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Singleton status and childhood obesity: Investigating effects and mechanisms

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Abstract

Over the past four decades, paralleling the increasing prevalence of childhood obesity, the share of families with only one child has been rising steadily. Using three waves of the National Survey of Children's Health, we examine the effect of being the only child in a family on childhood obesity and the mechanisms through which singleton status might affect childhood obesity. We find gender-specific and age-dependent singleton effects. That is, singletons have a higher level of body mass index and a higher obesity rate than children with siblings. The singleton effects are more pronounced for younger cohorts aged 10-13 than older cohorts aged 14-17 and for males than females. We also find that singletons exercise less, are less likely to participate in after-school sports teams or take sports lessons, and spend more time watching television/video and playing video/computer games. The findings not only suggest a potential target — singletons — for childhood obesity prevention and interventions, but also highlight the importance of coordinating policies on childhood obesity and fertility.

The seniority of authorship is equally shared.

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1. Introduction

Childhood obesity has more than doubled in children and quadruped in adolescents in the past 30 years in the United States – reaching 18% among children aged 6-11 and 21% for adolescents aged 12-19 (Ogden, et al., 2014). Paralleling the increasing prevalence of childhood obesity, family structure has been evolving rapidly. Among families with at least one child under age 18, the share of single child families increased from 27% in 1970 to 36% in 2011.[1] The question that arises is whether these two important trends – the increase in childhood obesity and the share of singleton families – are related and, more important, whether the latter contributes to the former.

A limited number of public health studies examine the association between being an only child and childhood obesity. The only study focusing on U.S. children is that of Chen and Escarce (2010). Using the Early Childhood Longitudinal Study-Kindergarten Cohort, they find that U.S. elementary school children who had no siblings had a higher body mass index (BMI) and a higher obesity rate than children with siblings. Other studies provide similar results for children in other countries. Using a multi-country survey including Italy, Estonia, Cyprus, Belgium, Sweden, Hungary, Germany and Spain, Hunsberger, et al. (2012) find that singletons aged 2-19 are more likely to be overweight than their counterparts with siblings. Studies on Japanese children also find a positive correlation between singleton status and overweight risk among fourth graders aged 9-10 (Ochiai, et al., 2012) and junior high school students (Wang, et al., 2007).

There are several notable gaps in the literature. First, the type and level of interactions between siblings may vary by gender (McHale, et al., 1999) and age cohort (Hohepa, et al., 2007, Sallis, et al., 2000). However, the literature has yet to address the gender-specific and age-dependent feature of the singleton effect on childhood obesity. Second, the relationship between childhood obesity and adolescent singletons in the United States has not been studied so far. Third, none of the previous studies investigate the mechanisms through which singleton status may affect childhood obesity. Understanding such mechanisms is important to childhood obesity prevention and interventions. This study will fill these gaps in the literature. Using three waves of the National Survey of Children's Health (NSCH 2003-04, 2007-08 and 2011-12), this study finds that singletons have a higher BMI and a higher obesity rate compared with children with siblings. The singleton effects are more pronounced among males than females and among early adolescents aged 10-13 than adolescents aged 14-17. By investigating the mechanisms, we find that singletons exercise less, are less likely to participate in after-school sports teams and/or take sports lessons, and spend more time watching television and video and/or playing video/computer games. The findings not only suggest a potential target — singletons — for childhood obesity prevention and interventions, but also highlight the importance of coordinating policies on childhood obesity and fertility.

2. Data source and description

The main data used in this study come from the NSCH 2003-04, 2007-08 and 2011-12. The NSCH was designed to examine the physical and emotional health of children from birth to age 17 in the United States. It contains a nationally representative random sample of households in each of the 50 states and the District of Columbia. One child is randomly selected from each sample household. As the NSCH 2007-08 and 2011-12 do not provide weight status (Obese,

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[1] Author's calculation based on the U.S. Census 1970 and the American Community Survey 2011.

Overweight, Normal and Underweight) of children younger than 10, this study focuses on children and adolescents aged 10-17. Each respondent was classified as overweight (obese) if his/her BMI is at or above the 85^{th} (95^{th}) percentile for his/her age and gender. The respondents were asked to report the total number of children under 18 in the family. We use this information to create a binary variable indicating whether the child has siblings (0) or not (1). All analyses are weighted by the sampling weights. Overall, the prevalence of obesity in the NSCH sample is comparable to the CDC's estimate (CDC, 2010). The average BMI in the NSCH sample is 20.62 for younger cohorts aged 10-13 (N = 23,896) and 22.46 for older cohorts aged 14-17 (N = 28,759).[2] The obesity rates are 17.20% for younger cohorts (N = 36,699) and 11.27% for older cohorts (N = 43,352).

