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Associations of childcare type, age at start, and intensity with body mass index trajectories from 10 to 42 years of age in the 1970 British Cohort Study

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Abstract

Background: Attending childcare is related to greater childhood obesity risk, but there are few long-term follow-up studies. We aimed to examine the associations of childcare type, age at start, and intensity with body mass index body mass index (BMI) trajectories from ages 10 to 42 years.

Methods: The sample comprised 8234 individuals in the 1970 British Cohort Study, who had data on childcare attendance (no, yes), type (formal, informal), age at start (4-5, 3-3.99, 0-2.99 years old), and intensity (1, 2, 3, 4-5 days/week) reported at age 5 years and 32 563 BMI observations. Multilevel linear spline models were used to estimate the association of each exposure with the sample-average BMI trajectory, with covariate adjustment. A combined age at start and intensity exposure was also examined.

Results: Attending vs not attending and the type of childcare (none vs formal/informal) were not strongly related to BMI trajectories. Among participants who attended childcare 1 to 2 days a week, those who started when 3 to 3.99 years old had a 0.197 (−0.004, 0.399) kg/m^2 higher BMI at age 10 years than those who started when 4 to 5 years old, and those who started when 0 to 2.99 years old had a 0.289 (0.049, 0.529) kg/m^2 higher BMI. A similar dose-response pattern for intensity was observed when holding age at start constant. By age 42 years, individuals who started childcare at age 0 to 2.99 years and attended 3 to 5 days/week had a 1.356 kg/m^2 (0.637, 2.075) higher BMI than individuals who started at age 4 to 5 years and attended 1 to 2 days/week.

Conclusions: Children who start childcare earlier and/or attend more frequently may have greater long-term obesity risk.

KEYWORDS

birth cohort study, body mass index, childcare, obesity, trajectories

1 | INTRODUCTION

Obesity is a major public health problem, accounting for four million deaths globally and 120 million disability-adjusted life-years in 2015.[1] In the United Kingdom (UK), approximately 25% of the adulthood population are currently affected by obesity, and 40% of men and 30% of women by overweight.[2] Even more worrying is that more recent generations are developing obesity at increasingly younger ages.[3] The latest available estimates from the UK's National Child Measurement Programme report that 22.3% of children in Reception year (aged 5 years) and 34.3% of children in Year Six (aged 10-11 years) were already classified as having overweight or obesity.[4] Because obesity tracks from childhood to adulthood,[5] this means that future rates of obesity in adulthood are projected to increase.[6]

Childcare settings (eg, nurseries and playgroups) may offer an ideal opportunity for population-level interventions and targeted policy changes. Namely because healthy behaviours and obesogenic trajectories are established early in life[3,7-13] and a rising number of children attend out-of-home childcare, with many starting as early as the first year of life and spending much of their week days in these settings.[14-16] Four recent reviews have summarized the literature on the association between exposure to childcare and obesity risk.[17-20] All these publications found that available evidence is largely limited to cross-sectional and short-term follow-up studies. The two reviews focusing on obesity risk during early childhood[19,20] found mostly mixed or harmful effects, while the two reviews that included outcomes at later ages[17,18] generally found no association or a harmful effect. There is some evidence that earlier age of starting childcare (indicating greater duration of exposure) and higher intensity of attendance are particularly associated with greater obesity. While certain aspects of childcare may be related to increased risk for obesity in childhood, we know almost nothing about how exposure to childcare might be associated with body mass index (BMI) into and across adulthood. Such knowledge would provide evidence that targeting childcare policies and practices might ultimately benefit adulthood health and wellbeing.

We aimed to examine the associations of childcare attendance, and type, age at start, and intensity among those children who did attend, with BMI trajectories from 10 to 42 years of age in the 1970 British Birth Cohort.

2 | METHODS

2.1 | Study sample

The 1970 British Cohort Study is based on 17 287 people born in 1 week in April 1970 in England, Scotland, and Wales.[21] Data collections have taken place at ages 0 (1970), 5 (1975), 10 (1980), 16 (1986), 26 (1996), 30 (2000), 34 (2004), and 42 (2012) years. The study has received ethical approval and obtained informed parental and/or participant consent for all data collection; detailed information is available from the cohort study website and Sheperd & Gilbert's[22] review of ethical procedures used for all sweeps of data collection. At the most recent sweep, the 9841 individuals still participating in the study remained broadly representative of the national population of men and women of the same age.

Starting with the 14 874 cohort members who were still participating at age 10 years (ie, when BMI was first assessed), 4843 were excluded because of missing childcare data, 608 because they did not have a single BMI measurement, and 1189 because of missing data on potential confounders. The resulting sample comprised 8234 individuals, representing 55% of the eligible cohort (ie, N = 14 874).

