ARTICLE

Pediatrics

Centre-based childcare in early childhood and growth in later childhood: a prospective cohort study

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BACKGROUND: Attending government-regulated centre-based childcare may influence important health behaviours including dietary quality, physical activity and routines related to child growth. However, the relationship between centre-based childcare and childhood obesity remains unclear.
OBJECTIVES: The primary objective was to evaluate the association between centre-based childcare attendance in early childhood and body mass index z-score (zBMI) in later childhood. Secondary objectives included exploring whether family income, child sex, or non-centre-based setting modified these relationships.
METHODS: A prospective cohort study of children aged 1 to 10 years who participated in the TARGet Kids! cohort was conducted. Linear mixed-effect modelling was used to evaluate the relationship between centre-based childcare attendance (in hours/week) compared to non-centre-based childcare between 1–4 years of age and zBMI between 4 and 10 years of age. Generalised estimating equation modelling was used to explore weight status categories. Models were adjusted for confounders and effect modification was explored.
RESULTS: A total of 3503 children were included. Children who attended centre-based childcare full-time (40 h/week) had 0.11 (95% CI: −0.19, −0.03; $p = 0.01$) lower zBMI at 4 and 7 years of age and lower odds of overweight and obesity at 4 years (OR 0.78; 95% CI: 0.62, 0.97; $p = 0.03$), but no evidence of an association was found at 10 years of age. Children from families with income < $50,000CDN who attended centre-based childcare full-time had 0.32 (95% CI: −0.50, −0.14; $p = 0.001$) lower zBMI and lower odds of overweight and obesity (OR 0.52; 95% CI: 0.28, 0.99; $p = 0.05$) at 10 years of age.
CONCLUSIONS: Attending centre-based childcare in early childhood was associated with a lower zBMI and odds of overweight and obesity in later childhood. These associations were stronger for children from lower income families. Centre-based childcare may be an early intervention for the prevention of childhood obesity.
CLINICAL TRIAL: Clinical Trial Registry Number: NCT01869530 (clinicaltrials.gov).

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INTRODUCTION

One in three children are living with overweight or obesity in Canada [1, 2]. Childhood overweight and obesity increases the risk of poor mental health and school performance and tracks into adulthood increasing the risk of type 2 diabetes and cardiovascular disease [3–6]. The burden of childhood obesity is disproportionately experienced by children from low-income families [2].

With the increase in dual-income families [7], an estimated 60% of children aged 0 to 5 years attend non-parental childcare in North America [8, 9] including government-regulated centre-based childcare, home-based childcare licensed by childcare agencies and unlicensed childcare [10]. Studies have found that centre-based childcare tends to be higher quality than other childcare settings [11–13]. Previous work has identified that regulations and programming in centre-based childcare may serve to promote healthy lifestyle behaviours, provide children with healthy meals and structured activity, and target health outcomes in this population [14–16]. Centre-based childcare may influence weight status by promoting positive dietary patterns, eating behaviours, physical activity, and daily routines during a sensitive period of growth which may persist throughout the life course [17–21].

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Two systematic reviews of observational studies evaluated the association between childcare attendance (≤5 years of age) and childhood weight status [22, 23]. Both had mixed findings for centre-based childcare while children who attended non-centre-based childcare settings had a higher risk of obesity compared to parental care [22, 23]. As the authors point out, interpretation was challenging due to heterogeneity between studies and variation in populations [22]. Few studies compared centre-based to non-centre-based childcare as parental care was often used as the comparator. Although many children are exposed to centre-based and non-centre-based childcare environments in childhood, studies which have evaluated the impacts on childhood obesity are limited, have had conflicting findings and conclusions remain unclear [22, 23]. A stronger understanding of these relationships is warranted as it provides important practical knowledge for parents that require external childcare to make an informed decision, as well as for childcare policy to evaluate settings, inform interventions, and support child health.

We hypothesised that attending centre-based childcare in early childhood would be associated with a lower body mass index z-score (zBMI) and odds of overweight and obesity due to the potential of the regulated environment to positively impact behaviours and growth during a sensitive period of development. Due to the role of socioeconomic status on childhood obesity risk, development, and health behaviours, we hypothesized that the effect would be stronger for children from lower income families.

The primary objective of this study was to evaluate the relationship between centre-based childcare attendance in early childhood and zBMI in later childhood compared to non-centre-based childcare. We also explored how family income, child sex, and non-centre-based childcare setting may modify the relationships.