The NSCH respondents were asked to report the number of days during the past week they exercised, played a sport, or participated in physical activity for at least 20 minutes that caused them to sweat and breathe hard, i.e., vigorous physical activity.[3] Based on their responses, we create a binary variable to indicate whether a respondent engaged in vigorous physical activity on at least five days during the past week (*Vigorous*_5). We also create another dummy variable indicating whether a respondent had been on a sports team or took sports lessons after school or on weekends over the past 12 months (*Sports*). As shown in Table 1 approximately half of the NSCH respondents reported that they had engaged in vigorous physical activity for at least 20 minutes on at least five days during the past week and more than half reported playing on a sports team or taking sports lessons outside school hours in the past year.

Insert Table 1 here!

The NSCH respondents were also asked to report the number of hours during an average weekday spent on watching television/video, or playing video/computer games, from which we create two variables: the number of hours spent watching television/video or playing video/computer games (*Screen_hours*) and a binary variable indicating whether the respondents spend more than two hours on sedentary activity (*Screen_2*) a day. As shown in Table 1, the NSCH respondents' screen time is 11-12 minutes on an average weekday and approximately half of them have more than 2 hours of screen time on an average weekday.

3. Empirical analyses

We first compare weight outcomes and physical/sedentary activity between singletons and non-singletons and test the hypothesis of equal means for each outcome variable. For the full sample, singletons have a statistically significantly greater obesity rate by approximately one percentage point and a higher BMI but the difference in BMI is not statistically significant (columns 1-2 in Table 1). Among younger cohorts aged 10-13, compared with non-singletons, singletons have a statistically higher BMI of nearly one unit and a higher obesity rate by five percentage points for both males and females (columns 3-6 of Table 1). For older cohorts aged

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[2] As the 2011-12 NSCH does not make children's weight and height publically available due to the confidentiality concerns, the BMI analysis is only based on two waves of the NSCH: 2003-04 and 2007-08.

[3] The physical activity question in the NSCH may not be consistent with the 2008 Physical Activity Guidelines for Americans (PAGA) (http://www.health.gov/paguidelines/default.aspx.). The PAGA recommend that Children and adolescents should engage in 60 minutes or more of physical activity daily for at least three days a week, of which most of the time should be spent on either moderate- or vigorous intensity aerobic physical activity.

14-17, the associations are not significant except that male singletons have a statistically higher BMI than their counterparts with siblings for males (columns 7-10 of Table 1). Furthermore, singletons are associated with a lower likelihood of engaging in vigorous physical activity for at least 20 minutes on at least five days in the past week or participating in after-school sports teams or lessons -- the probability decreases by 3.2 percentage points for the former and 2.9 percentage points for the latter (columns 1 and 2 of Table 1). In terms of sedentary activity, singletons have approximately eight more minutes of sedentary activity per weekday (0.013*60 = 7.8), and their probability of having more than two hours of screen time is 5.8 percentage points higher than children with siblings (columns 1 and 2 of Table 1). The associations are statistically significant and even stronger for younger cohorts. For older cohorts aged 14-17, the association between singleton status and physical activity is still negative but not statistically significant; the association is statistically significant for screen time for both genders and for the probability of having screen time of more than two hours on an average weekday for females.

Overall, Table 1 shows the following findings. First, the associations between singleton status and weight outcomes and physical/sedentary activity are age-specific. The associations are statistically significant for both genders aged 10-13. For older adolescents aged 14-17, singleton status is only statistically significantly associated with BMI and sedentary activity for males. Second, the associations exhibit gender differences. For younger cohorts, the differences in BMI, obesity rate, and sedentary activity between singletons and non-singletons are greater for males than females, but the difference in physical activity is greater for both genders. For adolescents aged 14-17, the associations are less statistically significant for females than males.

