

ORIGINAL ARTICLE

The global economic crisis, household income and pre-adolescent overweight and underweight: a nationwide birth cohort study in Japan

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BACKGROUND: We hypothesized that children from lower income households and in households experiencing a negative income change in connection to the global economic crisis in 2008 would be at increased risk of adverse weight status during the subsequent years of economic downturn.

METHODS: Data were obtained from a nationwide longitudinal survey comprising all children born during 2 weeks of 2001. For 16,403 boys and 15,206 girls, information about anthropometric measurements and household characteristics was collected from 2001 to 2011 on multiple occasions. Interactions between the crisis onset (September 2008) and household income group, as well as the crisis onset and a >30% negative income change in connection to the crisis, were assessed with respect to risk of childhood over- and underweight.

RESULTS: Adjusted for household and parental characteristics, boys and girls in the lower household income quartiles had a larger increase in risk of overweight after the crisis onset relative to their peers in the highest income group. (Odds ratio (95% confidence interval) for interaction term in boys = 1.23 (1.02–1.24); girls = 1.35 (1.23–1.49) comparing the lowest with the highest income group.) Among girls, an interaction between the crisis onset and a >30% negative change in household income with respect to risk of overweight was observed (odds ratio for interaction term = 1.23 (1.09–1.38)). Girls from the highest income group had an increased risk of underweight after the crisis onset compared with girls from the lowest income group.

CONCLUSIONS: Boys and girls from lower household income groups and girls from households experiencing a negative income change in connection to the global economic crisis in 2008, may be at increased risk of overweight. Vulnerability to economic uncertainty could increase risk of overweight in preadolescence.

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INTRODUCTION

Childhood overweight is a serious public health challenge globally.^{1,2} Although Japan has lower rates compared with many other high-income countries, the problem is increasing. In 2007, ~10% of the 6–11-year old children were overweight; a prevalence twice as large as that recorded in 1978.³

Socioeconomic disadvantage has in numerous studies been linked to childhood overweight, although the association differs depending on study setting, sex and ethnicity.^{4–6} Exposure to negative life events and psychosocial stressors in childhood—including parental stress and financial problems—may also increase risk of childhood overweight and obesity.^{7–10}

During the past 20 years of economic recession in Japan, growing socioeconomic disparities have been observed.¹¹ Concern for further erosion of social security arose in the fall of 2008 as Japan was one of the countries hardest hit by the global economic crisis. Gross domestic product dropped by 6.3% in 2009 and unemployment rates increased from around 4% in the first half of 2008 to 5.5% in July 2009.¹² The crisis disproportionately affected the low-income groups and workers with precarious employment; income inequality and poverty rates rose considerably,¹³ and social welfare programs have been unable to provide adequate support to those in need.¹⁴

In other high-income countries, the economic downturn has been linked to deteriorated health and increased psychosocial problems among children, in particular those from lower socioeconomic groups.¹⁵

Against this background, it is of relevance to assess the potential effects of the recent economic downturn on weight status among children in Japan. We examined the relation between household income and trajectories in weight statuses throughout the period of the economic crisis, using data from a nationwide longitudinal birth cohort study. Children in this cohort were born in 2001, and were thus exposed to the economic downturn at a possibly sensitive age for the development of overweight.^{3,16} In addition, we evaluated trajectories of underweight prevalence as underweight may be associated with socioeconomic factors^{17,18} and constitutes a health issue among girls in Japan¹⁵ and other Asian countries.¹⁹

MATERIALS AND METHODS

This study was based on data from the Longitudinal Survey of Newborns in the 21st Century, conducted by the Ministry of Health, Labour and Welfare in Japan between the years 2001 and 2011. All babies born in Japan between January 10 and 17, and July 10 and 17 in 2001 were identified using the birth record list of vital statistics for Japan ($n=53,575$).