2.2 | Data

2.2.1 | Outcome

Weight and height were measured by community medical officers, health visitors, or school nurses at ages 10 and 16 years according to standard protocols. At the adulthood sweeps, weight and height were self-reported in questionnaires (age 26 years) or face-to-face interviews (ages 30, 34, and 42 years). BMI was computed as weight (kg)/height (m^2). In total there were 32 563 observations of BMI. Approximately 65% of the sample had four or more observations (out of a maximum of six) and approximately 72% of the sample had serial BMI measurements spanning more than 20 years (out of a maximum of 32 years).

2.2.2 | Exposures

At age 5 years, mothers reported type of childcare setting, age when the participant started, and how many morning and afternoon sessions per week the participant attended. Because these data were collected only for the most recent and previous main childcare placements that lasted for 3 months or longer, our exposure variable is limited to the main childcare setting attended by the participant. The first exposure we computed was attendance: "no" if all placements were coded as does not attend or "yes" if any placement was coded as does attend. The second exposure was type: "formal" for nursery school, nursery class attached to a school, or day nursery or "informal" for playgroup. The "informal" classification is restricted to playgroup because no detailed information on the number of sessions per week and age at start and finish of other informal care, such as friends or grandparents. Nursery schools, nursery classes, and day nurseries were formal settings run by professionals, many linked or attached to primary schools, which could be privately owned or public.[23] Local authorities were responsible for providing this public provision, but it was not mandatory for local authorities to secure such provision.[23] Playgroups were a non-for-profit provision mainly set up by mothers during the 1960's to counter the lack of nursery school places available,[23] which were typically open for two or three sessions per week and each session lasting up to 3 hours.[24] Children reported as attending special education settings, a crèche, or other settings were removed from the sample due to low numbers. The third exposure was age at start: "4

to 5," "3 to 3.99," or "0 to 2.99" years old when started. The fourth exposure was intensity: "1 day/week" if attending 1 to 2 sessions, "2 days/week" for 3 to 4 sessions, "3 days/week" for 5 to 6 sessions, or "4 to 5 days/week" for 7 to 10 sessions. When the current placement started after 5 years of age, or a mother reported that their child did not attend childcare, or data were missing, we used the information from the most recent previous placement (with complete data) to derive exposures two to four.

2.2.3 | Potential confounders

In addition to sex (female vs male), Father's occupational class and mother's age of leaving full time education were considered as proxies of socio-economic position (SEP). Father's occupation, measured when the participant was 10 years old, was classified according to the Registrar General's Social Class (I professional, II managerial and technical, IIIN skilled non-manual, IIIM skilled manual, IV partly-skilled, and V unskilled).[25] Mother's age at leaving full time education was ascertained at the birth sweep, and was categorized as ≥17 years old, 16 years old, 15 years old, or ≤14 years old.

2.3 | Statistical analyses

Descriptive statistics were produced. Further, in order to understand the interrelatedness of childcare type, age at start, and intensity, these three categorical variables were tabulated against each other. χ^2 test were used to quantify the strength of association between any given two variables.

2.3.1 | Trajectory modelling

BMI trajectories were modelled in a multilevel general linear regression framework (measurement occasion at level one and individuals at level two),[26,27] incorporating systematic differences in the sample-average trajectory according to the childcare exposures and adjustment for potential confounders.

The time scale was decimal years of age modelled as a linear spline with a single knot at 26 years of age, thereby producing three easily interpretable parameters: (a) BMI (kg/m^2) at age 10 years, (b) BMI change (kg/m^2/year) between ages 10 to 26 years, and (c) BMI change (kg/m^2/year) between ages 26 to 42 years. The constant and two spline terms were allowed to have random effects at level two, with an unstructured variance-covariance matrix. Further, the level one variance (ie, error) was allowed to differ according to whether the data were measured or self-reported. Placing the knot at the other logical point (ie, age 30 years) or using more complex functions, including fractional polynomials, did not result in noticeably better fitting models.

2.3.2 | Individual childcare exposures

In the first set of models, each of the four childcare exposures was considered separately: (a) childcare attendance (yes vs no), (b) type of childcare (none, formal or informal childcare), (c) age at start of childcare ("4-5," "3-3.99," or "0-2.99" years old when started), and (d) intensity ("1 day/week," "2 days/week," "3 days/week," or "4-5 days/week"). Each exposure was included as a main effect and as interactions with the two spline terms, thereby producing estimates capturing the association of the exposure with BMI at age 10 years, BMI change between ages 10 to 26 years, and BMI change between ages 26 to 42 years. Sex, father's occupational class, and mother's age at leaving full time education were included in the same way to provide robust adjustment for these potential confounders. For parsimony, the two SEP variables were converted and entered into models as ridit scores; associated estimates capture the difference in BMI between the lowest and highest SEP. The models were also used to estimate associations of the exposures with BMI at ages 26 and 42 years. No strong evidence of effect modification by SEP was found in stratified models or in models incorporating exposure-by-SEP interaction terms. Similarly, sensitivity analysis further controlling for two additional SEP variables - childhood household income and housing tenure (as an indicator of wealth) - did not modify the results.