3.1 Does singleton status affect the weight outcomes of children and adolescents?

We pool the three NSCH waves and regress weight outcomes on the single child indicator and a rich set of control variables:

$$W_{it} = \beta_0 + \beta_1 Singleton_{it} + X_{it}\gamma + F_{it}\theta + S_t\delta + \tau_t + \epsilon_{it} \quad (1)$$

where the subscripts i and t index individual i in survey year t and ϵ_{it} is an error term. The dependent variable, W_{it}, is either BMI or a binary indicator for being obese. The independent variables consist of a binary indicator for being the only child in the family ($Singleton_{it}$), individual socio-economic characteristics (X_{it}), family and parental characteristics (F_{it}), and state-level characteristics (S_t). We also include year dummies (τ_t) to capture the time trend of adolescents' weight outcomes. Children' individual characteristics include gender, age, race/ethnicity and self-reported health condition. Family and parental information includes poverty measures (living 0-100%, 100-200%, or 200-300% of the federal poverty line), an indicator for living in a metropolitan statistical area (MSA) with more than 500,000 households,[4] mother's self-reported health condition, and a binary variable indicating single-mother families. All models include a series of state-level food environment characteristics to account for any unobserved state-level food environmental. The literature shows that being overweight or obese is positively associated with the frequency of eating out, especially the consumption of fast food among children and adolescents (Bowman, et al., 2004, Duffey, et al., 2007, Pereira, et al., 2005), the proximity and/or density of fast food restaurants (Davis and Carpenter, 2009), and being close to supermarkets but far from small grocery stores or fast food restaurants (Morland and Evenson, 2009). The relative prices of healthy and unhealthy foods are also found to be important in promoting healthy eating and thus, the so-called "fatty tax" has been proposed and implemented (Brownell, et al., 2009). Based on the USDA-ERS's Food Environment Atlas, we

[4] The NSCH data do not includes specific rural/urban information.

create several variables to characterize state-level food environments, including the number of fast food restaurants per 1,000 residents, per capita annual food expenditures on fast food restaurants, and sales tax on soda, chips and pretzels, and retail food in general.[5] All models are estimated with robust standard errors clustered by state to adjust for correlations within states.

The estimates are presented in Panel A of Table 2. We first examine the results for the full sample aged 10-17 (columns 1-4 of Table 2). Being an only child is associated with a 3.3 (2.5) percentage-points increase in obesity rate for males (females). The estimates for the BMI are also positive and statistically significant, 0.442 (0.402) for males (females). For younger cohorts aged 10-13, the singleton effects are greater in magnitude for males than females. The obesity rate is 5.7 (4.3) percentage-points higher for males (females) if they are the only child in their families (columns 5-6 of Table 2). The corresponding numbers for the BMI estimates are 0.793 and 0.631 for males and females, respectively (columns 7-8 of Table 2). For this age cohort, the average BMI and obesity rate for males with at least one sibling are 20.6 and 20.50%, respectively (column 3 of Table 1). Given the estimated singleton effects, the increases in the weight outcomes are approximately 4% for BMI and 28% for obesity rate for male singletons. The corresponding numbers for female singletons are 3% and 29%. Thus, the results suggest economically significant singleton effects on both BMI and obesity rate for younger cohorts aged 10-13. For older cohorts aged 14-17 we do not find significant singleton effects, although female singletons have a higher BMI by 0.255 units than non-singletons (columns 7-10 of Table 2). The age-dependence of the singleton effect does not come as a surprise as adolescents become increasingly independent of their families and expand their social networks external to the family environment as they move through adolescence (Hohepa, et al., 2007).

Insert Table 2 here!

Inspired by significant racial/ethnic and income disparities in obesity prevalence among U.S. children and adolescents (USCDC, 2010), we examine the heterogeneity of singleton effect for various subgroups of our sample. We first divide the sample by family income level (the cut-point is 300% of the federal poverty line). As shown in Panel B of Table 2, the results are qualitatively similar to the main results discussed above. There are several noteworthy new findings. First, the singleton effects are statistically significant for both the high- and low-income subsamples with only one exception (insignificant for the high-income subsample of older cohorts), but they are larger in magnitude for children from low-income families than those from high-income families. Such difference can be explained by potential differences between high- and low-income families. For example, singletons from high-income families are more likely to have better access to amenities conducive to physical activity such as neighborhood parks and playgrounds (Fan and Jin, 2014) and/or they are more likely to participate in after-school activities such as recreational sports and sport lessons (Voss, et al., 2008). In Panel C of Table 2, we also stratify our sample by ethnic background. For younger cohorts aged 10-13, the singleton effects are greater for non-Hispanic white children than for Hispanic/black children. The racial difference in physical activity is not likely to be driven by the comparable share of singletons between non-Hispanic white children (22.88%) and Hispanic/black children (21.13%) in the NSCH sample. Studies have found that Hispanic/ black children are consistently less physically active than their white counterparts (Franzini, et al., 2009, Olvera, et al., 2010). Therefore, the smaller and less significant singleton effects for Hispanic/black children are reasonable due to their low level of physical activity.

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[5] http://www.ers.usda.gov/data-products/food-environment-atlas.aspx#.Uzx2Y_ldVDw.