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Questionnaires were sent to parents with mail when the children were 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 7, 8, 9 and 10 years old. Parents returning the questionnaires to the Ministry of Health, Labour and Welfare were regarded as approving participation in the study. In total, 47,015 questionnaires were returned at 6 months, corresponding to an 88% response rate. A total of 10,753 children were excluded as parents did not report weight and height on at least one occasion before the crisis onset and after the crisis onset, respectively, and 4,653 children were then excluded as income for at least 1 year before and after the crisis onset were not recorded. This gave us a sample of 31,609 children (67% of the responding subjects), of which 16,403 were boys and 15,206 were girls. The study was exempt from approval by the Institutional Review Board as it was conducted by the Ministry of Health, Labour and Welfare and the data were stripped of all information enabling identification of individuals.

Parents were asked to report weight (to the nearest 0.1 kg) and height (to the nearest 0.1 cm) of the child as well as date of measurement. Body mass index (BMI) was determined according to the formula: weight (kg)/height² (m). Overweight and underweight were defined using age (by month) and sex-specific cut points from the International Obesity Task force starting from 2 years of age. The cut points correspond to a BMI of >25 (overweight) and <18.5 (underweight) at 18 years of age.

Other variables

Parents reported household income (father's income, mother's income and other incomes) for the years 2001, 2002, 2004, 2005, 2006, 2007 and 2010. The average household income for the years before the downturn in 2008 was compared with the household income in 2010 (after the crisis onset). Variables were generated for income reductions of >30, >20 and >10%.

Number of household members was recorded in questionnaires from the years 2002, 2005 and 2006. Household income was divided by the square root of the number of household members²⁰ for these years and income quartiles before the onset of the economic crisis were determined based on the average of the obtained values.

Father's and mother's education were reported at the 1.5 years follow-up and categorized into junior high school, high school, vocational school and higher education. Parents' age at birth of the child was categorized into <20, 20–24, 25–29 and >29 years. Residential area in 2011 (last follow-up) was grouped into the 20 designated cities as specified by the Japanese government, other cities and rural areas. Children were categorized as belonging to a three generation household—a potential risk factor for childhood overweight in Japan²¹—if at least one grandparent was living in the household in 2011.

Statistical analysis

Data were analyzed in STATA SE statistical package, version 12.1 (Stata Corporation., College Station, TX, USA). As previous studies have found differences between the sexes in associations between socioeconomic and psychosocial factors and risk of overweight^{10,22} as well as risk patterns for underweight,^{23,24} we performed separate analyses for boys and girls.

In our primary analyses, we assessed the changes in weight status in children before and after the onset of the economic downturn with respect to income quartile, and a >30% income reduction in connection to the crisis. We calculated odds ratios (ORs) for overweight and underweight, respectively, using a generalized estimating equation model,²⁵ with an exchangeable correlation structure. Data were based on 1-month intervals starting from January 2003 when the first batch of children included in the survey reached 2 years of age. To explore the potential point of changes in trajectories of the risks for developing over-/underweights, we carried out a series of analysis. The first model (model 1) included an age variable and a term for the crisis onset to assess the potential change in risk of the outcomes across the whole population during the study period and after the onset of economic downturn. Interaction terms for the step term (a dummy variable representing a potential time point of weight trajectory changes) and income quartile, and the step term and income reduction were also included to assess if changes in risk differed between the income groups and between the groups experiencing >30% income reduction and those that did not. To assess model fit for different step terms, Bayesian information criterion was compared between models with alternative step terms by 3-month intervals from June 2008 to December 2009. Our preliminary analysis showed that Bayesian information criterion was lowest for the model with the step term for September 2008 (data not shown) Thus, September 2008 was used for the step term in all analyses. In the next step (model 2), analyses were further adjusted for potential

confounding factors including parents' education and age, household composition (two parent household, single parent household, three generation household) and residential area.

Dummy variables were created for missing data on covariates and included in the analyses. We also performed analyses on income reductions between other years (2001–2004 vs 2005 and 2001–2005 vs 2007); using alternative income reduction cut offs, namely, of >20 and >10%; and excluding subjects with missing data on covariates.