2.3.3 | Different childcare age at start and intensity combinations

Because childcare type, age at start, and intensity were related to each other, it was not prudent to fit a single model that included mutual adjustment for these three variables. Instead, in the second set of models, the relationships of different age at start and intensity of childcare combinations with BMI trajectories were investigated in all children who were reported to attend childcare. The childcare intensity variable was collapsed and combined with the age at start of childcare variable to create a new exposure with six responses: (a) 4 to 5 years old when started and attended 1 to 2 days/week, (b) 4 to 5 years old when started and attended 3 to 5 days/week, (c) 3 to 3.99 years old when started and attended 1 to 2 days/week, (d) 3 to 3.99 years old when started and attended 3 to 5 days/week, (e) 0 to 2.99 years old when started and attended 1 to 2 days/week, and (f) 0 to 2.99 years old when started and attended 3 to 5 days/week. This exposure was entered into a single model in the same way that each individual exposure was investigated in the first set of models, with the same set of adjustments for potential confounders. Again, no strong evidence of effect modification, this time by childcare type (ie, informal vs formal), was observed in exploratory analyses.

All procedures were performed in Stata 15 (StataCorp LP, College Station, TX). The command runmlwin was used for the multilevel models.[28]

3 | RESULTS

Approximately 85% of the sample reported using childcare, with a preference for informal over formal childcare (62% vs 38%) (Table 1). Among those who attended any childcare, the majority (61%) started

TABLE 1 Description of sample of 8234 participants

Childcare		
No	N (%)	1265 (15.4)
Yes	N (%)	6969 (84.6)
Type		
Formal	N (%)	2634 (37.8)
Informal	N (%)	4335 (62.2)
Age at start		
4–5 years old when started	N (%)	1539 (22.1)
3–3.99 years old when started	N (%)	4216 (60.5)
0–2.99 years old when started	N (%)	1214 (17.4)
Intensity		
1 day/week	N (%)	2510 (36.0)
2 days/week	N (%)	1601 (23.0)
3 days/week	N (%)	1995 (28.6)
4-5 days/week	N (%)	863 (12.4)
Sex		
Male	N (%)	4188 (50.9)
Female	N (%)	4046 (49.1)
Ethnicity		
White British	N (%)	7930 (96.3)
Other	N (%)	255 (3.1)
Missing	N (%)	49 (0.6)
Father's occupational class at age 10 years		
I (Professional)	N (%)	451 (5.5)
II (Managerial and technical)	N (%)	2028 (24.6)
IIIN (Skilled non-manual)	N (%)	942 (11.4)
IIIM (Skilled manual)	N (%)	3307 (40.2)
IV (Partly-skilled)	N (%)	1028 (12.5)
V (Unskilled)	N (%)	478 (5.8)
Age mother left full time education		
≥17 years old	N (%)	1612 (19.6)
16 years old	N (%)	1490 (18.1)
15 years old	N (%)	4698 (57.1)
≤14 years old	N (%)	434 (5.3)
BMI (kg/m^2)		
Age 10 years (7478 observations)	Mean (SD)	16.9 (2.1)
Age 16 years (4654 observations)	Mean (SD)	21.1 (3.0)
Age 26 years (4138 observations)	Mean (SD)	23.6 (3.7)
Age 30 years (6054 observations)	Mean (SD)	24.8 (4.2)
Age 34 years (5330 observations)	Mean (SD)	25.8 (4.6)
Age 42 years (4909 observations)	Mean (SD)	26.8 (5.1)

between 3 to 4 years of age and the largest proportion (36%) attended for just 1 day a week. As shown in Table 2, however, age at start and intensity differed according to type of childcare, with children in formal childcare tending to start at a later age and attend more times per week than children who attended informal childcare. Conversely, those children who started at a later age tended to go more times per week.

