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Burden of Disease in Japan: Using National and Subnational Data to Inform Local Health Policy

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The Global Burden of Disease (GBD) study has been instrumental in guiding global health policy development since the early 1990s. The GBD 2010 project provided rich information about the key causes of mortality, disability-adjusted life years, and their associated risk factors in Japan and provided a unique opportunity to incorporate these data into health planning. As part of the latest update of this project, GBD 2013, the Japanese GBD collaborators plan to update and refine the available burden of disease data by incorporating sub-national estimates of the burden of disease at the prefectural level. These estimates will provide health planners and policy makers at both the national and prefectural level with new, more refined tools to adapt local public health initiatives to meet the health needs of local populations. Moreover, they will enable the Japanese health system to better respond to the unique challenges in their rapidly aging population and as a complex combination of non-communicable disease risk factors begin to dominate the policy agenda. Regional collaborations will enable nations to learn from the experiences of other nations that may be at different stages of the epidemiological transition and have different exposure profiles and associated health effects. Such analyses and improvements in the data collection systems will further improve the health of the Japanese, maintain Japan's excellent record of health equity, and provide a better understanding of the direction of health policy in the region.

Key words: Burden of disease, Japan, Comparative risk factor analysis, Health policy, Non-communicable disease, Aging

INTRODUCTION

The Global Burden of Disease (GBD) is a an essential tool in the global battle to improve health [1]. This project provides a systematic approach to calculating comprehensive, consistent, and comparable measures of health loss due to diseases, injuries, and their associated risk factors [2]. The latest GBD study, known as GBD 2010, was conducted by the Institute for Health Metrics and Evaluation (IHME) in collaboration with six academic partners worldwide including the University of Tokyo and was published in December 2012 [3,4]. In this study, the GBD research team introduced new analytical methods and a wider range of data. They also called on experts around the world to inform estimation methods with local advice and insights. Through these new approaches, the project's scope has expanded to cover 291 diseases and injuries in 187 countries from 21 regions, with estimations of these trends since 1990 [5]. The GBD 2010 also expanded on previous comparative risk factor analyses to cover a total of 67 risk factors [6].

The current iteration of the GBD, with its heavy focus on comparable and consistent disease burden and risk factor analyses between regions, makes it a useful tool not only for comparative health system assessment but also for planning

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public health programs and preventive interventions [7] and identifying gaps in international data systems [8]. For example, the GBD 2010 was able to describe trends in morbidity and mortality associated with the epidemiological transition in China [9]. The GBD studies can also be used, to some extent, for comparative health system assessments that allow for consistent and rigorous comparisons of health outcomes between countries with diverse social and health systems. For example, comparisons between the UK and the European Union clearly elucidated areas that were underperforming in the UK health system compared to its European counterparts [10]. Individual countries have also used the results of these comparisons to inform policy debate on issues specific to their own health needs. For example, Khang used the GBD 2010 results and project's detailed metrics to publish a review of non-communicable diseases (NCD) and strategies for NCD management in Korea [11].

Since the release of the GBD 2010 results, the GBD project has been aiming to not only include country experts but also create more detailed burden estimates using data that are only accessible to local researchers as well as at a sub-national level, where possible [12]. Sub-national estimates of disease burden and comparative risk would enable researchers and policy makers to explore variation and inequality within countries to better inform domestic and international health policy planning. As part of this effort to create detailed national estimates, the Department of Global Health Policy at the University of Tokyo has commenced a three-year project to update the GBD 2012 results at the national and sub-national level for Japan. This article describes the burden of disease, achievements in administering health care, future challenges, possible methods for estimating sub-national disease burden using the Japanese national burden of disease project, and the potential value of sub-national estimates of disease burden for policy makers in Japan.

THE BURDEN OF DISEASE IN JAPAN

Japan's achievements in health care administration have become a model for achieving good health at low cost. Japanese female life expectancy at birth has ranked number one globally since the 1980s. Life expectancy increased by 5.5% over 20 years, from 81.9 years in 1990 to 86.4 years in 2010 for females and from 75.9 years in 1990 to 79.6 years in 2010 among males [13]. After rapid improvements in life expectancy due to post-war advances in child health and vaccinations, this recent 20-year improvement has primarily resulted from the effective control of risk factors for NCD mortality [13,14]. For example, reductions in stroke-related mortality have occurred against a backdrop of low inequality and universal health coverage [15].