METHODS

Study design and participants

A prospective cohort study was conducted through the TARGet Kids! (The Applied Research Group for Kids) primary care research network in Toronto, Ontario, Canada (www.targetkids.ca). Children were recruited through TARGet Kids! between ages 0 and 5 years and followed through 10 years of age. Data were collected by trained research assistants during regularly scheduled primary care well-child visits at ages 2, 4, 6, 9, 12, 18 and 24 months and annually thereafter between June 2008 and August 2019 [24]. Children with health conditions affecting growth (e.g., failure to thrive, cystic fibrosis), chronic conditions (except asthma), those born very premature (<32 weeks gestation), and children with severe developmental delay were excluded from the TARGet Kids! cohort. In addition, children who did not have childcare data or attend childcare between 1 and 4 years of age were excluded from this study. Written informed consent was obtained from parents, and ethics approval was granted from the Hospital for Sick Children (#10000–12436) and Unity Health Toronto (#17–335).

Exposure

The primary exposure was a composite of the intensity (hours/week) of attendance to centre-based childcare between 1 and 4 years of age, measured continuously and as a dichotomous variable. These were measured using a parent-reported Nutrition and Health Questionnaire (NHQ) adapted from the Canadian Community Health Survey [25]. The NHQ is offered to TARGet Kids! participating families at all primary care visits. Type of childcare attendance was dichotomised into: (1) centre-based childcare and (2) non-centre-based childcare (licensed home childcare or unlicensed childcare including care in someone else's home by a non-relative, care in the child's home by a non-relative, and care by a relative). To determine childcare intensity, parents were asked, "How many hours per week do you use this method of childcare?". All childcare data collected on participants from visits between 1 and 4 years of age was used to determine if a child had attended centre-based childcare. Children were classified as having attended centre-based childcare if they reported doing so at any visit during the preschool period (1–4 years of age).

Outcome

The primary outcome was zBMI from 4 to 10 years of age, which is an age and sex adjusted measurement of body mass index (BMI). BMI was calculated by dividing weight (kg) by height (m^2) and z-scores were determined using the World Health Organization (WHO) growth standards [26]. Trained research assistants measured weight in kilograms and height in metres using standardised anthropometric procedures [27]. Weight was measured using a digital scale (SECA, Hamburg, Germany). Height was measured using a standardised recumbent length board (SECA, FL) for children under 2 years of age and a stadiometer (Healthometer, SECA, FL) for children over 2 years of age. WHO recommended weight status categories included underweight ($zBMI < -2$), normal weight ($-2 \le zBMI \le 1$), overweight ($1 < zBMI \le 2$) and obesity ($zBMI > 2$) [28, 29].

Covariates

Clinically relevant covariates which may confound the relationship between childcare attendance and childhood growth were identified a priori through a literature review [22, 23]. These included child age (months), child biological sex (male or female), birth weight (kg), maternal BMI, maternal education (college/university or high/public school), maternal employment (yes or no), maternal ethnicity (European, Asian, African, or other (mixed, Arab)), child living arrangement (1 parent, 2 parent or alternating household), breastfeeding duration (total months of any breastfeeding), and reported family income. Family income (CDN) was measured by parent response to the question "What was your total family income before taxes last year?". This was reported using four categories "< $50,000", "$50,000–$99,999", "$100,000–$149,999", and ">$150,000". The selection of income categories was related to the Low-Income Cut-Off (LICOs) in Canada ($49,106 for a family of four living in a large urban population) [30] and income eligibility for full and partial childcare subsidies in Ontario with family incomes of <$40,000 to ≤ $100,000 [31, 32]. Covariates were measured prior to the outcome and the information obtained closest in time to the outcome was used to reflect the most recent data for any time-varying variables.