3.1 | Individual childcare exposures

Table 3 shows the estimated associations of each childcare exposure with BMI trajectories from 10 to 42 years of age. Children who attended childcare did not have higher BMI at age 10 years than those who did not attend childcare (β 0.039 kg/m^2; 95% CI −0.103, 0.180), and there was no evidence that this association changed over follow-up. When childcare was separated into "formal" and "informal" we similarly found no evidence that these groups had different BMI trajectories compared to children who did not attend childcare. Results for the age at start exposure did show that the BMI of participants who started childcare at 0 to 2.99 years of age was 0.266 kg/m^2 (95% CI 0.095, 0.437) higher at 10 years of age than participants who started childcare at 4 to 5 years of age. But they subsequently gained less BMI between ages 10 to 26 years (β −0.013 kg/m^2/year; 95% CI −0.032, 0.006) such that effect sizes were attenuated and null at ages 26 and 42 years. For the intensity exposure, however, attending childcare 4 to 5 days a week (compared to 1 day a week) resulted in higher BMI at age 10 years (β 0.170 kg/m^2; 95% CI −0.006, 0.058) and this effect persisted to age 26 years (β 0.349 kg/m^2; 95% CI 0.024, 0.673) and age 42 years (β 0.380 kg/m^2; 95% CI −0.066, 0.826).

3.2 | Different age at start and intensity of childcare combinations

Table 4 shows the estimated associations of different age at start and intensity of childcare combinations with BMI trajectories. At 10 years of age, there was a clear dose-response relationship between greater exposure to childcare and increased BMI. For example, among participants who attended childcare 1 to 2 days a week, those who started when 3 to 3.99 years old had a 0.197 kg/m^2 (95%CI −0.004, 0.399) higher BMI than those who started when 4 to 5 years old, and those who started when 0 to 2.99 years old had a 0.289 kg/m^2 (95%CI 0.049, 0.529) higher BMI. Similarly, when holding age at start of childcare constant, estimated effects sizes were always larger for participants who attended childcare 3 to 5 days a week compared to those who attended 1 to 2 days a week. These results clearly demonstrate that age at start and intensity of childcare had additive effects on BMI in late childhood. Subsequently, at ages 26 and 42 years, the effect sizes were not as well ranked according to the level of exposure to childcare. Nonetheless, even at 42 years of age, individuals with the highest level of exposure (ie, 0-2.99 years old when started and attended 3-5 days/week) had a 1.356 kg/m^2 (95% CI 0.637, 2.075) higher BMI than individuals with the lowest level of exposure (ie, 4-5 years old when started and attended 1-2 days/week).

TABLE 2 Tabulations between childcare type, age at start, and intensity among 6969 participants

		Type		Intensity			
		Formal N = 2634	Informal N = 4335	1 day/week N = 2510	2 days/week N = 1601	3 days/week N = 1995	4–5 days/week N = 863
Age at start							
4-5 years old when started	N (%)	952 (36.1)	587 (13.5)	414 (16.5)	179 (11.2)	615 (30.8)	331 (38.4)
3–3.99 years old when started	N (%)	1360 (51.6)	2856 (65.9)	1687 (67.2)	1029 (64.3)	1108 (55.5)	392 (45.4)
0–2.99 years old when started	N (%)	322 (12.2)	892 (20.6)	409 (16.3)	393 (24.6)	272 (13.6)	140 (16.2)
Intensity							
1 day/week	N (%)	178 (6.8)	2332 (53.8)				
2 days/week	N (%)	208 (7.9)	1393 (32.1)				
3 days/week	N (%)	1432 (54.4)	563 (13.0)				
4–5 days/week	N (%)	816 (31.0)	47 (1.1)				

4 | DISCUSSION

Using data from a large UK birth cohort study, our results demonstrate a clear dose-response relationship between starting childcare earlier and attending more frequently with higher BMI at age 10 years, in line with the findings of the Black et al systematic review.[18] While this finding is important in and of itself, the real gap in the literature is that, after childhood, we know almost nothing about how exposure to childcare might be related to BMI trajectories. The key finding of the present paper is that greater exposure to childcare resulted in higher estimated BMI up until age 42 years, perhaps with intensity being more deleterious than age at start of childcare attendance.

Individuals with the highest level of childcare exposure were estimated to have between a 0.5 to 1.5 kg/m^2 higher BMI than individuals with the lowest level of exposure across the studied age range. This effect size corresponds to approximately 0.1 to 0.3 standard deviations (SDs), which is not negligible given that a BMI reduction of more than 0.20 to 0.25 SDs has been proposed to be clinically important.[29] To put the results into perspective, the difference in median BMI between the 1946 British cohort at 43 years (in 1989) and the 1970 British cohort at 42 years (in 2012) is only 1.5 units in males and 0.9 units in females.[3] So this study's predicted difference of +1.356 units in BMI at 42 years for children who started childcare before 3 years of age and attended 3 to 5 days/week vs those who started childcare ≥4 years of age and attended only 1 to 2 days/week is comparable to the total secular increase in adulthood BMI over 23 years. Additionally, research has shown that a 1 unit increase in young adulthood (18-30 years of age) BMI is related to an 8% increased risk of coronary heart disease.[30] As such, the predicted differences in BMI at both 26 (+0.568) and 42 years of age (+1.356) seen the children who started childcare before 3 years of age and attended 3 to 5 days/week are of clinical importance.