RESULTS

The average annual household income of the years before the crisis onset by income quartiles were (in Japanese yen (JPY)): 2,727,000 (s.d.=1,440,000), 4,384,000 (869,000), 5,709,000 (1,799,000) and 9,075,000 (5,180,000). In total, 3013 (9.5%) of the households experienced a reduction in household income of 30% or more after the crisis onset. The average annual income for these households was 6,348,000 (s.d.=6,134,000) Japanese yen before the onset of the economic downturn and 2,631,000 (2,718,000) Japanese yen in 2010 (Table 1). Overall, prevalence of overweight in boys increased from the age of 4 years (Supplementary Information 1), and in girls the general trend was an increase in

Table 1. Population characteristics: Japanese newborns in 2001 in the Longitudinal Survey of Babies in 21st Century, followed up until 2011

	Boys	Girls
<i>N</i> (%)	16,403 (51.9)	15,206 (48.1)
<i>Income quartile, n (%)</i>		
1 (lowest)	4120 (25.1)	3783 (24.9)
2	4085 (24.9)	3817 (25.1)
3	4119 (25.1)	3783 (24.9)
4 (highest)	4079 (24.9)	3823 (25.1)
>30% negative income change during economic crisis, <i>n (%)</i>	1531 (9.3)	1482 (9.8)
>20% negative income change during economic crisis, <i>n (%)</i>	2136 (13.0)	2096 (13.8)
>10% negative income change during economic crisis, <i>n (%)</i>	3225 (19.7)	3083 (20.3)
<i>Residential area, n (%)</i>		
20 designated cities	4209 (25.7)	3868 (25.4)
Other cities	10,640 (64.9)	9908 (65.2)
Rural	1505 (9.2)	1377 (9.1)
Missing	49 (0.3)	53 (0.4)
Mother's age (SD)	30.3 (4.3)	30.3 (4.3)
Father's age (SD)	32.5 (5.4)	32.4 (5.3)
Missing, <i>n (%)</i>	299 (1.2)	313 (1.4)
<i>Father's education, n (%)</i>		
Junior high school	860 (5.2)	789 (5.2)
High school	6220 (37.9)	5816 (38.3)
Vocational school	2579 (15.7)	2333 (15.3)
Higher education	6332 (38.6)	5896 (38.8)
Missing	412 (2.5)	372 (2.5)
<i>Mother's education, n (%)</i>		
Junior high school	418 (2.6)	392 (2.6)
High school	6108 (37.2)	5771 (38)
Vocational school	7120 (43.4)	6420 (42.2)
Higher education	2467 (15)	2373 (15.6)
Missing	290 (1.8)	250 (1.6)
<i>Single parent household, n (%)</i>	266 (1.6)	246 (1.6)
Missing, <i>n (%)</i>	5 (0)	5 (0)
Three generation household, <i>n (%)</i>	3781 (23.1)	3388 (22.3)

prevalence that plateaued at age 9 years (Supplementary Information 2); a pattern previously observed in Japanese children.^{26–28} Boys and girls in the two lower household income quartiles had consistently higher prevalence of overweight across the years of observation. (Figure 1) Trajectories of overweight prevalence for boys and girls from households with and without a >30% reduction in household income during the economic downturn are shown in Figure 2.

Overweight

Among boys, risk of overweight increased with age, and there was a significant increase in overweight risk after September 2008 (onset of economic downturn) in both models. However, there was no statistical evidence for differences in the trajectories of overweight risk after the onset of the crisis between households experiencing a >30% negative income change during the crisis and those that did not: OR=1.05 (95% confidence intervals =0.93–1.17) for the cross term between >30% negative income change and September 2008 (model 2). On the other hand, boys in the two lower income quartiles had a faster increase in overweight risk after September 2008 compared with their counterparts from the highest income quartile (OR for lowest quartile=1.12 (1.02–1.24); OR for second lowest quartile =1.15 (1.04–1.26) in model 2). (Table 2)