Table 1 shows the highest-ranked causes of disability-adjusted life years (DALYs) in Japan in 1990 and 2010 based on the GBD 2010 results [16]. In 2010, the highest-ranked causes of DALYs in Japan were lower back pain, cerebrovascular disease, and ischemic heart disease. These causes of DALYs are associated with increasing age and have been the highest-ranked causes of DALYs since 1990. Of the 25 most important causes of DALYs, road injury showed the largest decrease, falling by 42% from 1990 to 2010; however, self-harm remains one of the most important causes of DALYs.

Table 1. Top ten causes contributing to disability-adjusted life years in Japan in 1990 and 2010

Rank	1990	2010
1	Cerebrovascular disease	Low back pain
2	Low back pain	Cerebrovascular disease
3	Ischemic heart disease	Ischemic heart disease
4	Stomach cancer	Lower respiratory infections
5	Lower respiratory infections	Other musculoskeletal
6	Road injury	Lung cancer
7	Self-harm	Self-harm
8	Other musculoskeletal	Stomach cancer
9	Neck pain	Neck pain
10	Lung cancer	Falls

From Institute for Health Metrics and Evaluation. Global Burden of Disease country profile: Japan. Seattle: Institute for Health Metrics and Evaluation; 2012 [16].

Table 2. Top ten risk factors contributing to disability-adjusted life years in Japan in 1990 and 2010

Rank	1990	2010
1	Dietary risks	Dietary risks
2	High blood pressure	High blood pressure
3	Smoking	Smoking
4	Alcohol use	Physical inactivity
5	High fasting plasma glucose	High body mass index
6	Ambient PM pollution	High fasting plasma glucose
7	High body mass index	Alcohol use
8	Occupational risks	Ambient PM pollution
9	High total cholesterol	High total cholesterol
10	Drug use	Occupational risks

From Institute for Health Metrics and Evaluation. Global Burden of Disease country profile: Japan. Seattle: Institute for Health Metrics and Evaluation; 2012 [16].
PM, particulate matter.

Table 2 shows the contribution of the 10 most important risk factors to DALYs in Japan, also drawn from the GBD 2010 project [16]. In 2012, a country-specific comparative risk assessment was conducted in Japan under the GBD framework. This assessment explored these risk factors in more detail using 2007 datasets and focused on mortality rather than DALYs. This national assessment used a systematic review of the literature and analysis of locally available exposure data to build a more detailed picture of these risk factors than was otherwise made available at the global level by the GBD 2010 project. In doing so, this national assessment focused on only the top 16 risk factors for ill health in Japan and developed a measure of joint risk to represent the complexity of dietary risk factors, which are difficult to analyze separately. This national assessment also used richer data to estimate contributions to lost life expectancy and probability of death among these risk factors. In turn, this analysis provided a slightly different insight compared to results based only on DALYs such as in the GBD 2010 results. These results provide more detail about the relative balance of risks; however, the more detailed data sources and restricted set of risk factors has led to some differences with the GBD 2010. Nevertheless, both the GBD 2010 and this 2012 national assessment revealed the same top three risk factors including dietary risks, high blood pressure, and smoking, and the 2012 national assessment estimated the effect of these risk factors on life expectancy and mortality. The 2012 national burden of disease analysis was in broad agreement with GBD 2010 and demonstrates the power of a national burden of disease estimation conducted under the GBD framework [17].

Figure 1 shows the contribution of the top 16 risk factors in Japan to changes in life expectancy at 40 as well as the change in probability of death in the 15 to 60 and 60 to 75 year age groups. Smoking remains a key risk factor among men in Japan and is responsible for a total of nearly 2 years of lost life expectancy at the age of 40 and almost a 15% increase in mortality for men aged between 15 and 60 years old. For women and men, a complex joint risk factor profile built from high blood pressure, blood glucose, low-density lipoprotein cholesterol, and body mass index is responsible for a large proportion of the mortality. In women, this joint risk factor profile alone accounts for nearly a 1.5-year change in their life expectancy at 40. Therefore, Japan's preventive health and public health goals in the immediate future should be focused on the management of hypertension and risk factors for stroke and coronary heart disease that are embedded in this joint risk factor model as well as continuing to emphasize dietary interventions and improved management of suicide risks and depression.