Statistical analysis

Descriptive statistics were used to characterise participants at the time of childcare measurement. A linear mixed effects (LME) model was used to evaluate the adjusted relationship between centre-based childcare (hours/week) and zBMI measured continuously. The LME model accounts for repeated measures of zBMI and adjusts for within-subject correlation using subject specific random intercepts. Restricted cubic splines for child age at the outcome measurement (4–10 years) with five knots for the continuous analysis and three knots for the categorical analysis were used to allow for non-linear trajectories of zBMI, as has been previously conducted in the cohort [33, 34]. Binomial generalised estimating equations were used to evaluate weight status by comparing the odds of $zBMI > 1$ [overweight and obese] to $zBMI \le 1$ [reference] reported using odds ratios (ORs). For all models, pairwise comparisons using estimated marginal means were used to compare expected outcomes for different intensities of centre-based childcare, specifically at 10-hours (low intensity), 25-h (part-time intensity) and 40-hours (full-time intensity) to non-centre-based childcare (reference; 0 h of centre-based childcare) based on previous literature [22]. Sensitivity analyses were performed to evaluate the role of childcare intensity in the non-centre-based childcare group. However, there was no evidence that the estimated mean zBMI was different based on the intensity of childcare within the non-centre-based group suggesting that the a priori determination of non-centre-based childcare (0 h/week) was appropriate for comparisons. Baseline zBMI was not included as a covariate a priori, but a post-hoc sensitivity analysis adjusting for baseline zBMI was explored in a model and the results did not meaningfully change. Models were adjusted for specified covariates (child age, child sex, child birthweight, maternal BMI, maternal education, maternal employment, maternal ethnicity, child living arrangement, family income and breastfeeding duration). Interaction terms for child sex, family income, non-centre-based childcare setting (licensed home-based childcare vs. unlicensed childcare) and age in later childhood were explored and included if the likelihood ratio test result was $P < 0.30$ [35]. Results were reported at 4, 7 and 10 years of age.

All missing data were assumed to be missing at random, conditional on the other variables in the model. Multiple imputation using 20 imputed data sets was used to account for missing data with all exposures, outcomes, and covariates in the models [36]. All baseline variables included in the final model had <10% missing data before imputation. Restricted maximum likelihood mixed effects models were used to account

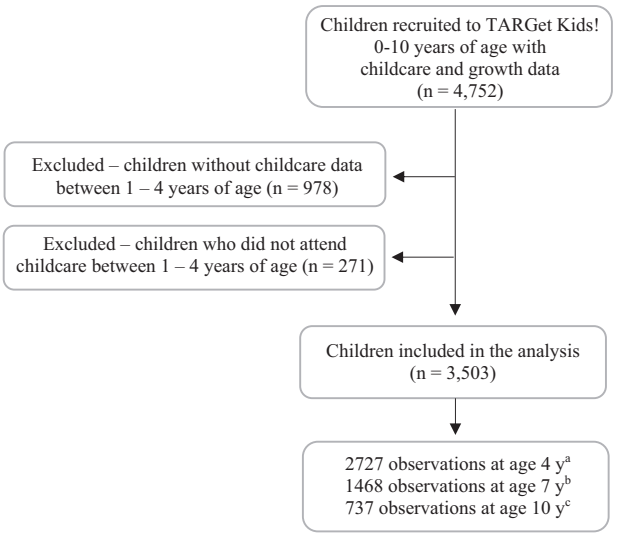

Fig. 1 Participant flow diagram. [a]Age 4 years is defined as children who attended a visit between ages 48–58 months. [b]Age 7 years is defined as children who attended a visit between ages 78–88 months. [c]Age 10 years is defined as children who attended a visit between ages 112–124 months.

for longitudinal missingness, which is valid when the outcome is missing at random, conditional on the covariates and other outcome measurements on those subjects in the model [37]. Residual plots were assessed for linearity and normality. Potential non-linearity of childcare intensity was evaluated using residual plots; however, there was insufficient evidence of non-linearity. Multicollinearity was evaluated using the variance inflation factor, which was <1.5 for all covariates. The sample size for this analysis was dictated by the number of children enroled in the ongoing registry. For all statistical tests, an alpha level of 0.05 and 95% confidence intervals (CIs) were used. All analyses were conducted using R version 4.0.5. (R Project for Statistical Computing) [38]. Statistical code used to produce the analysis is available upon request.

RESULTS

A total of 3503 children who attended childcare between 1 and 4 years of age were included in the analysis (Fig. 1). Baseline participant characteristics are described in Table 1. The mean child age at baseline was 2.6 years (SD 0.7), and 52% of children were male. 54% of children attended centre-based and 46% attended non-centre-based childcare. Within the non-centre-based childcare group, 5.0% of children attended licensed home-based childcare and 95.0% of children attended unlicensed childcare. Children attended centre-based childcare for an average of 30.7 h/week (SD 15.1). In the < $50,000 family income category, 42.1% of children were in centre-based childcare relative to 57.9% of children in non-centre-based childcare. At baseline, the mean zBMI was 0.29 (SD 1.0) for children who attended centre-based and 0.31 (SD 1.0) for children who attended non-centre-based childcare. The mean follow-up duration was 2.6 years and 71% of children had ≥2 follow-up visits.