Girls from households experiencing a >30% income reduction after the crisis onset, had a higher risk of overweight after September 2008 compared with their peers from households with no such income change (OR=1.23 (1.09–1.38)). Girls in the lower income quartiles had a faster increase in overweight risk after the onset of the economic downturn compared with girls from the highest quartile with the association being more pronounced in

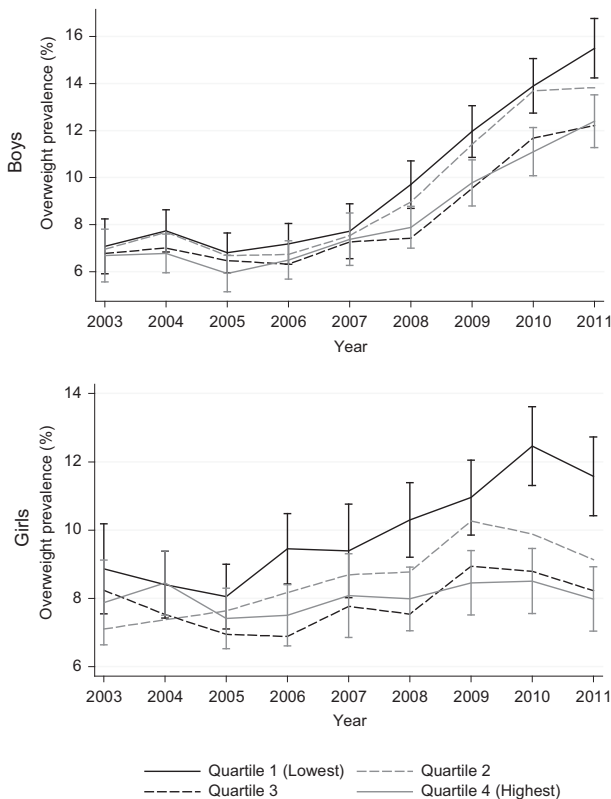


Figure 1. Overweight prevalence with 95% confidence intervals in boys and girls by year and household income quartile.

the lowest two quartiles (OR for the lowest income quartile = 1.35 (1.23–1.49), OR for the second lowest quartile = 1.25 (1.13–1.38)).

Results did not differ materially in both boys and girls when using >20% income reduction and >10% income reduction cut offs; the OR (95% CI) for the cross term between September 2008 and income reduction was 1.03 (0.93–1.14) for >20% and 1.06 (0.98–1.16) for >10% in boys. The corresponding numbers for girls were 1.14 (1.03–1.27) for >20%, and 1.11 (1.02–1.21) for >10% (Supplementary Information 3). Results were not considerably different when excluding subjects with missing information on covariates (data not shown). Further analyses using alternative time points for calculating income reductions showed that our original analyses (comparing the average household income during 2001–2007 with 2010) showed the most robust results across the models using the different income reduction cut offs of >30, >20 and >10% (Supplementary Information 3).

Underweight

Among boys, prevalence of underweight decreased with age in both models. Models showed higher risk of underweight (adjusted for the decreasing risk by age) after September 2008. No clear evidence of interactions was seen between the crisis onset and income group or between the crisis onset and negative income change during the economic crisis (Table 2).

Among girls, risk of underweight decreased with age and was higher after September 2008 in both models. Girls in the highest income quartile had faster increase in underweight risk after the onset of the economic downturn compared with girls from the lowest quartile (OR for the lowest quartile compared with the highest 0.90 (0.83–0.98); Table 3).