SUB-NATIONAL ESTIMATES OF RISK AND MORTALITY IN JAPAN

It has been suggested that inequality based on region, cause, and wealth [18] as well as other risk factors that influence mortality are increasing in Japan [19]; however, these trends have changed since the early 1990s due to economic stagnation and other social determinants of health [20]. Given the regional variations in health financing and performance [15] and the challenges facing Japan's health system in the future [21], a detailed understanding of the sub-national variations in the causes of death and illness as well as their associated risk factors is essential.

Initial research that focuses on identifying variations among the causes of death at prefectural and municipal level may be the most effective tool to inform sub-national health policy making. Figure 2 shows the crude mortality rate among 50 to 59 year olds in Japan in 2010 [22] and the different patterns of mortality across the country. A broad tendency towards higher mortality was found in the north. Variations in the culture of these areas, urban planning, and the different income structures and lifestyle patterns across Japan may explain these variations in risk.

The use of geographical differences in mortality demonstrates the role that sub-national burden estimates can play in identifying variations in health and indicate possible causes of future divergence in health outcomes between regions. By conducting a sub-national analysis, it is possible to identify region-specific health intervention needs and begin constructing a local policy framework from data collected at the national level.

THE ROLE OF SUB-NATIONAL ESTIMATION IN POLICY DEVELOPMENT

The 2011 *Lancet* series on Japan identified major policy challenges facing the Japanese health system, considering that its universal health care system serves one of the most rapidly aging populations. Moreover, this series recommended that prefectural governments play a key role in forming and