Previous research in another of the UK nationally-representative studies, the 2000 Millennium Cohort Study, reported that children in informal childcare were more likely to be affected by overweight at age 3 years than those cared for by a parent, but this may have been driven by 75% of informal care in that sample being primarily by grandparents.[31] Other studies have also reported higher BMI in children cared for by grandparents.[32,33] Unfortunately, data on care by grandparents was not collected in the 1970 British Cohort Study. Mothers whose primary source of childcare was grandparents would have either selected "other" or chosen one of the other options (eg, playgroup), and this might explain why we found no association between childcare type and BMI trajectories. The Millennium Cohort Study paper also found that the relationship of informal childcare with greater overweight risk was strongest among more advantaged groups (eg, managerial or professional background).[31] This might be because, with higher SEP, childcare increasingly represents a less healthy environment than that found at home. We found no formal evidence of effect modification by father's occupational class and mother's age of leaving full time education, but this may reflect the lower power in these sub-group analyses. While the 1970 British Cohort Study offers the opportunity to model childhood to adulthood BMI trajectories, incorporating effect modification into these longitudinal models requires three-way interactions and thus a very large sample size. The Millennium Cohort Study now has data to age 14 years and would allow detailed investigation with many different outcomes in a contemporaneous sample.

There are only two studies that we are aware of that have investigated the association of childcare with BMI in adulthood. In a sample of 783 women attending Cracow or Opole universities in Poland in 2005, Wronka and Pawlinnska-Chmara found no association of childcare type with BMI at 20 to 24 years of age.[34] In another of the UK nationally-representative studies, the 1958 National Child Development Study, Batty et al found that the BMI at age 44/45 years of individuals who attended nursery was only 0.01 (–0.05, 0.07) SDs higher compared to individuals who did not attend nursery.[35] We similarly found no evidence of an association between childcare attendance or type with BMI at ages 42 years but did find evidence for childcare intensity. Batty et al also reported no association of nursery attendance with a range of cardiometabolic disease risk factor (eg, blood pressure and cholesterol) and mortality. Further work, however, needs to investigate the relationships of age at start and intensity of childcare with these and other outcomes.

TABLE 3 Associations of childcare type, age at start, and intensity with BMI trajectories from ages 10 to 42 years, among 8234 participants, estimated from four separate multilevel linear spline models

		BMI (kg/m^2) Age 10 years			BMI change (kg/m^2/year) Ages 10-26 years			BMI (kg/m^2) Age 26 years			BMI change (kg/m^2/year) Ages 26-42 years			BMI (kg/m^2) Age 42 years		
	N	B	95% CI	P	B	95% CI	P	B	95% CI	P	B	95% CI	P	B	95% CI	P
Childcare																
No	1265	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yes	6969	0.039	-0.103, 0.180	0.592	−0.015	−0.030, 0.001	0.064	−0.198	−0.460, 0.064	0.138	0.006	−0.011, 0.023	0.502	−0.103	−0.463, 0.256	0.573
Type																
No childcare	1265	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Formal	2634	0.090	−0.066, 0.246	0.257	−0.017	−0.034, 0.001	0.059	−0.176	−0.465, 0.113	0.233	0.002	−0.017, 0.021	0.826	−0.142	−0.538, 0.255	0.484
Informal	4335	0.004	−0.143, 0.152	0.953	−0.014	−0.030, 0.003	0.104	−0.212	−0.486, 0.061	0.128	0.008	−0.010, 0.026	0.365	−0.079	−0.456, 0.297	0.679
Age at start																
4–5 years old when started	1539	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3–3.99 years old when started	4216	0.108	−0.024, 0.241	0.109	0.003	−0.012, 0.017	0.706	0.153	−0.091, 0.397	0.219	−0.006	−0.022, 0.010	0.467	0.059	−0.278, 0.395	0.733
0–2.99 years old when started	1214	0.266	0.095, 0.437	0.002	−0.013	−0.032, 0.006	0.173	0.059	−0.254, 0.373	0.712	0.003	−0.017, 0.023	0.764	0.108	−0.322, 0.539	0.622
Intensity																
1 day/week	2510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 days/week	1601	0.059	−0.083, 0.202	0.413	−0.002	−0.017, 0.013	0.800	0.028	−0.231, 0.286	0.833	0.009	−0.007, 0.026	0.284	0.172	−0.182, 0.527	0.341
3 days/week	1995	0.036	−0.097, 0.169	0.594	0.007	−0.007, 0.021	0.335	0.150	−0.093, 0.392	0.227	0.009	−0.006, 0.025	0.237	0.300	−0.033, 0.634	0.077
4-5 days/week	863	0.170	−0.006, 0.345	0.058	0.011	−0.008, 0.030	0.256	0.349	0.024, 0.673	0.035	0.002	−0.019, 0.023	0.858	0.380	−0.066, 0.826	0.095