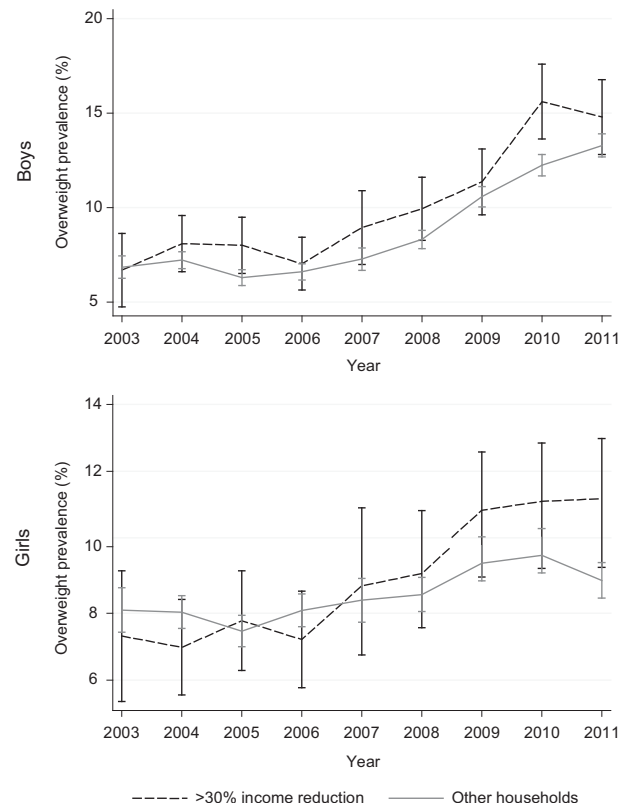


Figure 2. Overweight prevalence by year in boys and girls from households experiencing a >30% income reduction in connection to the global economic crisis and in children from households with no such income reduction.

Table 2. Odds ratio (OR) and 95% confidence interval (CI) for risk of overweight and underweight relative to normal weight in boys

	Overweight		Underweight	
	Model 1	Model 2	Model 1	Model 2
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Observations	99,504	99,504	99,504	99,504
Age (years)	1.02 (1.01–1.04)	1.02 (1.01–1.04)	0.86 (0.85–0.87)	0.86 (0.85–0.87)
<i>Household income quartile before 2008</i>				
1 (lowest)	1.15 (1.02–1.30)	0.92 (0.80–1.05)	1.10 (1.01–1.20)	1.11 (1.01–1.21)
2	1.07 (0.95–1.21)	0.95 (0.83–1.08)	1.09 (1.00–1.18)	1.09 (1.00–1.19)
3	1.00 (0.89–1.14)	0.95 (0.84–1.08)	1.02 (0.94–1.11)	1.02 (0.94–1.12)
4 (highest)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
<i>> 30% negative income change during economic crisis</i>				
No	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Yes	1.14 (0.99–1.31)	1.08 (0.93–1.24)	1.06 (0.96–1.17)	1.05 (0.95–1.16)
<i>Step term</i>				
Before September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
After September 2008	1.52 (1.39–1.66)	1.52 (1.39–1.67)	1.51 (1.40–1.63)	1.51 (1.40–1.63)
<i>Interaction between income change and step term</i>				
≤ 30% negative income change after September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
> 30% negative income change after September 2008	1.04 (0.93–1.17)	1.05 (0.93–1.17)	0.96 (0.87–1.06)	0.96 (0.87–1.06)
<i>Interaction between income quartile and step term</i>				
Income quartile 1 after September 2008	1.12 (1.02–1.23)	1.12 (1.02–1.24)	1.04 (0.96–1.13)	1.04 (0.96–1.13)