Primary analysis

The intensity of centre-based childcare between 1 and 4 years of age was associated with lower mean zBMI (overall p value = 0.03). Children who attended centre-based childcare for 10, 25, and 40 h/week had 0.04 (95% CI: −0.12, 0.04; $p = 0.36$), 0.06 (95% CI: −0.13, 0.00; $p = 0.06$), and 0.09 (95% CI: −0.15, −0.02; $p = 0.01$) lower mean zBMI between 4 and 10 years compared to non-centre-based childcare, respectively. Children who attended centre-based childcare full-time (40 h/week) had 0.11 (95% CI: −0.19, −0.03; $p = 0.01$), 0.11 (95% CI: −0.19, −0.03; $p = 0.01$) and 0.08 (95% CI: −0.17, 0.02; $p = 0.11$) lower mean zBMI at 4, 7 and 10 years compared to non-centre-based childcare, respectively (Table 2 and Fig. 2). For example, a 4-year-old child of average height who attended centre-based childcare full-time had an estimated 0.15 kg lower weight than a similar child who attended non-centre-based childcare. Children who attended centre-based childcare part-time (25 h/week) had 0.09 (95% CI: −0.16, −0.01; $p = 0.03$), 0.09 (95% CI: −0.15, −0.01; $p = 0.03$) and 0.05 (95% CI:

Table 1. Participant characteristics.

Characteristics[a]	Centre-based childcare ($n = 1908$)[b]	Non-centre-based childcare ($n = 1595$)[b]	Total cohort ($n = 3503$)[b]
Child characteristics			
Sex			
Male	1040 (54.5)	782 (49.0)	1822 (52.0)
Female	868 (45.5)	813 (51.0)	1681 (48.0)
Age, mo	32.8 (7.1)	28.7 (8.8)	31.0 (8.2)
Birth weight, kg	3.3 (0.6)	3.3 (0.6)	3.3 (0.60)
Breastfeeding duration, mo	11.9 (7.8)	11.6 (8.0)	11.8 (7.9)
Number of siblings	0.74 (0.7)	0.91 (0.8)	0.8 (0.7)
Living arrangement			
1 parent household	86 (4.5)	31 (2.0)	117 (3.4)
2 parent household	1792 (94.2)	1540 (97.3)	3332 (95.6)
Alternating household	25 (1.3)	12 (0.8)	37 (1.1)
Intensity of centre-based childcare, hours/week	30.7 (15.1)	0.0 (0.0)	30.7 (15.1)
zBMI	0.29 (1.0)	0.31 (1.0)	0.30 (1.0)
Family characteristics			
Family income, Canadian $			
<50,000	109 (6.2)	150 (10.6)	259 (8.2)
50,000–99,999	254 (14.6)	300 (21.3)	554 (17.6)
100,000–149,999	393 (22.5)	301 (21.3)	694 (22.0)
>150,000	989 (56.7)	659 (46.7)	1648 (52.2)
Maternal ethnicity			
European	1250 (70.5)	1035 (69.1)	2285 (69.9)
Asian[c]	271 (15.3)	275 (18.4)	546 (16.7)
African	134 (7.6)	88 (5.9)	222 (6.8)
Other (mixed, Arab)	118 (6.7)	99 (6.6)	217 (6.6)
Maternal education			
College/University	1768 (94.9)	1422 (91.6)	3190 (93.4)
High or public school	95 (5.1)	131 (8.4)	226 (6.6)
Maternal employment			
No	229 (12.4)	342 (22.3)	571 (16.9)
Yes	1622 (87.6)	1190 (77.7)	2812 (83.1)
Maternal BMI, kg/m^2	24.6 (4.6)	24.9 (4.9)	24.7 (4.8)

[a]Values are expressed as mean (SD) or No. (%). Numbers may not add up to total due to missing values.
[b]Values reflect participant characteristics at the exposure visit who met the inclusion criteria.
[c]East, South and Southeast Asian.

Table 2. Pairwise comparisons for the association between centre-based childcare attendance (hours/week) and zBMI or odds of overweight and obesity compared to non-centre-based childcare by child age in later childhood.