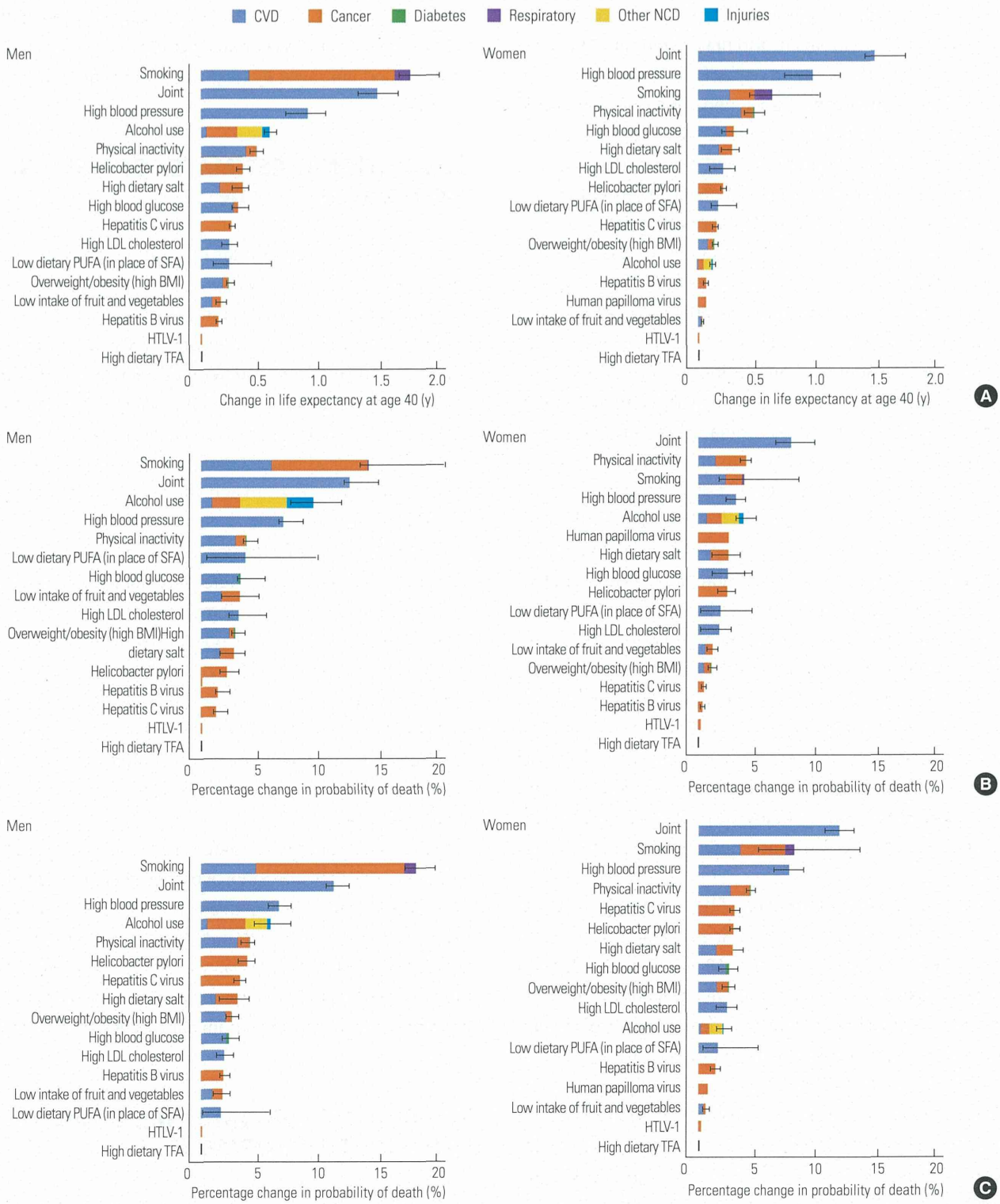

Figure 1. Influence of the 16 key risk factors on mortality outcomes in Japan in 2007. (A) Effect of risk factors on life expectancy at age 40. (B) Percentage change in probability of death at age 15 to 60. (C) Percentage change in probability of death at age 60 to 75 years. Ikeda N, et al. PLoS Med 2012;9(1):e1001160, according to the Creative Commons Attribution License [17]. LDL, low-density lipoprotein; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; BMI, body mass index; HTLV-1, human T-lymphotropic virus-1; TFA, trans-fatty acids; CVD, cerebrovascular disease; NCD, non-communicable diseases.

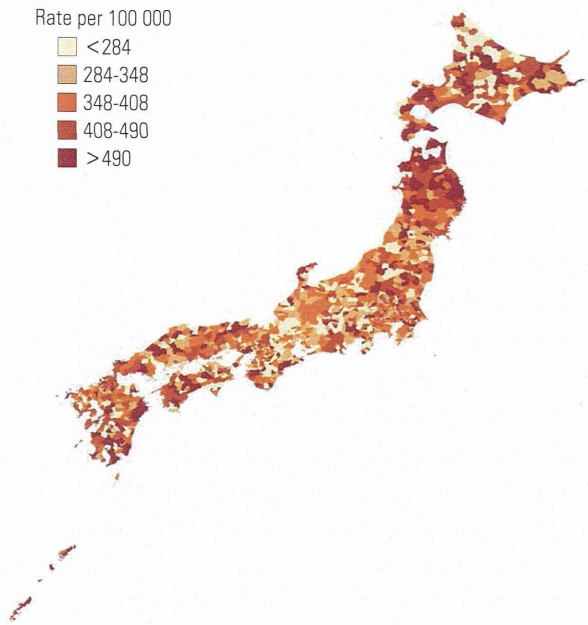

Figure 2. Mortality rate among 50 to 59 years old Japanese women in 2010. From Vital Health and Social Statistics Division. Vital statistics in Japan 2011. Tokyo: Ministry of Health Labour and Welfare; 2013 [22].

implementing health policy because of the huge regional variations in health insurance premiums within Japan [21]. However, for prefectural governments to play this role they will need to have access to high quality data on both the health challenges of their communities, the major risk factors for ill health, and past trends in these risk factors. Sub-national burden of disease estimates are an ideal tool for engaging with policy-makers, and the visualization tools developed by the IHME, such as the GBD compare tool [23], make it possible for policy-makers with little knowledge of epidemiology to quickly and easily compare their prefectural health profile with both their own historic profile and the profile of other prefectures.