Income quartile 2 after September 2008	1.14 (1.04–1.26)	1.15 (1.04–1.26)	0.98 (0.91–1.07)	0.98 (0.91–1.07)
Income quartile 3 after September 2008	0.99 (0.90–1.09)	0.99 (0.90–1.09)	1.07 (0.99–1.16)	1.07 (0.99–1.16)
Income quartile 4 after September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
<i>Father's education</i>				
Junior high school		1.00 (ref)		1.00 (ref)
High school		0.92 (0.79–1.08)		1.04 (0.91–1.19)
Vocational school		0.87 (0.73–1.04)		1.01 (0.87–1.17)
Higher education		0.73 (0.62–0.87)		1.03 (0.90–1.19)
Missing		0.89 (0.62–1.30)		0.97 (0.71–1.33)
<i>Mother's education</i>				
Junior high school		1.00 (ref)		1.00 (ref)
High school		0.72 (0.58–0.88)		0.97 (0.81–1.17)
Vocational school		0.66 (0.54–0.82)		0.95 (0.79–1.15)
Higher education		0.62 (0.50–0.79)		0.94 (0.77–1.15)
Missing		0.80 (0.52–1.25)		1.31 (0.90–1.9)
<i>Single parent household</i>				
No		1.00 (ref)		1.00 (ref)
Yes		1.18 (0.88–1.59)		0.89 (0.68–1.16)
Missing		2.15 (0.45–10.23)		0.40 (0.04–3.72)
<i>Three generation household</i>				
No		1.00 (ref)		1.00 (ref)
Yes		1.39 (1.28–1.51)		0.95 (0.88–1.01)
<i>Residential area</i>				
20 designated cities		1.00 (ref)		1.00 (ref)
Other cities		1.07 (0.98–1.17)		0.93 (0.87–1.00)
Rural		1.11 (0.97–1.27)		0.98 (0.88–1.09)
Missing		1.73 (0.96–3.14)		0.96 (0.57–1.63)
<i>Father's age</i>				
< 20 years		1.00 (ref)		1.00 (ref)
21–25 years		2.10 (0.91–4.85)		0.77 (0.43–1.35)
26–30 years		1.77 (0.76–4.11)		0.79 (0.44–1.39)
> 30 years		2.10 (0.91–4.88)		0.79 (0.45–1.40)
Missing		2.32 (0.93–5.81)		0.98 (0.51–1.89)
<i>Mother's age</i>				
< 20 years		1.00 (ref)		1.00 (ref)
21–25 years		1.08 (0.68–1.73)		1.35 (0.89–2.05)
26–30 years		1.07 (0.67–1.72)		1.24 (0.81–1.89)
> 30 years		1.14 (0.71–1.83)		1.22 (0.80–1.86)