		Primary analysis		Secondary analysis	
Age of outcome measurement (years)	**Intensity of CB vs. NCB[a]**	**zBMI[b] (Estimate (95% CI; *p* value)**	**Overweight/ Obesity[b,d] (OR (95% CI; *p* value)**	**zBMI [<$50,000][c] (Estimate (95% CI; *p* value)**	**Overweight/Obesity [<$50,000][c,d](OR (95% CI; *p* value)**
4	10 vs. 0	−0.06 (−0.15, 0.03; 0.17)	0.83 (0.64, 1.07; 0.15)	−0.29 (−0.47, −0.12; 0.001)	0.57 (0.31, 1.05; 0.07)
	25 vs. 0	−0.09 (−0.16, −0.01; 0.03)	0.80 (0.65, 0.99; 0.04)	−0.32 (−0.49, −0.15; 0.0002)	0.55 (0.30, 0.99; 0.05)
	40 vs. 0	−0.11 (−0.19, −0.03; 0.01)	0.78 (0.62, 0.97; 0.03)	−0.35 (−0.52, −0.18; 0.0001)	0.53 (0.29, 0.95; 0.03)
7	10 vs. 0	−0.06 (−0.15, 0.03; 0.20)	0.90 (0.69, 1.18; 0.45)	−0.29 (−0.47, −0.11; 0.001)	0.62 (0.33, 1.16; 0.13)
	25 vs. 0	−0.09 (−0.15, −0.01; 0.03)	0.87 (0.70, 1.09; 0.23)	−0.32 (−0.49, −0.15; 0.0002)	0.59 (0.33, 1.09; 0.09)
	40 vs. 0	−0.11 (−0.19, −0.03; 0.01)	0.84 (0.67, 1.07; 0.15)	−0.35 (−0.52, −0.17; 0.0001)	0.57 (0.31, 1.05; 0.07)
10	10 vs. 0	−0.02 (−0.13, 0.08; 0.63)	0.84 (0.61, 1.15; 0.27)	−0.26 (−0.45, −0.08; 0.005)	0.57 (0.29, 1.09; 0.09)
	25 vs. 0	−0.05 (−0.14; 0.04; 0.27)	0.81 (0.61, 1.08; 0.15)	−0.29 (−0.47, −0.11; 0.001)	0.55 (0.29, 1.04; 0.06)
	40 vs. 0	−0.08 (−0.17, 0.02; 0.11)	0.79 (0.58, 1.06; 0.11)	−0.32 (−0.50, −0.14; 0.001)	0.52 (0.28; 0.99; 0.05)

CB centre-based childcare; *NCB* non-centre-based childcare

[a]Centre-based childcare (hours/week) vs. non-centre-based childcare group [reference, 0 h].

[b]Model adjusted for child age at exposure, child sex, child birthweight, maternal BMI, maternal education, maternal employment, maternal ethnicity, child living arrangement, family income and breastfeeding duration. Child age during outcome period included as interaction term.

[c]Model adjusted for child age at exposure, child sex, child birthweight, maternal BMI, maternal education, maternal employment, maternal ethnicity, child living arrangement, and breastfeeding duration. Child age during outcome period and family income included as interaction terms.

[d]OR overweight and obesity (zBMI > 1) relative to zBMI ≤1 [reference].

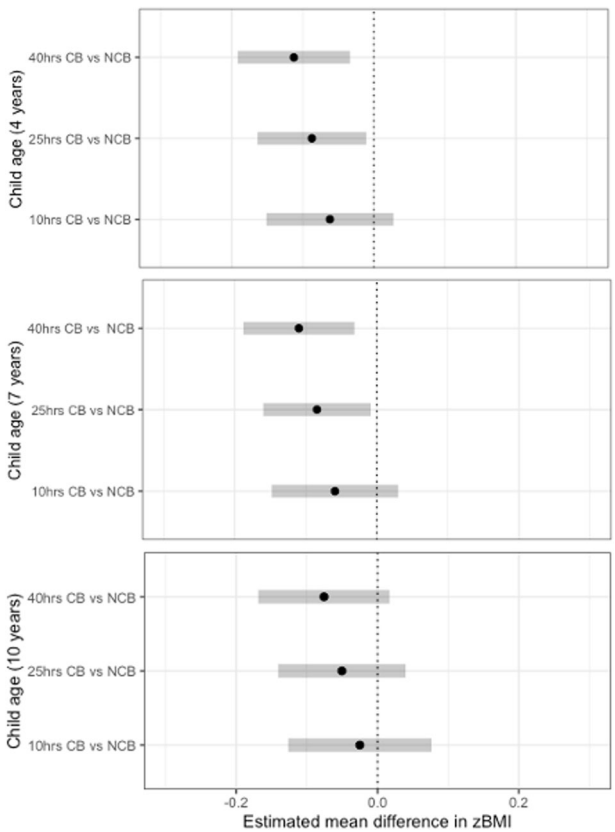

Fig. 2 Linear mixed effects models adjusted for clinically relevant covariates with child age [4, 7 and 10 years] as an effect modifier. Confidence intervals (shaded area) that do not cross 0 suggest evidence of a difference between comparisons ($P < 0.05$). Childcare intensity (hours/week) was included in the model as a continuous variable with estimates reported at 10-, 25-, and 40-hours. CB: centre-based childcare; NCB: non-centre-based childcare.