3.2 What are the mechanisms through which singleton status affects weight outcomes?

Why do singletons have higher BMI and obesity rate than children with siblings? We examine both physical and sedentary activity to explain the differences. Physical activity has been shown to be correlated with childhood obesity by voluminous studies.[6] A large proportion of U.S. children and adolescents fail to meet the recommended level of physical activity. For example, nearly a quarter (23%) of 9th- through 12th-grade students did not meet this recommended level (Hausenblas and Fallon, 2006). Among family and parental factors that affect physical activity among children and adolescents, siblings are found to provide support and encouragement for physical activity, especially when parents cannot allocate their time to play with the child (Cawley and Liu, 2012, Duncan, et al., 2004, Hohepa, et al., 2007, Raudsepp and Viira, 2000, Sallis, et al., 2000, Springer, et al., 2006). We use following model to examine whether singletons engage in less physical activity and/or more sedentary activity:

$$PSA_{it} = \alpha_0 + \alpha_1 Singleton_{it} + X_{it}\rho + F_{it}\delta + S_t\theta + \tau_t + \mu_{it} \quad (2)$$

where PSA_i is one of the four measures of physical or sedentary activity defined above, namely, *Vigorous_5*, *Sports*, *Screen_hours*, and *Screen_2*. The independent variables, $Singleton_{it}$, X_{it}, F_{it}, S_t, and τ_t, are the same as equation (1). The error term is indicated by μ_{it}. All models are estimated with robust standard errors clustered by state.

As shown in Table 3, singleton status reduces physical activity and increases sedentary activity. For younger cohorts, the probability of engaging in vigorous physical activity for at least 20 minutes per day on at least five days a week decreases by 3-4 percentage points for singletons relative to children with siblings. Similarly, singletons are less likely to participate in sports teams or take sports lessons after school or on weekends – a decrease of 3 (5) percentage points for males (females). Moreover, singletons have higher levels of screen time – approximately 9 minutes more for males and 7 minutes more for females for an average weekday. The likelihood of spending more than two hours of screen time increases by 6-7 percentage points. The singleton effects on physical and sedentary activities are consistently significant for both genders in younger cohorts aged 10-13. However, for older cohorts, singleton status is only statistically associated with more screen time and a higher probability of spending more than two hours watching TV/videos, or playing video/computer games on an average weekday.

Insert Table 3 here!

Table 3 clearly shows age-dependent and gender-specific patterns of the singleton effect on physical and sedentary activity. Singleton status has a statistically significant and positive effect on physical activity in the younger cohorts aged 10-13, but not in the older cohorts aged 14-17. Being an only child also has a positive effect on sedentary activity for all age cohorts, and the effect is larger in magnitude for the younger cohorts. Other studies also find age-dependent sibling effects on physical and/or sedentary activity (Duncan, et al., 2004, Sallis, et al., 2000, Springer, et al., 2006). Table 3 also shows a stronger singleton effect for males than females, which partly explains the stronger effect on weight outcomes for males than females as discussed above.

The significant singleton effect on both physical and sedentary activity for the younger cohorts and on sedentary activity for the older cohorts decreases energy expenses, leading to higher BMI and/or a higher obesity risk among singletons. Although the NSCH does not have information on food consumption or dietary habits, we are able to infer the singleton effects on

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[6] See Steinbeck (2001) and Must and Tybor (2005) for review of cross-sectional and longitudinal studies.

food consumption based on the observations that singletons have greater screen time and previous studies on food consumption and television viewing. Increased screen time is found to be positively associated with energy intake (Crespo, et al., 2001, Ebbeling, et al., 2002) and children's exposure to (unhealthy) food marketing and advertisements (Kotz and Story, 1994, Kovacic, et al., 2008, Strasburger, 2006). According to a 2008 report from the Federal Trade Commission, U.S. food industry spent nearly two billion dollars on marketing and advertising foods and beverages to children, including $474 million alone on sugar-sweetened beverage advertising in 2006 (Kovacic, et al., 2008). Consequently, children viewed more than 4,000 food advertisements on television alone in 2006 (Strasburger, 2006). One study of typical Saturday morning children's television programming provides the following stunning findings (Kotz and Story, 1994): no advertisements for fruits or vegetables, but significant proportion of food advertisements fell into the fats, oils, and sweets group (44%) and fast-food restaurant advertising (11%). Thus, given the increased exposure to food marketing and advertisements that appear to focus on less healthy foods, singletons who were found to have a longer screen time are likely to consume more unhealthy foods. Veerman, et al. (2009) find that childhood obesity in the United States could decrease by 2.5-6.5 percentage points if there were a complete ban on food advertising on television. Thus, given the strong positive correlation between television viewing and (unhealthy) food consumption, we expect that singletons are more likely to have higher energy intakes and consume more unhealthy foods than children with siblings. We also expect that singletons are likely to consume more food due to the effect of family size on per capita food expenditures. Deaton and Paxson (1998) find that conditional on constant per capita total expenditures the per capita demand for food decreases as family size increases in both developed (including the U.S.) and developing countries. All else being equal, singletons are likely to consume more food and, thus, have a higher risk of obesity than children with siblings.