A generalized estimating equation model,²⁵ with an exchangeable correlation structure was used for the analysis.

Results did not differ materially in both boys and girls when using > 20% income reduction and > 10% income reduction cut offs or when excluding subjects with missing information on covariates (data not shown).

DISCUSSION

In this nationwide cohort study from Japan, we found that boys and girls from lower income households were at a higher risk of being overweight after the onset of the 2008 economic downturn

Table 3. Odds ratio (OR) and 95% confidence interval (CI) for risk of overweight and underweight relative to normal weight in girls

	Overweight		Underweight	
	Model 1	Model 2	Model 1	Model 2
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Observations	92,267	92,267	92,267	92,267
Age (years)	0.99 (0.97–1.00)	0.99 (0.97–1.00)	0.94 (0.93–0.95)	0.94 (0.93–0.95)
<i>Household income quartile before 2008</i>				
1 (lowest)	1.14 (1.01–1.29)	0.90 (0.79–1.03)	1.08 (0.99–1.18)	1.09 (0.99–1.21)
2	1.00 (0.88–1.13)	0.86 (0.76–0.98)	1.10 (1.01–1.20)	1.10 (1.00–1.22)
3	0.91 (0.81–1.04)	0.85 (0.74–0.96)	1.05 (0.96–1.15)	1.05 (0.95–1.15)
4 (highest)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
<i>> 30% negative income change during economic crisis</i>				
No	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Yes	0.98 (0.84–1.13)	0.92 (0.80–1.07)	0.96 (0.86–1.07)	0.96 (0.86–1.07)
<i>Step term</i>				
Before September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
After September 2008	1.06 (0.97–1.17)	1.06 (0.97–1.17)	1.50 (1.39–1.61)	1.50 (1.39–1.61)
<i>Interaction between income change and step term</i>				
≤ 30% negative income change after September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
> 30% negative income change after September 2008	1.22 (1.08–1.37)	1.23 (1.09–1.38)	1.00 (0.91–1.11)	1.00 (0.91–1.11)
<i>Interaction between income quartile and step term</i>				
Income quartile 1 after September 2008	1.35 (1.22–1.49)	1.35 (1.23–1.49)	0.90 (0.83–0.98)	0.90 (0.83–0.98)
Income quartile 2 after September 2008	1.25 (1.13–1.38)	1.25 (1.13–1.38)	0.94 (0.87–1.02)	0.94 (0.87–1.02)
Income quartile 3 after September 2008	1.18 (1.07–1.31)	1.18 (1.07–1.31)	0.99 (0.92–1.08)	0.99 (0.92–1.08)
Income quartile 4 after September 2008	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
<i>Father's education</i>				
Junior high school		1.00 (ref)		1.00 (ref)
High school		0.93 (0.78–1.10)		1.04 (0.90–1.20)
Vocational school		0.90 (0.74–1.09)		1.11 (0.95–1.30)
Higher education		0.79 (0.65–0.95)		1.05 (0.90–1.22)
Missing		0.98 (0.64–1.50)		0.92 (0.65–1.31)
<i>Mother's education</i>				
Junior high school		1.00 (ref)		1.00 (ref)
High school		0.63 (0.51–0.78)		0.88 (0.73–1.07)
Vocational school		0.51 (0.41–0.64)		0.89 (0.73–1.08)
Higher education		0.47 (0.36–0.60)		0.86 (0.70–1.07)
Missing		0.58 (0.35–0.96)		1.22 (0.80–1.84)
<i>Single parent household</i>				
No		1.00 (ref)		1.00 (ref)
Yes		1.06 (0.75–1.50)		0.97 (0.73–1.29)
Missing		1.38 (0.13–14.13)		5.17 (1.53–17.49)
<i>Three generation household</i>				
No		1.00 (ref)		1.00 (ref)
Yes		1.27 (1.15–1.39)		0.95 (0.88–1.02)
<i>Residential area</i>				
20 designated cities		1.00 (ref)		1.00 (ref)
Other cities		1.17 (1.06–1.29)		0.92 (0.86–0.99)
Rural		1.41 (1.21–1.63)		0.86 (0.76–0.97)
Missing		0.77 (0.32–1.85)		0.79 (0.46–1.34)
<i>Father's age</i>				
< 20 years		1.00 (ref)		1.00 (ref)
21–25 years		0.85 (0.39–1.85)		0.55 (0.30–1.00)
26–30 years		0.94 (0.43–2.08)		0.62 (0.34–1.13)
> 30 years		1.11 (0.50–2.46)		0.63 (0.34–1.14)
Missing		0.80 (0.32–1.98)		0.59 (0.29–1.18)
<i>Mother's age</i>				
< 20 years		1.00 (ref)		1.00 (ref)
21–25 years		1.22 (0.69–2.18)		1.53 (0.93–2.52)
26–30 years		1.14 (0.63–2.04)		1.35 (0.81–2.23)
> 30 years		1.24 (0.69–2.23)		1.32 (0.80–2.19)

A generalized estimating equation model,²⁵ with an exchangeable correlation structure was used for the analysis.

compared with their peers from higher-income households. Moreover, girls from households experiencing an income reduction in connection to the economic downturn had a higher risk of overweight after the crisis onset than did girls in households without such income reductions. These associations were not seen for underweight.

Although a large number of studies have investigated the relationship between socioeconomic level and childhood overweight and obesity, only a handful have used longitudinal data to assess child BMI in relation to trajectories of socioeconomic status or distress. In a cohort from the United States, children who belonged to low-income groups throughout

childhood were more likely to maintain their overweight status and children who became low income during childhood were at higher risk of obesity between 2 and 15 years of age compared with their peers who never were of low-income status.⁷ Another US-based study showed that children experiencing downward mobility in household income and stable low income had greater BMI percentile at 15 years of age relative to children in households with more favorable income trajectories.²⁹ However, a third US report showed that children from households going in and out of poverty had lower risk of becoming overweight between ages 4 and 14 years, compared with children from never poor households.³⁰

The observational nature of this study precludes conclusions regarding causality. Although the observed increase in overweight risk after the crisis for girls in household experiencing a negative income change implies that social and economic hardships may alter the BMI trajectory of the child, changes in household income may not be regarded as happening at random. Moreover, the divergence in BMI trajectories between the income groups may have occurred in preadolescence regardless of the economic crisis.

