recommendation, and only 10% met the physical activity recommendation, thus indicating a potential for improving their lifestyle. National data showed that 22% to 54% of children between 2 and 18 years old meet the vegetables and fruit recommendation [39], 35% of children between 5 and 17 years old meet the physical activity recommendation and only 15% meet all three movement recommendations (i.e. physical activity, screen time and sleep) [40]. Therefore, suboptimal lifestyle habits during childhood seem widespread. Improving lifestyle habits, by increasing vegetable and fruit consumption, physical activity practice and sleep time and by reducing screen time, would be important for all children. It would be particularly important for GDM+ children since they are exposed to increased risk for long-term adverse outcomes, including obesity and central adiposity [2—5], and seem to improve their adiposity profile by adopting healthy lifestyle habits.

5. Study limitations and strengths

The present study has some limitations. As mentioned above, the annual family income and the maternal education level were relatively high and may limit the generalizability of the results. Moreover, the use of physical activity log as a subjective measure of sleep often leads to overestimation, partly due to delay between bedtime and sleep onset or to night awakenings [41]. An algorithm has been developed to objectively distinguish children's nocturnal sleep from daytime activities with accelerometer data [41], but is not validated for irregular schedule (e.g. summer break) and is not designed to discern naps from sedentary behavior during daytime. Due to this limitation, accelerometer data were not considered in the current study to assess sleep time. Approximatively 90% of children in our cohort completed their visit during summer (i.e. from mid-June to mid-September) (data not shown). Therefore, physical activity may be underestimated due to the exclusion of aquatic activities (e.g. pool, beach, water games, etc), a well-known limitation of accelerometers [42]. Finally, the limited number of subjects could lead to low statistical power and increase the risk for false negative results. Therefore, these findings should be interpreted with caution and confirmed in further larger studies. Strengths of this study include the investigation of GDM only, excluding other types of diabetes potentially associated with various outcomes for exposed children. Moreover, the analysis of many markers of lifestyle combined into a lifestyle profile is innovative, while previous studies analysed lifestyle habits separately. Furthermore, exposure and outcomes were assessed using objective and valid measurements. The use of two dietary recalls to evaluate children's diet reduced the daily variability in dietary intakes while minimizing burden of participants. The use of vegetable and fruit intake as an indicator of diet quality is a valid marker that can be easily obtained [29—31]. Accelerometers provide an objective measure of physical activity and sedentary time and DXA scan is among the most reliable methods for body composition analysis [43].

6. Conclusion

In conclusion, results of this study suggest that this population of children presents suboptimal lifestyle habits and more specifically, GDM+ children had lower physical activity practice and lower fruit intake than GDM- children. In addition, this study highlights the importance of having a healthy lifestyle, particularly for GDM+ children, given their increased risk to develop obesity and central adiposity later in life. The adoption of healthy lifestyle habits, through increased consumption of vegetables and fruit, increased duration of physical activity and sleep time, and reduced duration of screen time, could represent a promising approach to prevent deteriorated adiposity values among this high-risk population.

Author contribution

SJW, IM, AT and JR participated in the conception and the design of the study. MB, CD and JP made a substantial contribution to data acquisition. MB and JR participated in data analysis and interpretation. SMR participated in physical activity data analysis and interpretation. MB wrote the first draft of the manuscript. All

authors revised it critically for important intellectual content and approved the final version. JR is responsible of the integrity of the study.

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