3.3. Robustness check using two-stage least squares (2SLS) approach

One may argue that children's weight status and family size can be affected by some unobserved family characteristics such as parents' perspective of an "ideal" family and a "model" child. Such potential endogeneity might bias the singleton effect on childhood obesity. Furthermore, the OLS results show statistically significant and positive singleton effects on children weight measures for the younger cohorts aged 10-13 but not for the older cohorts aged 14-17. The heterogeneous results between different age cohorts could be driven by such endogeneity. The findings would be more convincing if the results still hold after the potential endogeneity is properly dealt with.

To address the potential endogeneity, we identify a set of instruments for singleton status and employ the 2SLS approach to estimate the singleton effects. The ideal instrumental variables introduce exogenous variations in fertility and family planning but are not correlated with children's weight outcomes. When instruments introducing individual exogenous changes are not available, state-level variables are often used as instruments (Anderson, et al., 2003, Cawley and Liu, 2012). We use the following state-level variables as instruments. One is the state-level share of single-child families among all families with at least one child under 18 based on the American Community Survey (ACS). Second, maternal labor force participation, which is not available in the NSCH, is expected to be negatively associated with fertility rates (Ahn and Mira, 2002). We create the share of labor force participation for female adults aged 20-60 by state and year. Compared with individual mother's labor force participation, the state-level female labor participation is less likely to be correlated with children's weight status. Third, religion can affect family size and fertility (Frejka and Westoff, 2008, Voas, 2007). We use the 2000 Religious

Congregations and Membership Study designed and completed by the Association of Statisticians of American Religious Bodies to construct share of adherents, a proxy for the level of religiosity, for each state.[7] Fourth, family size is influenced by birth control regulations such as legal abortion (Gruber, et al., 1999) and the availability of oral contraceptive pills (Ananat and Hungerman, 2012). The National Abortion and Reproductive Rights Action League (NARAL) compiles state-level laws and regulations related to birth control and abortion and assigns a letter grade to each state based on women's reproductive rights in each state.[8] The NARAL's letter grades for the state-level reproductive rights in 2004 (the earliest version) is used as one of the instrument variables.

Table 4 presents the 2SLS estimation results. The heteroskedasticity-robust Kleibergen–Paap F statistics suggest that the set of instruments pass weak instrument tests according to critical values computed by Stock and Yogo (2005) for all the models. The Hansen J statistics for the overidentication test of all instruments suggest that we cannot reject the null hypothesis that instruments are valid at the 5% significance level, and thus the required orthogonally conditions are satisfied for all the models except the male sample aged 10-17. For this particular case, the rejection of the null hypothesis of the endogeneity test indicates that singleton status is exogenous for the male sample aged 10-17 with obesity as the dependent variable, and thus, the benefits of instrumental variables are not worth their costs and the OLS estimates are preferred.

Insert Table 4 here!

We find that the coefficients of the singleton dummy in Table 4 provide strong evidence that being an only child positively impacts obesity for males in all age cohorts, but not for females. The 2SLS estimates, however, are substantially larger in magnitude than their OLS counterparts**.** This finding may indicate that the set of state-level instruments is not sufficiently powerful, although the exclusion restriction is valid. We conduct a robustness check of the 2SLS results by excluding the state-level controls (e.g. food environments variables). As expected, the predictive power of the instruments typically improves in these specifications; however, the overall conclusions of this study remain unchanged. We also experiment with a smaller set of instruments by excluding the state-level female labor participation rate from the instrument variables. The results are consistent.

4. Conclusions

This study examines the singleton effects on BMI and obesity rate among U.S. children and adolescents aged 10-17 using three waves of the NSCH. We find that singleton status increases BMI and obesity rate and the singleton effect is more pronounced for males than females and for the younger cohorts aged 10-13 than the older cohorts aged 14-17. In particular, male singletons aged 10-13 have a 0.8-unit, statistically significantly higher BMI (a 4% increase) and a 4 percentage-points higher obesity rate (a 28% increase) than non-singleton males. The

[7] Participants in the survey included 149 Christian denominations, associations, or communions (including Latter-day Saints and Unitarian/Universalist groups); two specially defined groups of independent Christian churches; Jewish and Islamic totals; and counts of temples for six Eastern religions. It is important to understand the methodology producing these data and its limitations. While these data contain membership information for many religious groups in the United States, including most of the larger groups, they do not include every group. Finke and Scheitle (2005) discusses how to adjust adherence rates.

