

BMJ Open Impact of the consumption tax rate increase on out-of-hospital cardiac arrest in Japan: an interrupted time series analysis

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ABSTRACT

Objectives The Japanese government increased the consumption tax rate from 5% to 8% on 1 April 2014. The impact of this policy on the incidence of out-of-hospital cardiac arrest (OHCA) is unknown. Thus, we aimed to evaluate a potential association between the consumption tax rate increase and OHCA.

Design An interrupted time series design.

Setting National registry data for all cases of OHCA in Japan.

Participants All OHCA cases of presumed cardiac origin in Japan between January 2005 and December 2016.

Primary outcome measure We used a quasiexperimental design with interrupted time series analysis to investigate whether the consumption tax rate increase was associated with changes in OHCA trends after adjusting for baseline trends. The effective date of the consumption tax rate increase (1 April 2014) was used to split the OHCA data into categories of before and after the change.

Results In total, 808 055 OHCA cases of presumed cardiac origin were reported during the study period. Prior to the consumption tax rate increase, the mean monthly OHCA rate was 5.12 cases per 100 000 population (mean monthly count: 5483.45). After adjusting for underlying trends, there was a substantial step change in the incidence of OHCA (relative risk (RR): 0.921; 95% CI 0.889 to 0.955).

Conclusions The implementation of the consumption tax rate increase was associated with a significant decrease in the incidence of OHCA in Japan.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a significant public health issue of industrialised countries.¹ Although survival following an OHCA has improved in recent years, the survival rate remains low at 8%.² A major risk factor for sudden cardiac arrest is coronary artery disease, while a family history of cardiac arrest and lifestyle factors, such as smoking, physical activity, diet and weight, can raise the risk of OHCA.³ Many studies that have quantified the impact of OHCA have had difficulties accounting for potential strategies. However, OHCA continues to be

Strengths and limitations of this study

- The implementation of the consumption tax rate increase was associated with a significant decrease in the incidence of out-of-hospital cardiac arrest (OHCA) in Japan.
- There was no significant interaction effect by sex and age.
- The consumption tax increase may have beneficial effect on OHCA.
- We could not obtain information about individual or regional factors.
- We could not examine other effects of policy change that may be important.

a leading and important cause of death due to heart disease. Therefore, it is essential to refine estimates of potential adaptation and help prioritise mitigation and adaptation strategies for OHCA.

The Japanese government increased the consumption tax from 5% to 8% on 1 April 2014⁴ and scheduled the next increase, to 10%, for October 2019. The consumption tax covers a wide range of products and services in Japan. The use of taxation to increase prices and reduce consumption is an important strategy for improving tobacco, alcohol and food consumption patterns and their associated health outcomes.⁵ For example, increases in the cigarette excise tax are associated with significant reductions in smoking prevalence, acute myocardial infarction and asthma hospitalisation rates, and sudden cardiac death rates.⁶ Many studies also indicate that alcohol price and taxes are inversely associated with alcohol consumption rates.⁷ The US Earned Income Tax Credit has had beneficial impacts on food security, smoking and weight loss; in contrast, it has had a detrimental impact on metabolic factors.⁸ Furthermore, taxation of unhealthy foods has reduced cardiovascular disease mortality by 2% in the UK, and taxes

on salt, sugar and fat have been imposed in several countries.⁵ In India, curtailing palm oil intake by taxation may decrease cardiovascular mortality and hyperlipidaemia, which is expected to be especially beneficial for men and urban populations.⁹ Moreover, the sustained taxation of sugar-sweetened beverages in India and Mexico may reduce obesity, diabetes and cardiovascular disease morbidity and mortality.¹⁰ In view of the previous studies, tax systems could have beneficial effects on cardiovascular disease health, and it is speculated that an increase in the consumption tax would decrease the burden of OHCA. However, no studies have examined how the consumption tax rate increase affects the incidence of OHCA.

We thus sought to determine how the consumption tax rate increase was associated with the incidence of OHCA using the Japanese national registry data for all OHCA cases in Japan by an interrupted time series analysis. We also investigated potential differences in the effects of this consumption tax rate increase according to basic demographic characteristics, such as sex and age.