−0.14, 0.04; $p = 0.27$) lower mean zBMI at 4, 7 and 10 years compared to non-centre-based childcare, respectively.

Children who attended centre-based compared to non-centre-based childcare for 10, 25 and 40 h/week had 15% (OR 0.85; 95% CI: 0.68, 1.06; $p = 0.15$), 18% (OR 0.82; 95% CI: 0.70, 0.97; $p = 0.02$), and 21% (OR 0.79; 95% CI: 0.66, 0.95; $p = 0.01$) lower odds of overweight and obesity between 4 and 10 years of age, respectively. Children who attended centre-based childcare full-time (OR 0.78; 95% CI: 0.62, 0.97; $p = 0.03$) and part-time (OR 0.80; 95% CI: 0.65, 0.99; $p = 0.04$) had lower odds of overweight and obesity at 4 years of age compared to children who attended non-centre-based childcare (Table 2).

Secondary analysis

The association between the intensity of centre-based childcare and zBMI was stronger for children with lower family income (overall p value = 0.01). Children who attended centre-based childcare in early childhood had a lower zBMI at all intensities (low, part-time, and full-time) from 4 to 10 years of age (Fig. 3). Children from families with income < $50,000 who attended centre-based childcare full-time had 0.35 (95% CI: −0.52, −0.18; $p = 0.0001$), 0.35 (95% CI: −0.52, −0.17; $p = 0.0001$) and 0.32 (95% CI: −0.50, −0.14; $p = 0.001$) lower mean zBMI at 4, 7 and 10 years of age compared to non-centre-based childcare, respectively (Table 2). For example, a child of average height from a family with income < $50,000 who attended centre-based childcare had an estimated 0.53 kg, 0.88 kg and 1.37 kg lower weight at 4, 7 and 10 years of age, respectively than a similar child who attended non-centre-based childcare. Children from families with income < $50,000 who attended centre-based childcare full-time compared to non-centre-based childcare had lower odds of overweight and obesity at 4 (OR 0.53; 95% CI: 0.29, 0.95; $p = 0.03$), 7 (OR 0.57; 95% CI: 0.31, 1.05; $p = 0.07$), and 10 (OR 0.52; 95% CI: 0.28, 0.99; $p = 0.05$) years of age (Table 2).

Additional data by income categories and weight status frequencies by child age and income level are presented in the supplementary material (Tables S1–S3). It was estimated that children from families with income $50,000–$99,999 who attended centre-based childcare full time (40 h/week) had a 0.14

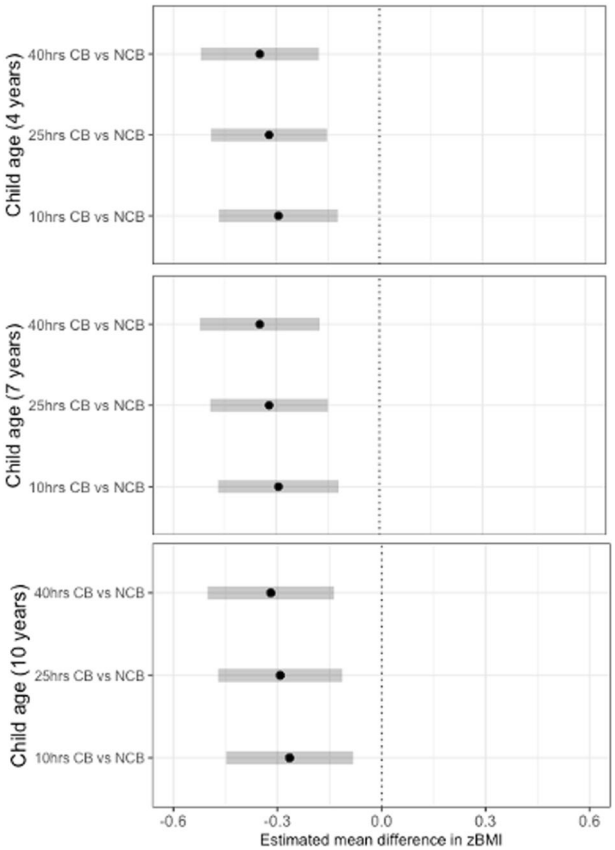

Fig. 3 Linear mixed effects models adjusted for clinically relevant covariates with child age [4, 7 and 10 years] and family income as effect modifiers. Confidence intervals (shaded area) that do not cross 0 suggest evidence of a difference between comparisons ($P < 0.05$). Childcare intensity (hours/week) was included in the model as a continuous variable with estimates reported at 10-, 25- and 40-hours. CB centre-based childcare, NCB non-centre-based childcare.