[8] More details can be found on NARAL's official website: http://www.prochoiceamerica.org/.

corresponding numbers for female singletons are comparable – BMI increased by 0.6 units (a 3% increase) and obesity rate increased by 6 percentage points (a 29% increase). However, the singleton effect for adolescents aged 14-17 is limited, which can be explained by increasing independence from families and expansion of social networks external to the family environment as adolescents move through adolescence. The singleton effects are found to be age- and gender-specific, which requires different interventions to be adopted for different age cohorts and gender groups to battle childhood obesity. Such age- and gender-specific effect on childhood obesity is also found for neighborhood parks and playgrounds (Fan and Jin, 2014). We also find plausible mechanisms for the correlation between being an only child and childhood obesity. We find that singletons exercise less, are less likely to participate in after-school sports teams or take sports lessons, and have more screen time. As the literature has documented a strong, positive association between screen time and (unhealthy) food consumption and a negative association between family size and food consumption, it is not unreasonable to expect singletons to have higher energy intakes than their counterparts with siblings.

This study provides important insights for understanding the rapid growth in childhood obesity from a perspective of sibling size. First, the findings suggest that the increase in the share of singleton families in the United States since the 1970s likely contribute to childhood obesity epidemic. It is unlikely (though not impossible) that the declining trend in fertility will reverse or family size will increase in the near future (Lutz, et al., 2006, Pearce, 2011). The findings suggest a potential target, singletons, for childhood obesity prevention and interventions. Increasing physical activity and/or reducing sedentary activity among singleton is likely to be more challenging than for non-singletons (Epstein, et al., 1986). Second, maternal employment has been found to be negatively correlated with fertility (Brewster and Rindfuss, 2000), time spent with children (Bianchi, 2000), and food preparation time (Cawley and Liu, 2012). This study shows another indirect health effect of maternal employment on children due to low fertility: lacking siblings causes singletons to be less physically active and potentially consume more (unhealthy) food. The findings demonstrate the importance of coordinating policies on childhood obesity and family planning/fertility.

There are also several caveats in this study due to data limitations. First, some important information on parents and neighborhoods such as parents' diet and physical activity habits, individual maternal employment status, and neighborhood food environment is missing. Second, this study compares singletons to non-singletons, where the age interval between siblings for non-singletons and gender patterns of siblings are ignored. However, a 8-year boy may play with his 10-year old sibling but may not play with his 16-year old sibling, whereas relative to a 12-year old child, a 16-yead old child may have a stronger influence on his/her 10-year old sibling. Siblings of the same gender may be more likely to physically play together than those of different genders. Thus, the singleton effect may be under- or over-estimated depending on the age interval and gender patterns between siblings among non-singletons. Third, although we made some inferences on food consumption based on the findings and controlled for state-level food environments, the lack of direct analyses on the mechanisms through which food consumption and singleton status may affect childhood obesity merits future research using different data sets with richer food consumption and family structure information. We suggest more data concerning children's health and family/sibling structure are crucial to understand the role of decreasing fertility played in childhood obesity epidemic are needed.

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Table 1. Weight outcomes and physical/sedentary activity by gender and singleton status for the full sample and different age cohorts