METHODS

Study design

An interrupted time series analysis was used to compare the OHCA rates per month in Japan before and after the increase in consumption tax rate on 1 April 2014. Interrupted time series analysis is a useful, quasiexperimental design for evaluating the effects of interventions based on longitudinal data.¹¹ It uses population-level data collected over time to investigate how population-level interventions that occur at a distinct time affect trends. An interrupted time series design requires a clear differentiation of the periods before and after the intervention, and population-level intervention is defined as a potential interruption to the underlying trends over time.¹² The consumption tax rate increase in Japan had a clear implementation date, beginning on 1 April 2014.

Data sources

We collected data on OHCA cases occurring in Japan between 1 January 2005 and 31 December 2016, from the Fire and Disaster Management Agency (FDMA). Under Japan's Fire Service Act, municipal governments provide emergency medical services (EMSs) at approximately 800 fire stations and associated dispatch centres. Since termination of resuscitation in the field is not permitted for EMS providers, all EMS-treated OHCA patients are transferred to a hospital. EMS personnel, with the assistance of the physician in charge, summarise each OHCA case in accordance with the standardised Utstein-style guidelines. The cause of cardiac arrest (ie, presumed cardiac or non-cardiac) was determined clinically by the physician in charge in cooperation with the EMS personnel. The arrest was considered to be of cardiac origin unless it was caused by drowning, trauma, drug overdose, exsanguination, asphyxia or any other obvious non-cardiac cause. The fire stations with dispatch centres in 47 prefectures

send this data to the FDMA, which is integrated into the national registry system on the FDMA database server. In Japan, registration of OHCA episodes is required under the Fire Service Act; therefore, the OHCA data registry is considered complete across the country. Detailed information on Japan's EMS system has been previously reported.¹³

Ethical approval

The need for written informed consent was waived because the study had a retrospective observational design using national registry data, and the enrolled individuals were deidentified by the FDMA.

Outcome measures

We extracted a monthly time series of OHCA cases. Monthly cases for OHCA were calculated from the daily records based on the day of onset. The age range of patients was 18–110 years. The physician in charge in cooperation with EMS staff determined whether the clinical cause of the cardiac arrest was cardiac or non-cardiac in origin; the arrest was considered cardiac in origin unless it was due to drowning, trauma, overdose, exsanguination, asphyxia or other obvious non-cardiac causes. Each patient included in the study had an OHCA of presumed cardiac origin. Population denominators were calculated using annual population estimates from the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan.¹⁴

Statistical analysis

An interrupted time series analysis with a generalised linear model was used to evaluate whether postintervention trends in OHCA differed significantly from preintervention trends after adjusting for the underlying trend and seasonality.¹⁵ OHCA cases in Japan per month were referred to as the dependent variables, whereas a dummy variable indicating the preintervention or postintervention period and elapsed months since the start of the study were referred as independent variables. Elapsed months since the start of the study were incorporated into the model to allow for the underlying trend. To account for any seasonal effects that were not directly due to the consumption tax rate increase, Fourier terms up to the second harmonic were included in the model.¹⁵ Fourier terms can capture repeated periodic (eg, seasonal) patterns comprising a combination of pairs of sine and cosine terms (harmonics) of varying wavelength. An autoregressive term at an order of one was incorporated into the models to allow for autocorrelations.¹⁶ SEs were scaled to account for overdispersion.¹⁷ Plots of model residuals and a partial autocorrelation function of the residuals (online supplementary figure S1) suggested that this was an adequate amount of adjustment for seasonal effects. The age-standardised population was included as an offset variable to convert a monthly OHCA cases into a rate and adjust for any potential changes in the population over time. Since we also hypothesised the slope

change due to the intervention, the interaction term between elapsed time and intervention was also included in the model.

Time was divided into two segments according to when the consumption tax increase was implemented: a preimplementation and postintervention periods. This time period spanned a total of 144 months (111 preintervention and 33 postintervention). Within this framework, we assessed whether there was a step change in the rate of OHCA after the exposure period. A Wald test was used to evaluate whether the underlying trend in OHCA changed after the postintervention period compared with the preintervention period.

We also performed stratified analyses to investigate effect modification by sex and age (18–39, 40–49, 50–59, 60–69, 70–79 and ≥ 80 years). By stratifying the models by these factors, we assessed the potential of effect modification in each model. Population denominators were calculated separately for each series using monthly population estimates from the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan.