(95% CI: −0.26, −0.02; $p = 0.02$) lower mean zBMI at 4 and 7 years of age compared to non-centre-based childcare. Although estimates were trending in a similar direction, there was insufficient evidence of an association between centre-based childcare and child zBMI from 4 to 10 years of age for children from families with income $100,000–$149,999 and >$150,000.

There was insufficient evidence that type of non-centre-based childcare and child sex were potential effect modifiers of the association ($P > 0.30$) and were not included in the final models.

Interpretation

In this prospective cohort study of 3503 healthy children, attending centre-based childcare in early childhood was associated with lower zBMI compared to non-centre-based childcare. Full-time and part-time centre-based childcare was associated a lower mean zBMI at 4 and 7 years and lower odds of overweight and obesity at 4 years of age. Children from families with income <$50,000 who attended centre-based childcare at all intensities had a lower zBMI in later childhood. For example, full-time attendance was associated with 0.32 lower zBMI and 48% lower odds of overweight and obesity by 10 years of age. The observed differences in zBMI may be clinically meaningful, as intervention studies for preventing childhood obesity have been found to be similar in magnitude [39–41].

Studies on the relationship between childcare and childhood obesity have largely focused on centre-based childcare compared to parental care or non-centre-based childcare including parental care making comparisons challenging. The most recent systematic review [22] identified only one study that compared centre-based to non-centre-based childcare. This study found that children who attended the Head Start Programme between 3 and 5 years of age had a 0.17 lower zBMI and 41% lower odds (OR: 0.59) of overweight between 5 and 6 years of age compared to children who attended non-centre-based childcare [42]. Although the Head Start Programme is centre-based childcare, it is a specialised programme for low-income families that meet specific eligibility criteria in the United States, which may limit generalisability to other countries and general populations. Findings from the present study are consistent with previous results suggesting that attending centre-based childcare in early childhood was associated with a lower zBMI in children from lower income families with findings persisting into later childhood and highlights the potential benefit of centre-based childcare environments for the general population.

Relatively little is known about how the intensity of centre-based childcare may influence growth outcomes [22, 23]. In the present study, the association between centre-based childcare and zBMI became stronger with a higher childcare intensity (h/week). The estimated mean differences in zBMI between centre-based and non-centre-based childcare were largest for children who attended centre-based childcare full-time (40 h/week). While the associations appeared to be trending in a similar direction, there was no evidence of a statistical difference in zBMI for children who attended centre-based childcare at a low intensity (10 h/week) compared to non-centre-based childcare in the primary analysis. A systematic review by Black et al. suggested that many studies defined childcare exposure as greater than 10 h per week due to the hypothesis that low intensities of childcare are unlikely to influence child weight status, but that this may have led to the misclassification of childcare exposures [22]. The present study evaluated centre-based childcare intensity continuously which provided granularity to the findings, allowed for evaluation of non-linear trends and dose-responsiveness and an understanding of how intensity may have influenced observed relationships without diminishing the potential role of an exposure to this setting.

According to Bronfenbrenner's Ecological Systems Theory, many interrelated environmental systems influence child development and childcare exists within the most proximal system to the child [43]. The potential mechanisms through which centre-based childcare may reduce zBMI is unknown. Structure around eating and routines may help promote healthy lifestyle behaviour during an important period of child development [17, 44]. In Ontario, Canada childcare centres are mandated to meet extensive regulations including designated time for physical activity, providing meals and snacks that adhere to Health Canada's nutrition guidelines, and established daily programme plans [10]. Childcare centres in Ontario are subject to provincial oversight, quality monitoring and enforcement of regulations [10, 11, 13]. Furthermore, centres are required to employ licensed Early Childhood Educators which may provide higher quality childcare [10, 13]. Care providers in non-centre-based environments may lack education about healthy feeding practices including appropriate portion sizes, meal spacing, not using food as a reward, and avoiding eating in front of screens [45–47]. Greater exposure to environments that promote healthy eating, physical activity, and routines may result in lasting changes to healthy behaviours in children [21, 48–50].