In addition to enabling the development of locally driven plans to modify key risk factors and develop plans to reduce future health burdens, these local profiles also enable prefectural governments to identify gaps in the data and make investments in high quality data collection systems. For modern health planning, collecting high quality data is essential. Just as the GBD projects have revealed areas for improvement in data collection systems globally [8], so too will the local profiles naturally lead local organizations to improve their own local data systems. This kind of local response to gaps in the data may also lead to bottom-up pressure for the development of high quality data at a national level as prefectural government planners who assign priorities and plan for future health needs begin to understand the importance of burden estimates where national-level data systems are lacking.

However, national and sub-national burden of disease calculations cannot be the only analyses. One of the key methodological advances of the GBD study is the use of data across regions so that nations with sparse data in one health area can draw information from data available for other countries in the region. This process of data synthesis can also be used for national and sub-national estimates. Regional collaborations will enable nations at the same stage of epidemiological transition to share data on exposure risks and effect sizes, especially where exposures are more common in one nation or sub-national region than another. This kind of collaboration will also enable these nations to draw on the experience of others further along this epidemiological pathway, enabling better estimates of current and future NCD burden. Both technically and institutionally, collaboration is essential to improving GBD estimates and national and sub-national burden estimations.

DISCUSSION

In 1990 and 2010, Japan had the lowest age-standardized mortality rate and age-standardized rate of years of life losts globally [24]. Japanese life expectancy increased from the late 1950s and remained the highest in the world at the end of the 1980s. The early increase in longevity during the 1950s to 1960s has been credited to the implementation of effective infectious disease control programs [14], with the Japanese government enacting 32 health laws within ten years after the end of World War II [24]. Interventions that prevented infant and child mortality at that time included clean water, institutional delivery, and universal vaccinations. Subsequently, the implementation of preventive measures against NCD mortality and the maintenance of an equitable and accessible universal health system assured continued gains in the health of the Japanese population throughout the epidemiological transition [13]. Because of these interventions, Japan came to represent a model for universal health development [15,25], and these achievements are reflected in the results of the GBD 2010 project.

Although Japan performed well in promoting the popula-

tion's health status, several challenges for the Japanese health system remain. Cancer, heart disease, and cerebrovascular disease, the three leading causes of death, have contributed to approximately 50% of the population's lifetime risk [17]. Therefore, reducing NCD mortality is the key to prolonging the population's longevity. Lifestyle risk factors such as smoking are the most important factors associated with NCDs. Japan has successfully reduced the population's average blood pressure, which can be associated with an unhealthy diet, but the management of other lifestyle risk factors is still important. The next challenge for dietary interventions involves improving the methods used to address the complex joint risk factors including high blood pressure, blood glucose, low-density lipoprotein cholesterol, and body mass index. These complex risk factors are associated with urbanization, aging, and dietary changes as more Western food is incorporated into Japanese diets. Therefore, sophisticated interventions and policies at both the national and local level will be required.

Although smoking rates have been declining in Japan, smoking is still the leading preventable risk factor accounting for approximately 50% of adult mortality among young men [26]. Highly effective policies for tobacco control are needed in Japan, such as higher cigarette prices and stricter tobacco control ordinances consistent with the Framework Convention on Tobacco Control [27]. Another challenge for the Japanese health system is reducing mortality and morbidity rates associated with self-harm. More than 30 000 suicides have occurred in Japan every year since 1998, and, although the government has implemented several interventions and strategies to prevent suicide, no substantial improvements have been noted [28]. Therefore, effective interventions in the community and in workplaces are necessary for self-harm prevention.

Although Japan's health system is famous for maintaining equity in health coverage [25], we have shown that significant variations in patterns of mortality and risk are evident by age, region, and wealth. Maintaining equity in the future will require interventions and policy instruments to target these regional- and wealth-based inequities. Moreover, any policy development should rely on the analysis of risk factors using high quality data available at the regional and local level. Beginning with analyses at the prefectural level, it is our goal to develop estimates of years of life lost to death and disability as well as the major contributing risk factors within the GBD framework to guide policy development and inform local health decisions. These sub-national estimates will help to inform national and prefectural governments about evident health challenges and provide detailed assessments of disease burden to those who allocate resources and plan interventions. In addition, these sub-national estimates will provide renewed impetus to reform the relationships between central and local governments as well as improve data systems and research [21].