To examine whether the results were sensitive to the levels of control for seasonal patterns, sensitivity analyses were conducted using different degrees of seasonal control (first and fourth harmonics). All statistical analyses were carried out using Stata V.15.1 and R 3.5.1 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria). The significance level for all tests was $p < 0.05$ (two sided).

Patient involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for recruitment, design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. There are no plans to disseminate the results of the research to study participants or the relevant patient community.

RESULTS

Between 1 January 2005 and 31 December 2016, there were 1 401 936 OHCA cases in Japan. Of these cases, 808 055 (57.6%) were of presumed cardiac origin and 593 881 (42.4%) were of non-cardiac causes. Between January 2005 and March 2014, there were 1 072 451 OHCA cases, of which 608 663 (56.8%) were of presumed cardiac origin and 463 788 (43.2%) were of non-cardiac causes. Between April 2014 and December 2016, there were 329 485 OHCA cases, of which 199 392 (60.5%) were of presumed cardiac origin and 130 093 (39.5%) were of non-cardiac causes.

In this study, we analysed a total of 808 055 OHCA cases of presumed cardiac origin. Between January 2005 and March 2014, the monthly mean OHCA count was 5483.45, and the OHCA rate was 5.12 cases per 100 000 population. The monthly count and rate of OHCA increased over this period: in the 33 months following the

implementation of the consumption tax rate increase, monthly mean OHCA counts increased to 6042.18 (5.62 cases per 100 000 population). Age-adjusted mean monthly OHCA rate per 100 000 population was 0.19 before the preintervention period and 0.19 after the postintervention period (table 1).

The relationship between the consumption tax rate increase and the rate of OHCA is shown in figure 1. After adjusting for underlying trends, we estimated a substantial step change in the risk of OHCA (relative risk (RR): 0.921; 95% CI 0.889 to 0.955) after the postintervention period compared with the preintervention period (table 1). There was also significant trend change in the risk of OHCA (RR: 0.996; 95% CI 0.994 to 0.999) after the postintervention period compared with the preintervention period.

Stratified analyses by sex revealed that the substantial step change in the risk of OHCA was observed for both men (RR: 0.938; 95% CI 0.905 to 0.972) and women (RR: 0.899; 95% CI 0.866 to 0.934) after the postintervention period compared with the preintervention period (table 1). We also found significant trend change in the risk of OHCA for both males (RR: 0.997; 95% CI 0.995 to 0.999) and females (RR: 0.996; 95% CI 0.993 to 0.998) after the postintervention period compared with the preintervention period. Interaction models showed no significant difference in step change ($p = 0.622$) or trend change ($p = 0.362$) by sex.

Stratified analyses by age group showed that there was a substantial decrease in step change in the risk of OHCA after the intervention period decreased in those aged 80 years or older (RR: 0.887; 95% CI 0.853 to 0.922) after the postintervention period compared with the preintervention period (table 1). We also found significant trend change in those aged 80 years or older (RR: 0.995; 95% CI 0.993 to 0.997) after the postintervention period compared with the preintervention period. However, interaction models showed that there was no evidence of an interaction effect for either the step change ($p = 0.097$) or trend change ($p = 0.628$) by age.

In sensitivity analyses, the 1 and 4 harmonic models yielded a RR of 0.922 (95% CI 0.882 to 0.963) and 0.919 (95% CI 0.890 to 0.948) for step change, respectively, with respect to the incidence of OHCA. Changes to these estimates were small, suggesting that our findings were robust.

DISCUSSION

We found that the consumption tax rate increase was associated with a decreased risk of OHCA. Previous studies have examined the effects of specific aspects of tax increases on cardiovascular diseases and suggested that socioeconomic factors may have considerable impact on sudden cardiac arrest.¹⁸ These findings are in line with our results that monthly rates of OHCA are affected by the consumption tax rate increase. This association may be linked to findings that the increase in consumption

Table 1 The impact of consumption tax rate increase on out-of-hospital cardiac arrest (OHCA)