Sample	Full Sample (10-17)		Younger Cohorts (10-13)				Older Cohorts (14-17)			
BMI	52,655		12,167		11,729		14,796		13,963	
Others outcomes	80,051		18,770		17,929		22,552		20,800	
			Male		Female		Male		Female	
Singleton Status	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
BMI	21.361	22.152	20.596	21.490	20.347	21.090	22.654	22.918	22.136	22.293
	(0.055)	(0.055)	(0.106)	(0.131)	(0.114)	(0.129)	(0.107)	(0.090)	(0.108)	(0.103)
Equal mean test	0.790 [0.637]		0.894*** [0.000]		0.743*** [0.000]		0.264* [0.059]		0.157 [0.292]	
Obese	0.152	0.164	0.205	0.263	0.150	0.198	0.148	0.164	0.096	0.091
	(0.003)	(0.004)	(0.007)	(0.011)	(0.007)	(0.012)	(0.007)	(0.007)	(0.006)	(0.005)
Equal mean test:	0.012** [0.028]		0.057*** [0.000]		0.048*** [0.000]		0.013 [0.177]		-0.005 [0.516]	
Vigorous_5	0.506	0.474	0.603	0.572	0.490	0.445	0.529	0.515	0.387	0.386
	(0.004)	(0.005)	(0.008)	(0.012)	(0.008)	(0.013)	(0.009)	(0.009)	(0.009)	(0.009)
Equal mean test	-0.032*** [0.000]		-0.032** [0.028]		-0.034** [0.027]		-0.014 [0.291]		-0.002 [0.904]	
Sports	0.611	0.582	0.667	0.632	0.621	0.571	0.613	0.593	0.531	0.547
	(0.004)	(0.005)	(0.008)	(0.013)	(0.008)	(0.013)	(0.009)	(0.009)	(0.010)	(0.009)
Equal mean test	-0.029*** [0.000]		-0.036** [0.017]		-0.051*** [0.000]		-0.020 [0.124]		0.016 [0.234]	
Screen_hours	0.184	0.197	1.867	2.057	1.683	1.821	2.087	2.199	1.734	1.752
	(0.017)	(0.018)	(0.031)	(0.042)	(0.029)	(0.043)	(0.041)	(0.036)	(0.034)	(0.028)
Equal mean test	0.013** [0.000]		0.188** [0.000]		0.139*** [0.008]		0.113** [0.038]		0.014 [0.743]	
Screen_2	0.464	0.521	0.487	0.561	0.426	0.495	0.508	0.567	0.436	0.466
	(0.004)	(0.005)	(0.082)	(0.012)	(0.008)	(0.013)	(0.009)	(0.009)	(0.010)	(0.010)
Equal mean test	0.058*** [0.000]		0.074*** [0.000]		0.070*** [0.000]		0.059*** [0.000]		0.030** [0.026]	

Notes: Numbers in parentheses are standard errors and those in brackets are p-values for the equal means tests for weight outcomes and physical/sedentary activity between singletons and non-singletons. Asterisks, ***, ** and *, indicate 1, 5, and 10 percent statistical significance, respectively.

Table 2. Singleton effect on weight outcomes

	All Age Cohorts (10-17)				Younger Cohorts (10-13)				Older Cohorts (14-17)			
	Obese		BMI		Obese		BMI		Obese		BMI	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Full Sample												
Single Child	0.033***	0.025**	0.442***	0.402**	0.057***	0.043**	0.793***	0.631**	0.012	0.005	0.145	0.255**
	(0.008)	(0.010)	(0.117)	(0.156)	(0.009)	(0.021)	(0.198)	(0.271)	(0.010)	(0.006)	(0.136)	(0.125)
# of Obs.	41,322	38,729	26,963	25,692	18,770	17,929	12,167	11,729	22,552	20,800	14,796	13,963
Panel B: High-income vs. Low-income												
Rich	0.025***	0.018**	0.254*	0.317**	0.050***	0.022	0.602***	0.520**	0.004	0.009*	0.006	0.197*
	(0.009)	(0.008)	(0.127)	(0.144)	(0.008)	(0.017)	(0.171)	(0.223)	(0.011)	(0.005)	(0.179)	(0.107)
# of Obs.	23,959	22,351	15,830	14,921	10,460	9,974	6,894	6,555	13,499	8,936	12,377	8,366
Poor	0.042***	0.030**	0.646***	0.540***	0.065***	0.069**	0.982***	0.805**	0.021*	-0.003	0.357**	0.371*
	(0.011)	(0.014)	(0.167)	(0.196)	(0.016)	(0.026)	(0.290)	(0.331)	(0.012)	(0.010)	(0.146)	(0.187)
# of Obs.	17,363	11,133	16,378	10,771	8,310	7,955	5,273	5,174	9,053	8,423	5,860	5,597
Panel C: White vs. Black and Hispanic												
Non-Hispanic White	0.033***	0.020***	0.474***	0.472***	0.079***	0.044***	1.025***	0.739***	0.002	0.003	0.093	0.323**
	(0.008)	(0.006)	(0.126)	(0.095)	(0.012)	(0.014)	(0.269)	(0.100)	(0.011)	(0.006)	(0.198)	(0.126)
# of Obs.	29,862	27,690	19,820	18,711	13,255	12,480	8,843	8,320	16,607	15,210	10,977	10,391
Black and Hispanic	0.044***	0.031	0.473***	0.396	0.049***	0.053	0.331*	0.463	0.037	0.007	0.514***	0.352
	(0.015)	(0.022)	(0.154)	(0.479)	(0.016)	(0.039)	(0.193)	(0.809)	(0.026)	(0.012)	(0.165)	(0.309)
# of Obs.	8,644	8,257	5,467	5,367	4,145	4,064	2,535	2,614	4,499	4,193	2,932	2,753