Results of the new GBD 2013 study, which will become the most recent burden of disease study, are scheduled to be published in late 2014 [4]. This new GBD study will estimate trends in the burden of disease throughout 1990 to 2013 with the addition of more risk factors than were included in the GBD 2010. This iteration of the GBD project also aims to use data that are directly available from national collaborators. Since the release of GBD 2010, the IHME has been actively seeking collaborators at the national level to provide more accurate, comprehensive, and detailed data as well as to give expert advice on the findings. A study as broad and complex as the GBD project requires many simplifications and approximations, but also has many gaps in the data and local knowledge. By incorporating national-level collaborators and detailed data, estimates that are even more accurate will hopefully be produced and updated frequently. We aim to incorporate our sub-national estimation process into the next round of the GBD project, thus enabling our results on sub-national variation and inequality to inform the data on national and sub-national variation in other parts of the region, which is similar to how the variations between nations has informed estimates within regions in the GBD 2010 project [5].

CONCLUSION

The GBD framework has been essential to understanding the successes and challenges in reducing mortality and the burden of health in Japan. By providing comprehensive information on the national and sub-national disease burden, the GBD studies will be crucial in informing future agendas and policies in countries throughout the region and especially in Japan. However, the quality of the GBD outcomes is dependent on the commitment and involvement of country-level collaborators. Nations throughout Asia should commit to this unique and challenging project and encourage epidemiologists throughout the region to participate.

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CONFLICT OF INTEREST

The authors have no conflicts of interest with the material presented in this paper.

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Farewell to free access: Japan's universal health coverage

22nd February, 2014

Author: Etsuji Okamoto, NIPH

While the Obama administration is struggling to achieve universal health coverage in the US, Japan celebrated the 50th anniversary of its universal health coverage system in 2011. Japan's universal health insurance coverage is now deeply rooted in both patients' and doctors' minds. But the principle of 'free access' to medical procedures and medications is being challenged by the economic realities of sustaining this system.

Under Japan's current health insurance system, a uniform fee schedule, which the government determines, regulates the price of all medical procedures and drugs. In sharp contrast to American doctors, who believe in their 'professional freedom' of deciding the prices they charge, Japanese doctors rarely question government regulations in the sector. The price of health care is uniform throughout the country and people can receive care at any clinic or hospital so long as they contribute to the specified co-payments, which is often around 10–30 per cent. 'Free access' is the core principle of Japan's universal health coverage maintained in the last half century, in which patients have full freedom to choose their own health care providers and all approved drugs are covered by insurance. Japan's universal health coverage negates the need for things such as managed care, gatekeepers, preauthorisation and restrictive formularies. And in the absence of control on the supply side, Japan has become a country most heavily equipped with medical facilities and technology among OECD member countries in terms of the number of hospital beds, dialysis units, CTs and MRIs per population.

But free access to new and expensive drugs is increasingly placing a strain [1] on Japan's health insurance system. When Japan achieved universal health coverage over 50 years ago,

medical care and drugs were primitive and cheap. Free access was economically feasible. But development and innovation of medical technology brought about effective but expensive drugs — the most expensive being Zevalin, which is used to treat lymphoma. One set of Zevalin comes with a price tag of US$26,000 (AU$29,000). One set of Ilaris, used to treat rare paediatric chronic diseases, comes with a price tag of US$14,000 (AU$15,600). And unlike Zevalin, which is for one-off use, patients may need multiple repeats of Ilaris. Under Japan's current universal health coverage, doctors are free to prescribe expensive drugs such as Zevalin and Ilaris without any pre-authorisation. Patients, of course, will have to contribute to co-payments of approximately 10–30 per cent, but can claim back the amount exceeding certain limits from their insurers.