Characteristic	Mean monthly OHCA population		Mean monthly OHCA population		Age-adjusted mean monthly OHCA per 100 000 population		Step change, relative risk (95% CI)	P value for interaction	Trend, relative risk (95% CI)	P value for interaction
	Before	After	Before	After	Before	After				
Total	5483.45	6042.18	5.12	5.62	0.19	0.19	0.921 (0.889 to 0.955)		0.996 (0.994 to 0.999)	
Sex										
Male	3151.39	3442.30	6.12	6.65	0.26	0.26	0.938 (0.905 to 0.972)	0.622	0.997 (0.995 to 0.999)	0.362
Female	2332.06	2599.88	4.23	4.67	0.14	0.14	0.899 (0.866 to 0.934)		0.996 (0.993 to 0.998)	
Age (years)										
18–39	119.95	103.12	0.34	0.33	0.03	0.03	0.965 (0.910 to 1.023)	0.097	0.998 (0.994 to 1.002)	0.628
40–49	181.17	203.85	1.08	1.09	0.08	0.08	0.974 (0.926 to 1.025)		1.000 (0.997 to 1.003)	
50–59	393.20	347.82	2.30	2.24	0.13	0.13	0.970 (0.926 to 1.015)		0.999 (0.996 to 1.002)	
60–69	794.41	811.18	4.56	4.43	0.19	0.18	0.964 (0.926 to 1.003)		0.998 (0.995 to 1.001)	
70–79	1384.08	1395.33	10.72	9.91	0.26	0.24	0.973 (0.936 to 1.012)		0.998 (0.995 to 1.001)	
≥80	2610.64	3180.88	32.77	31.70	0.28	0.27	0.887 (0.853 to 0.922)		0.995 (0.993 to 0.997)	

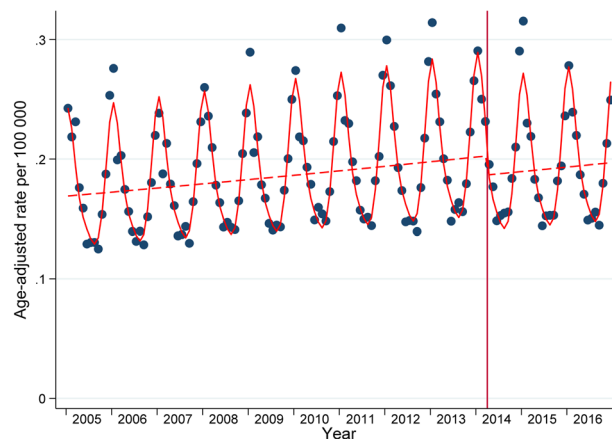


Figure 1 Effect of consumption tax rate increase on out-of-hospital cardiac arrest (OHCA) in Japan. Observed (circles) and predicted (solid lines) OHCA rate per 100 000 population in Japan. Vertical line represents the beginning of the consumption tax rate increase (postintervention period), beginning on April 2014. The dashed line represents the temporal trend, and the step at the postintervention period is the estimated effect.

tax rate makes everything more expensive, and thus decreasing alcohol, tobacco and food consumption patterns. The report of Council for Tobacco Business of Ministry of Finance, Japan, indicated that tobacco sales decreased dramatically according to the consumption tax increase.¹⁹ Prospective cohort studies provided evidence that psychosocial factors are independent aetiological and prognostic factors for coronary heart disease.²⁰ Psychosocial factors cause direct acute or chronic pathophysiological changes and affect health-related behaviours such as alcohol consumption, smoking, diet or physical activity, which are major causative factors for coronary heart disease.²⁰ Thus, our findings are physiologically plausible and indicate that the consumption tax rate increase can have a substantial impact on OHCA.

Past preventive strategies for cardiovascular diseases included the use of taxation to reduce the intake of tobacco, alcohol and unhealthy foods and subsidies to promote the consumption of healthy foods.²¹ A recent simulation study in Mexico reported that a tax increase on sugar-sweetened beverages was associated with a substantial reduction in cardiovascular disease events and deaths.¹⁰ Our results are consistent with these results. Additionally, although OHCA is influenced by factors that cause departures from typical seasonal patterns, confounding bias due to factors that might explain seasonal patterns did not affect our findings. Previous studies also indicated important differences in the effect of taxation on smoking, alcohol and food and that these relationships can also vary according to income level and country of residence.²² In any case, our findings demonstrate the important impact of an increase in the consumption tax rate on the incidence of OHCA.