TABLE 4 Associations of childcare age at start and intensity with BMI trajectories from ages 10–42 years, among 6969 participants, estimated from one single multilevel linear spline model

			BMI (kg/m²) Age 10 years			BMI change (kg/m²/year) Ages 10-26 years			BMI (kg/m²) Age 26 years			BMI change (kg/m²/year) Ages 26–42 years			BMI (kg/m²) Age 42 years		
		N	B	95% CI	P	B	95% CI	P	B	95% CI	P	B	95% CI	P	B	95% CI	P
Age at start	Intensity																
4–5 years old when started	1-2 days/week	593	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4–5 years old when started	3-5 days/week	946	0.158	−0.075, 0.390	0.185	0.014	−0.011, 0.040	0.281	0.382	−0.047, 0.811	0.081	0.024	−0.004, 0.052	0.098	0.763	0.171, 1.355	0.012
3–3.99 years old when started	1-2 days/week	2716	0.197	−0.004, 0.399	0.055	0.009	−0.013, 0.031	0.407	0.346	−0.023, 0.715	0.066	0.014	−0.010, 0.039	0.242	0.578	0.068, 1.088	0.026
3–3.99 years old when started	3-5 days/week	1500	0.220	0.004, 0.436	0.046	0.015	−0.008, 0.039	0.205	0.464	0.068, 0.860	0.022	−0.002	−0.028, 0.024	0.876	0.431	−0.116, 0.977	0.123
0–2.99 years old when started	1-2 days/week	802	0.289	0.049, 0.529	0.018	−0.009	−0.035, 0.017	0.497	0.145	−0.294, 0.583	0.518	0.003	−0.026, 0.031	0.849	0.189	−0.415, 0.793	0.540
0–2.99 years old when started	3-5 days/week	412	0.509	0.222, 0.797	0.001	0.005	−0.027, 0036	0.763	0.586	0.062, 1.111	0.028	0.048	0.015, 0.082	0.005	1.356	0.637, 2.075	<0.001

The pathways through which childcare experiences may affect the risk of obesity are poorly understood.[32,36] Different types and characteristics of childcare providers may have different influences on the development of obesity-related risk factors, such as physical activity, sedentary behavior, sleep, diet, and stress.[37-39] For example, a recent systematic review reported that some childcare staff behaviors (eg, providing portable play equipment and positively prompting children to be active) were associated with increased physical activity in children in cross-sectional studies.[39] However, this was not seen across all studies. Given the existing evidence of associations between physical activity, sedentary behavior, sleep, diet, and stress with increased adiposity in early childhood,[36,40] it has been hypothesized that these risk factors are possible pathways through which the childcare experience may influence the development of obesity.[41] However, the scarcity of published studies investigating the longitudinal associations of childcare during the early years and subsequent risk factors such as physical activity and sedentary behavior[42] limit the ability to confirm this hypothesis.

The main strengths of the present article are (a) the thorough analysis of longitudinal BMI data collected on a large cohort over three decades of follow-up and (b) the ability to investigate multiple aspects of childcare (ie, attendance, type, age at start, and intensity). In terms of limitations, (a) childcare in the 1970's may be very different from today, although analyses in more recent cohorts have also demonstrated deleterious consequences for short-term obesity risk,[31] thereby suggesting that our results may be relevant for contemporary childcare settings, (b) we were unable to investigate the potential effects of concurrent attendance to multiple childcare settings because data on age at start and intensity of attendance were only available for the main childcare setting attended, (c) height and weight at ages 26 and 42 years were self-reported so BMI may be under estimated in adulthood, particularly in individuals with overweight or obesity,[43] (d) BMI is only a limited indicator of adiposity and the reported associations may also reflect greater fat-free mass,[10,44,45] (e) despite adjustment for father's occupational class and mother's age of leaving full time education, we cannot rule out the possibility of residual confounding by SEP or other factors (eg, child's health during early childhood, or concurrent care by other informal providers such as grandparents), (f) there may be some recall bias in the childcare exposure data due to the retrospective reporting of this data at age 5 years, although the wide intervals used in the definition of age at start and intensity of attendance categories likely reduce the possible effects of such bias, and (g) we cannot assess or rule out reverse causality because BMI was not assessed before age 10 years in this cohort.