A study evaluating childcare utilisation between 12 months of age and school entry across Canada using the 2011 General Social Survey found that children participating in licensed childcare arrangements were more likely to be from high-income families (61.0%) compared to low-income families (39.4%) [11]. The present study had similar descriptive findings whereby in the highest (>$150,000) income category, 60.0% of children attended

centre-based childcare compared to 42.1% in the lowest (< $50,000) income category. In Canada, difficulties obtaining centre-based childcare exists due to availability (i.e., limited spaces or location) and affordability (i.e., higher costs) barriers. Many low-income families require financial subsidies for childcare and may experience additional difficulties finding a centre-based childcare placement due to lack of availability [11, 13]. Stronger relationships between centre-based childcare and zBMI for children from low-income families may be related to health and developmental inequities [51, 52]. Children from low income families are at a higher risk for childhood obesity [2], food insecurity [53] and unhealthy lifestyle patterns [54]. A cross-sectional study of children in the TARGet Kids! cohort study ($n = 3333$) found that difficulty buying food was associated with lower intake of fruits and vegetables and higher intake of sugary drinks and fast food [55]. Children from low-income families may have reduced access to healthy foods and opportunities for physical activity which centre-based childcare environments may provide.

Findings from the present study suggest that attending centre-based childcare in early childhood may be protective against obesity in later childhood. Future studies are needed to better understand the observed relationships and determine causality. Given the movement towards national universal childcare systems, research on the impact of centre-based childcare on child growth and other important health, nutritional and developmental outcomes are needed to better understand mechanisms and inform policy and interventions in these settings. Clinical trials evaluating the role of centre-based childcare for general populations would provide much needed evidence about causal relationships. Such trials could evaluate the cost effectiveness of centre-based childcare including the upstream and downstream savings from the prevention of obesity. This may also be useful for policy makers when considering interventions to reduce socioeconomic health gradients over the life course. Finally, a stronger understanding of parental reasons for childcare choices and perceptions of childcare settings may identify opportunities for education and knowledge translation.

The strengths of this study include the prospective design which allowed for evaluation of repeated zBMI measurements through 10 years of age minimising the risk of reverse causality. The large ethnically diverse cohort of healthy children, detailed questionnaire and anthropometric data allowed for adjustment of numerous clinically relevant covariates. Standardised anthropometric protocols and questionnaires were used to collect survey data which minimised the risk of measurement error and response bias. Factors hypothesized to modify the associations, such as family income and childcare intensity, provided granularity to the findings. Finally, the complex analytical approach allowed for evaluation of non-linear trends and mixed effects modelling which accounted for within- and between-subject variability increased the power to detect differences.

The limitations of this study include a possibility of residual confounding from unmeasured variables due to the observational design. While adjustment for important sociodemographic, child and family characteristics were included, the quality of childcare practices in each setting were not measured. Parents were asked to provide their main childcare arrangement which limited evaluation of multiple arrangements simultaneously. However, previous research in Canadian children suggested that multiple childcare arrangements were uncommon, and preschool children typically attended the same type of childcare [56]. Furthermore, national data on childcare arrangements in Canada suggested that 58% of children attend centre-based care between 1 and 3 years of age and 51% of children between 1 year of age and school entry in Ontario, which is similar to 54% in the TARGet Kids! population [11, 57]. While zBMI is a recommended indicator of weight status in children, it is not a direct measure of body composition [58]. However, BMI has been strongly correlated with direct measures of adiposity [59, 60]. Sample size limitations necessitated collapsing overweight and obesity categories. Furthermore, there was a relatively small sample size in the lowest income category (<$50,000). However, effects may be stronger in this population [22, 23] highlighting the importance of exploration. Finally, while participants were from an ethnically diverse population of healthy urban children, they may not be representative of all children or childcare in other populations.

CONCLUSION

Centre-based childcare attendance in early childhood was associated with lower zBMI and lower odds of overweight and obesity in later childhood. These relationships were stronger for children from low-income families. These findings may promote dialogue among childcare policy makers by highlighting the potential benefits of centre-based childcare, particularly for children from lower income families, and encourage policy and advocacy efforts to improve access, availability, and affordability. These findings may be important to healthcare professionals and policy makers who are interested in the potential of centre-based childcare as an early intervention to support healthy childhood growth, to level socioeconomic gradients in health and for the prevention of childhood obesity.

DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are not publicly available as we do not have REB approval for data sharing.

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AUTHOR CONTRIBUTIONS

MK and JM conceptualised and designed the research study, performed the initial statistical analyses, interpreted the data, drafted the initial manuscript, and reviewed and revised the manuscript. CKS designed the study, supervised the statistical analyses and interpretation of data, and critically reviewed the manuscript for important intellectual content. CB and MP designed the study and critically reviewed the manuscript for important intellectual content. All authors read and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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ADDITIONAL INFORMATION

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TARGET KIDS! COLLABORATION

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