In 2013, the Central Social Insurance Health Care Committee (CSIHCC), which reviews the revision of the uniform fee schedule as well as the drug price list every two years, proposed to introduce economic evaluation in granting the health insurance coverage and setting prices. Economic evaluations will aim to measure how much it will cost to prolong one year of life for anti-cancer drugs, and how much it will cost to improve the quality of life for drugs for chronic diseases in comparison with other existing, less-expensive drugs or treatments. Drugs must be effective to be approved — but must be effective enough to justify their price tags to be covered by Japan's insurance system. CSIHCC will first establish methodology and standards to carry on economic evaluation and plans to introduce it in as early as 2016. Thresholds of £20,000–30,000 (AU$37,000–55,000) for prolonging one quality-adjusted year of life used in the UK National Health Service were quoted in the discussion paper presented at CSIHCC.

At present, all approved drugs are automatically covered by insurance and prices were set to ensure pharmaceutical manufacturers to recoup the investment for new drugs. It is not yet certain what threshold will be adopted nor if any drugs in the present price list will be excluded from insurance coverage. One thing is certain: it is a radical departure from the 'free access' principle that came with Japan's universal health coverage over half a century ago. If a patient wants access to medication that is not covered by insurance, he or she will be required to pay fully out of pocket. Inevitably, patients will be selected based on their ability to pay. Also, in economic evaluation, lives are not treated equal. One year of life in pain and agony is valued less than one year of life in full health. The aforementioned thresholds may be lowered if the drug is not effective enough to achieve full health.

The departure from the 'free access' principle currently in place in Japan is an inevitable compromise to sustain universal health coverage into the future. For now, Japan will have to face a grim fact that lives are not created equal.

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

P Ueda[1,2], N Kondo[3] and T Fujiwara[4]

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] 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.[2]

Socioeconomic disadvantage has in numerous studies been linked to childhood overweight, although the association differs depending on study setting, sex and ethnicity.[3–5] 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.[6–9]

During the past 20 years of economic recession in Japan, growing socioeconomic disparities have been observed.[10] 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.[11] The crisis disproportionally affected the low-income groups and workers with precarious employment; income inequality and poverty rates rose considerably,[12] and social welfare programs have been unable to provide adequate support to those in need.[13]

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.[14]

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.[2,15] In addition, we evaluated trajectories of underweight prevalence as underweight may be associated with socioeconomic factors[16,17] and constitutes a health issue among girls in Japan[14] and other Asian countries.[18]

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)/height^2 (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 members[19] 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 Japan[20]—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. As previous studies have found differences between the sexes in associations between socioeconomic and psychosocial factors and risk of overweight[9,21] as well as risk patterns for underweight,[22,23] 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,[24] 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 prevalence that plateaued at age 9 years (Supplementary Information 2); a pattern previously observed in Japanese children.[25–27] 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 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

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

	Boys	*Girls*
N (%)	16,403 (51.9)	15,206 (48.1)
Income quartile, n *(%)*		
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, *n* (%)	1531 (9.3)	1482 (9.8)
>20% negative income change during economic crisis, *n* (%)	2136 (13.0)	2096 (13.8)
>10% negative income change during economic crisis, *n* (%)	3225 (19.7)	3083 (20.3)
Residential area, n *(%)*		
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, *n* (%)	299 (1.2)	313 (1.4)
Father's education, n *(%)*		
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)
Mother's education, n *(%)*		
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)
Single parent household, n (%)	266 (1.6)	246 (1.6)
Missing, *n* (%)	5 (0)	5 (0)
Three generation household, *n* (%)	3781 (23.1)	3388 (22.3)

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).

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).