In conclusion, our results provide evidence that starting childcare at an earlier age and attending more frequently have additive effects on increasing BMI which seem to persist from late-childhood to mid-adulthood. Use of childcare is both necessary and highly prevalent.[14-16] As such, strategic research is needed to understand what policies and practices regarding physical activity, sedentary behavior, and diet exist and are implemented in these settings, and how these could be changed so that childcare plays a

key role in the establishment of healthy behaviors and weight across the life course, instead of being associated with a more adverse BMI trajectory.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUITIONS

William Johnson and Silvia Costa conceptualized the study. William Johnson carried out the analyses and Silvia Costa drafted the initial manuscript. Silvia Costa, David Bann, Sara E. Benjamin-Neelon, Jean Adams, and William Johnson made substantial contributions to the interpretation of the data, revised the manuscript critically for important intellectual content, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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REFERENCES

1. Global Burden of Disease 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. *N Engl J Med*. 2017;377(1):13-27.
2. Fuller E, Mindell J, Prior G. *Health Survey for England 2016*. London, England: NHS Digital; 2017.
3. Johnson W, Li L, Kuh D, Hardy R. How has the age-related process of overweight or obesity development changed over time? Co-ordinated analyses of individual participant data from five United Kingdom birth cohorts. *PLoS Med*. 2015;12(5):e1001828.
4. ND. National Child Measurement Programme, England - 2017/18 School Year [PAS] 2018. Retrieved from: https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2017-18-school-year/age
5. Aarestrup J, Bjerregaard LG, Gamborg M, et al. Tracking of body mass index from 7 to 69 years of age. *Int J Obes*. 2016;40(9):1376-1383.
6. Ward ZJ, Long MW, Resch SC, Giles CM, Cradock AL, Gortmaker SL. Simulation of growth trajectories of childhood obesity into adulthood. *N Engl J Med*. 2017;377(22):2145-2153.
7. Biddle SJ, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviours of young people: a systematic review. *PrevMed*. 2010;51(5):345-351.
8. Craigie AM, Lake AA, Kelly SA, Adamson AJ, Mathers JC. Tracking of obesity-related behaviours from childhood to adulthood: a systematic review. *Maturitas*. 2011;70(3):266-284.
9. Hawley NL, Johnson W, Nu'usolia O, McGarvey ST. The contribution of feeding mode to obesogenic growth trajectories in American Samoan infants. *Pediatr Obes*. 2014;9(1):e1–e13.
10. Johnson W, Choh AC, Lee M, Towne B, Czerwinski SA, Demerath EW. Is infant body mass index associated with adulthood body composition trajectories? An exploratory analysis. *Pediatr Obes*. 2017;12(1):10-18.
11. Johnson W, Soloway LE, Erickson D, et al. A changing pattern of childhood BMI growth during the 20th century: 70 y of data from the Fels longitudinal study. *Am J Clin Nutr*. 2012;95(5):1136-1143.
12. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. *Am J Prev Med*. 2013;44(6):651-658.
13. Madruga SW, Araujo CL, Bertoldi AD, Neutzling MB. Tracking of dietary patterns from childhood to adolescence. *Rev Saude Publica*. 2012;46(2):376-386.
14. United Nations Children's First Fund (UNICEF). The Childcare Transition Innocenti Report Card Florence. 2008.
15. Benjamin SE, Rifas-Shiman SL, Taveras EM, et al. Early child care and adiposity at ages 1 and 3 years. *Pediatrics*. 2009;124(2):555-562.
16. Laughlin L. *Who's Minding the Kids? Child Care Arrangements*. Washington, DC: US Census Bureau; 2013.
17. Costa S, Adams J, Gonzalez-Nahm S, Benjamin Neelon SE. Childcare in infancy and later obesity: a narrative review of longitudinal studies. *Curr Pediatr Rep*. 2017;5(3):118-131.
18. Black L, Matvienko-Sikar K, Kearney PM. The association between childcare arrangements and risk of overweight and obesity in childhood: a systematic review. *Obes Rev*. 2017;18(10):1170-1190.
19. Alberdi G, McNamara AE, Lindsay KL, et al. The association between childcare and risk of childhood overweight and obesity in children aged 5 years and under: a systematic review. *Eur J Pediatr*. 2016;175(10):1277-1294.
20. Swyden K, Sisson SB, Lora K, Castle S, Copeland KA. Association of childcare arrangement with overweight and obesity in preschool-aged children: a narrative review of literature. *Int J Obes*. 2016;41:1.
21. Elliott J, Shepherd P. Cohort profile: 1970 British birth cohort (BCS70). *Int J Epidemiol*. 2006;35(4):836-843.
22. Shepherd P, Gilbert E. 1970 British cohort study - ethical review and consent. London: UCL Institute of education. 2019 01/01/2019.
23. West A, Noden P. Public funding of early years education in England: An historical perspective. London, UK: London School of Economics and Political Science; 2016. Report No.: 21 Contract No.: 21.
24. Finch J. The deceit of self help: preschool playgroups and working class mothers. *J Soc Pol*. 1984;13(1):1-20.
25. Bland R. Measuring "social class": a discussion of the registrar-General's classification. *Sociology*. 1979;13:283-291.
26. Johnson W. Analytical strategies in human growth research. *Am J Hum Biol*. 2015;27(1):69-83.
27. Johnson W, Balakrishna N, Griffiths PL. Modeling physical growth using mixed effects models. *Am J Phys Anthropol*. 2013;150(1):58-67.
28. Leckie G, Charlton C. Runmlwin: a program to run the MLwiN multilevel modeling software from within Stata. *J Stat Softw*. 2012;52(11):1-40.
29. US Preventive Services Task Force, Grossman DC, Bibbins-Domingo K, et al. Screening for obesity in children and adolescents: US Preventive Services Task Force recommendation statement. *JAMA*. 2017;317(23):2417-2426.
30. Owen CG, Whincup PH, Orfei L, et al. Is body mass index before middle age related to coronary heart disease risk later in life? Evidence from observational studies. *Int J Obes*. 2009;33(8):866-877.