Stratified analyses showed a substantial step change in OHCA rates after the implementation of the consumption tax rate increase in both men and women. We also found a considerable reduction in OHCA rates among patients aged ≥ 80 years. However, we did not find evidence that sex or age had substantial effect modification. Our findings are in line with that from a recent study conducted in North Carolina, which suggests that sex is not a significant effect modifier in the association between lower median household income and sudden cardiac death.²³ A previous study in the USA showed a strong association between socioeconomic status and incidence of sudden cardiac arrest in those younger than 65 years.²⁴ The findings of our age-stratified analysis are partly in agreement with this finding and the discrepancy might be due to differences in socioeconomic, demographic, environmental and behavioural factors associated with OHCA. Additionally, most previous studies have not controlled for seasonality and long-term trends. Thus, there may be limitations related to study design and methodology. Moreover, the unprecedented rate of population ageing in industrialised countries including Japan is a significant social and medical issue.¹³ Further investigation of these interaction effects may elucidate effective control and prevention strategies for OHCA.

To measure the effects of the consumption tax rate increase on OHCA, we used interrupted time series analysis. This approach is frequently used to investigate how population-level interventions affect the changes in level and slope of outcomes over time.¹² Our quantitative approach used seasonality (Fourier terms) to model changes in the patterns of OHCA cases, which is helpful for analysing social and environmental effects on health outcomes and adjusting for confounding variables. However, an interrupted time series design cannot confirm the causal relationship between the consumption tax rate increase and observed changes in OHCA. Therefore, caution is warranted in the interpretation of our results in these respects, and it is essential to conduct further studies to consider a variety of socioeconomic and demographic factors.

Our findings have important practical implications. The intention underpinning the imposition of most taxes usually involves raising revenue rather than affecting health outcomes.²⁵ A recent multicountry longitudinal study showed a positive association between government health spending and taxes on income, profits and capital gains, but no such association exists with consumption taxes.²⁶ Our results may help to increase understanding of the complex association between consumption tax rates and OHCA and may also support decision making from a public health and policy perspective. The Japanese government has scheduled the next consumption tax increase, from 8% to 10%, for October 2019. Based on the findings in the present study, public health officials might attempt to increase the impact of this consumption tax rate increase on OHCA rates by implementing adaptive management strategies, such as by providing advice

on public health and medical issues and refining the healthcare system. Our results suggest that consumption tax increase may have beneficial effect on OHCA.

Several limitations of the present study warrant mention. First, we could not obtain information about individual or regional factors, such as the socioeconomic status, comorbidities and community characteristics of OHCA patients. In particular, left ventricular ejection fraction, underlying diseases, such as ischaemic cardiomyopathy or non-ischaemic cardiomyopathy, hypertension and diabetes mellitus, and smoking status could be associated with an elevated risk of OHCA.¹ Moreover, several studies have reported that any tax increase tends to have a bigger burden on low-income groups.²⁶ Risk factors for sudden cardiac arrest and coronary artery disease such as smoking, lack of exercise, hypercholesterolaemia, hypertension, obesity and diabetes mellitus are more prevalent among people with lower socioeconomic status.¹⁸ Tax simulation models found that access to nutrition and healthcare for poorer households is reduced by consumption taxes.²⁶ Consideration should be given to these factors in future studies. Second, we could not examine other effects of policy change that may be important, for instance, those involving government awareness of OHCA rates or the frequency of misuse of ambulance dispatch services. Especially, the Japanese Society of Hypertension has published the new guidelines for the management of hypertension in 2014,²⁷ and this may have contributed to our findings. Examination of these issues was outside the scope of the present study. These will be critical topics for future study.

In summary, we found evidence that the implementation of the consumption tax rate increase was associated with a significant decrease in the incidence of OHCA. There was no significant interaction effect by sex and age. Our results suggest that consumption tax increase may have beneficial effect on OHCA. Further studies are necessary to continue monitoring these trends.

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Contributors DO made substantial contributions to conception and design, analysed data and wrote the manuscript. KN and AH was involved in drafting the manuscript and critically revising it for important intellectual content. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

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Patient consent for publication Not required.

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Data sharing statement Additional data from the study can be obtained for the corresponding author.

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