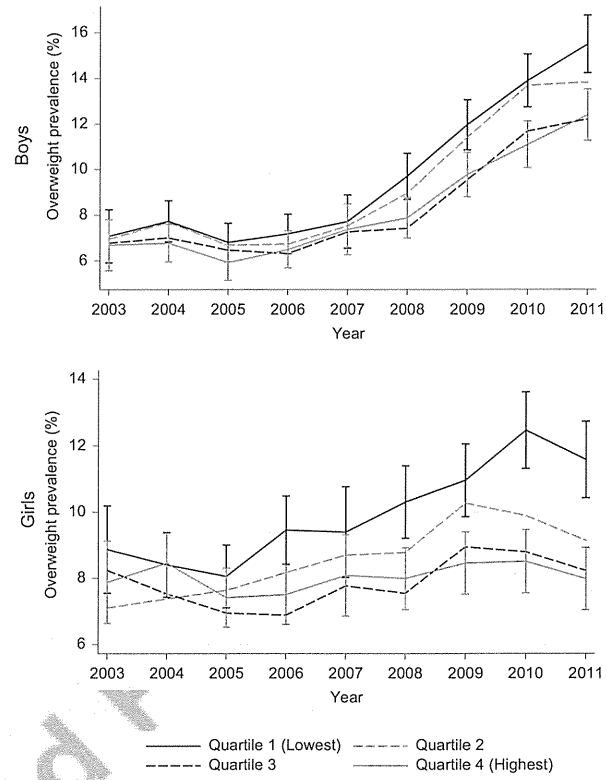

Figure 1. Overweight prevalence with 95% confidence intervals in boys and girls by year and household income quartile.

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 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.[6] 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.[28] 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.[29]

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

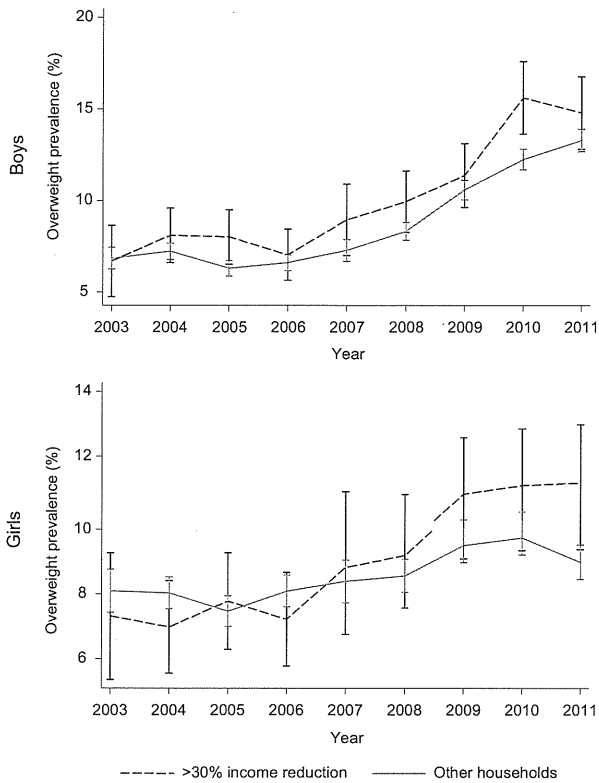

Figure 2. Overweight prevalence by year in boys and girls from households experiencing a >30% income reduction in connection to the global economic crisis and in children from households with no such income reduction.

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.[7,8,30] Negative life events in the family may result in a higher food intake, in particular comfort foods,[31,32] which function to alleviate stress at a neurobiological level.[33] Moreover, cuts in the family budget may lead to decreased consumption of fruits and vegetables[34] and increased consumption of fast food.[35] In Japan, longer maternal working hours, in particular among contract workers, have been correlated to increased risk of overweight.[36] 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.[14] 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,[3,4] negative life events,[9,21] psychosocial stresses[37,38] and overweight risk may be more pronounced among girls. Eating response to stress is reported more frequently among women.[39,40]

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[23,41] 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.[42] Accurate reports of children's anthropometric data may also have been facilitated in our study as parents could specify any date of measurement.[43] 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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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)
Household income quartile before 2008				
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)
>30% negative income change during economic crisis				
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)
Step term				
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)
Interaction between income change and step term				
⩽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)
Interaction between income quartile and step term				
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)
Father's education				
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)
Mother's education				
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)
Single parent household				
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)
Three generation household				
No		1.00 (ref)		1.00 (ref)
Yes		1.39 (1.28–1.51)		0.95 (0.88–1.01)
Residential area				
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)
Father's age				
<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)
Mother's age				
<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,[24] with an exchangeable correlation structure was used for the analysis.