If causal, the observed associations could be explained by a number of potential mechanisms. Studies from other high-income countries show that negative life events that may be associated with the economic downturn—including maternal stress, family health problems, financial strain and unstable parental employment—are associated with childhood overweight.^{8,9,31} Negative life events in the family may result in a higher food intake, in particular comfort foods,^{32,33} which function to alleviate stress at a neurobiological level.³⁴ Moreover, cuts in the family budget may lead to decreased consumption of fruits and vegetables³⁵ and increased consumption of fast food.³⁶ In Japan, longer maternal working hours, in particular among contract workers, have been correlated to increased risk of overweight.³⁷ These pathways are supported by studies from other countries in which the economic crisis has been linked to worsening nutrition habits and increased mental health problems in children, particularly among those from disadvantaged families.¹⁵ Low-income families may be more vulnerable to the stressors induced by the crisis as they do not have adequate resources to cope with them.

We only found significant associations between income reduction and increased risk of overweight after the crisis onset among girls. The relationship between socioeconomic disadvantage,^{4,5} negative life events,^{10,22} psychosocial stresses^{38,39} and overweight risk may be more pronounced among girls. Eating response to stress is reported more frequently among women.^{40,41}

Girls in the highest income groups had a higher risk of underweight after the crisis onset. In Japan underweight prevalence seems to be underpinned by body shape ideals favoring thinness among girls^{24,42} and it could be speculated that girls from higher-income households may be aware of body ideals compared with girls from lower income households as they reach preadolescence, and that the diversion of their BMI trajectories coincided with the onset of the economic crisis.

Strengths of this study include repeated measures of weight and height data from a nationwide sample of Japanese children and information about a number of important covariates in the assessment of the relation between the economic downturn and childhood overweight. Our study has limitations, however. Data on household income, and weight and height of the children were based on parents' report. However, a study from Japan found fairly precise parental reports of children's weight status. The sensitivity and specificity for obesity was 83.3–93.3% and 96.3–98.9%, respectively.⁴³ Accurate reports of children's anthropometric data may also have been facilitated in our study as parents could specify any date of measurement. Furthermore, one-third of the households responding to the initial questionnaire could not be included as required BMI or household income data were not available. Subjects with missing data did not differ from included

subjects with respect to sex ($P=0.718$), but had lower annual household income before 2008 (4,716,000 (s.d.=4,290,000) vs 5,842,000 (3,307,000) JPY, $P<0.001$), younger mothers (29.0 vs 30.3 years at birth, $P<0.001$), and were more likely to reside in rural areas in 2001 (20.0% vs 18.8%, $P=0.001$) and to have single parents (3.6% vs 1.6%, $P<0.001$), that is, they were possibly of lower socioeconomic status. There is no apparent reason however, to suspect that subjects with missing data would differ systematically with respect to the relation between the exposures and the outcomes, and thereby cause spurious associations. If anything, the households most severely affected by hardships during the crisis may have been more likely to drop out from the study and also having children gaining more weight. In such a case, a conservative bias may prevail. In addition, all children were born in the same year and followed for ten years, with which we were not able to adjust for the potential variations in the effects across ages. Future studies should test our hypothesis with the data composed of children born in various years.

CONCLUSIONS

Boys and girls from lower income households and girls from households experiencing an income reduction during the global economic crisis starting in 2008, were at increased risk of overweight, but not underweight after the crisis onset. These findings provide yet another argument for policy measures aiming to support households going through financial and social hardships, in particular in the context of the increasing social disparities in Japan.

DISCLAIMER

The study sponsors had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

NK, PU and TF conceived the study. PU and KN conducted the statistical analysis. PU, NK and TF wrote the manuscript. KN is the guarantor.

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