31. Pearce A, Li L, Abbas J, et al. Is childcare associated with the risk of overweight and obesity in the early years? Findings from the UK millennium cohort study. *Int J Obes*. 2010;34(7):1160-1168.
32. Kim J, Peterson KE. Association of infant child care with infant feeding practices and weight gain among US infants. *Arch Pediatr Adolesc Med*. 2008;162(7):627-633.
33. Tanskanen AO. The association between grandmaternal investment and early years overweight in the UK. *Evol Psychol*. 2013;11(2):417-425.
34. Wronka I, Pawlinska-Chmara R. Childcare, height and BMI among female Polish university students, 2005. *Econ Hum Biol*. 2007;5(3):435-442.
35. Batty GD, Ploubidis GB, Goodman A, Bann D. Association of nursery and early school attendance with later health behaviours, biomedical risk factors, and mortality: evidence from four decades of follow-up of participants in the 1958 birth cohort study. *J Epidemiol Community Health*. 2018;72(7):658-663.
36. Monasta L, Batty GD, Cattaneo A, et al. Early-life determinants of overweight and obesity: a review of systematic reviews. *Obes Rev*. 2010;11(10):695-708.
37. Bernard K, Peloso E, Laurenceau JP, Zhang Z, Dozier M. Examining change in cortisol patterns during the 10-week transition to a new child-care setting. *Child Dev*. 2015;86(2):456-471.
38. Iwata S, Iwata O, Iemura A, Iwasaki M, Matsuishi T. Determinants of sleep patterns in healthy Japanese 5-year-old children. *Int J Dev Neurosci*. 2011;29(1):57-62.
39. Ward S, Belanger M, Donovan D, Carrier N. Systematic review of the relationship between childcare educators' practices and preschoolers' physical activity and eating behaviours. *Obes Rev*. 2015;16(12):1055-1070.
40. Torres SJ, Nowson CA. Relationship between stress, eating behavior, and obesity. *Nutrition*. 2007;23(11–12):887-894.
41. Costa S, Adams J, Phillips V, Benjamin Neelon SE. The relationship between childcare and adiposity, body mass and obesity-related risk factors: protocol for a systematic review of longitudinal studies. *Syst Rev*. 2016;5(1):141.
42. Costa S, Benjamin-Neelon SE, Winpenny E, Phillips V, Adams J. Relationship between early childhood non-parental childcare and diet, physical activity, sedentary behaviour, and sleep: a systematic review of longitudinal studies. *Int J Environ Res Public Health*. 2019;16:4652.
43. Shields M, Connor Gorber S, Tremblay MS. Estimates of obesity based on self-report versus direct measures. *Health Rep*. 2008;19(2):61-76.
44. Demerath EW, Schubert CM, Maynard LM, et al. Do changes in body mass index percentile reflect changes in body composition in children? Data from the Fels longitudinal study. *Pediatrics*. 2006;117(3):e487-95.
45. Flegal KM, Shepherd JA, Looker AC, et al. Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. *Am J Clin Nutr*. 2009;89(2):500-508.

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