Notes: Each entry corresponding to the variable, Single Child, represents a separate OLS model estimation in which the dependent variable is either a binary variable indicating whether the respondent is obese or BMI. The independent variables include (a) an indicator for singleton status; (b) children' individual characteristics (gender, age, race/ethnicity and self-reported health condition); (b) family/parental information (poverty measures, an indicator for living in a metropolitan statistical area, mother's self-reported health condition, and a binary variable indicating single-mother families); (c) state-level food environment characteristics (the number of fast food restaurants per 1,000 residents, per capita annual food expenditures on fast food restaurants, and sales tax on soda, chips and pretzels, and retail food in general). Robust standard errors clustered on state are in parentheses. Asterisks, *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Singleton effects on physical and sedentary activity based on the OLS regressions

	Full Sample (10-17)		Younger Cohorts (10-13)		Older Cohorts (14-17)	
	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
Vigorous_5	-0.020**	-0.010	-0.035***	-0.027*	-0.009	0.004
	(0.010)	(0.006)	(0.012)	(0.015)	(0.012)	(0.010)
Sports	-0.028**	-0.031***	-0.032**	-0.052***	-0.018	-0.007
	(0.011)	(0.007)	(0.013)	(0.013)	(0.012)	(0.007)
Screen_hours	0.133***	0.083***	0.155***	0.116***	0.122**	0.077**
	(0.028)	(0.022)	(0.024)	(0.036)	(0.047)	(0.032)
Screen_2	0.064***	0.050***	0.067***	0.064***	0.062***	0.049***
	(0.012)	(0.007)	(0.013)	(0.013)	(0.017)	(0.009)
# of Obs.	41,322	38,729	18,770	17,929	22,522	20,800

Notes: Each entry represents a separate OLS model estimation in which the dependent variable is *Vigorous_5*, *Sports*, *Screen_hours*, and *Screen_2*. The independent variables include (a) an indicator for singleton status; (b) children' individual characteristics (gender, age, race/ethnicity and self-reported health condition); (b) family/parental information (poverty measures, an indicator for living in a metropolitan statistical area, mother's self-reported health condition, and a binary variable indicating single-mother families); (c) state-level food environment characteristics (the number of fast food restaurants per 1,000 residents, per capita annual food expenditures on fast food restaurants, and sales tax on soda, chips and pretzels, and retail food in general). Robust standard errors clustered on state are in parentheses. Asterisks, *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Singleton effect on weight outcomes (2SLS)

	All Age Cohorts (10-17)				Younger Cohorts (10-13)				Older Cohorts (14-17)			
	Obese		BMI		Obese		BMI		Obese		BMI	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Single Child	0.414**	0.187	6.087**	0.460	0.850**	0.271	7.667	1.669	0.270**	0.150	5.978***	1.796
	(0.191)	(0.211)	(2.701)	(2.506)	(0.361)	(0.290)	(6.241)	(4.155)	(0.119)	(0.193)	(1.928)	(2.197)
Kleibergen_Paap F	29.511	26.064	35.231	33.826	25.956	11.611	9.171	10.600	13.035	19.158	30.338	16.383
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen's J	7.977	4.717	5.046	3.852	7.236	7.053	5.222	4.473	3.043	3.976	2.977	2.767
	(0.046)	(0.194)	(0.168)	(0.278)	(0.065)	(0.070)	(0.156)	(0.215)	(0.385)	(0.264)	(0.395)	(0.429)
Observations	41,322	38,729	26,963	25,692	18,770	17,929	12,167	11,729	22,552	20,800	14,796	13,963

Notes: Each entry corresponding to the variable, Single Child, represents a separate 2SLS model estimation in which the dependent variable is either a binary variable indicating whether the respondent is obese or BMI. The independent variables include (a) an indicator for singleton status; (b) children' individual characteristics (gender, age, race/ethnicity and self-reported health condition); (b) family/parental information (poverty measures, an indicator for living in a metropolitan statistical area, mother's self-reported health condition, and a binary variable indicating single-mother families); (c) state-level food environment characteristics (the number of fast food restaurants per 1,000 residents, per capita annual food expenditures on fast food restaurants, and sales tax on soda, chips and pretzels, and retail food in general). Robust standard errors clustered on state are in parentheses. Asterisks, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.