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Decrease in blood donation rates in Japan: a time series analysis

Redução na taxa de doadores de sangue no Japão: uma análise de série temporal

Yutaka Owari[I,II] iD, Nobuyuki Miyatake[II] iD, Hiromi Suzuki[II] iD

ABSTRACT: *Objective:* To clarify that one of the causes for the decrease in blood donation (BD) rates was the introduction of the 400 ml BD program in 1986. *Method:* BP rates were monitored over 48 years (1965–2012) and were divided into pre- and post-intervention periods prior to analysis. An interrupted time series analysis was performed using annual data on BD rates, and the impact of the 400 ml BD program was investigated. *Results:* In a raw series, autoregressive integrated moving average analysis revealed a significant change in slope between the pre- and post-intervention periods in which the intervention factor was the 400 ml BD program. The parameters were as follows: intercept (initial value) = 0.315, confidence interval (CI) = (0.029, 0.601); slope (pre-intervention) = 0.316, CI = (0.293, 0.340); slope difference = -0.435, CI = (-0.462, -0.408); slope (post-intervention) = -0.119, CI = (-0.135, -0.103); all, $p = 0.000$; goodness-of-fit, $R^2 = 0.963$. After adjusting for stationarity and autocorrelation, the parameters were as follows: intercept (initial value) = -0.699, CI = (-0.838, -0.560); slope (pre-intervention) = 0.136, CI = (0.085, 0.187); slope difference = -0.165, CI = (-0.247, -0.083); slope (post-intervention) = -0.029, CI = (-0.070, 0.012); all, $p = 0.000$ (except for slope (post-intervention), $p = 0.170$); goodness-of-fit, $R^2 = 0.930$. *Conclusion:* One of the causes for decrease in BD rates may be due to the introduction of the 400 ml BD program in Japan.

Keywords: Blood donors. Time series studies. Japan.

[I]Shikoku Medical College – Utazu, Kagawa, Japan.

[II]Department of Hygiene, Faculty of Medicine, Kagawa University – Miki, Kagawa, Japan.

Corresponding author: Yutaka Owari. 62-1, Hamagobann-cho, Utazu, Kagawa 769-0205, Japan. E-mail: owari@med.kagawa-u.ac.jp

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RESUMO: *Objetivo:* Esclarecer que uma das causas para a diminuição das taxas de doação de sangue (BP) foi a introdução do programa de doação de sangue BP de 400 mL em 1986. *Método:* As taxas de BP foram monitoradas ao longo de 48 anos (1965–2012) e divididas em períodos pré e pós-intervenção antes da análise. Uma análise de séries temporais interrompidas foi realizada usando dados anuais sobre as taxas de BP, e investigamos o impacto do programa de BP de 400 mL. *Resultados:* Em uma série bruta, a análise integrada autorregressiva de médias móveis revelou uma mudança significativa na inclinação entre os períodos pré e pós-intervenção em que o fator de intervenção foi o programa de 400 mL da BP. Os parâmetros foram os seguintes: intercepto (valor inicial) = 0,315, intervalo de confiança (IC) = (0,029, 0,601); inclinação (pré-intervenção) = 0,316, IC = (0,293, 0,340); diferença de inclinação = -0,435, IC = (- 0,462, -0,408); inclinação (pós-intervenção) = -0,119, IC = (-0,135, -0,103); todos, p = 0,000; poder explicativo do modelo, R^2 = 0.963. Após o ajuste para estacionariedade e autocorrelação, os parâmetros foram os seguintes: intercepto (valor inicial) = -0,699, CI = (-0,838, -0,560); inclinação (pré-intervenção) = 0,136, IC = (0,085, 0,187); diferença de inclinação = -0,165, IC = (-0,247, -0,083); inclinação (pós-intervenção) = -0,029, IC = (-0,070, 0,012); tudo, p = 0,000 (com exceção da inclinação (pós-intervenção), p = 0,170); poder explicativo do modelo, R^2 = 0.930. *Conclusão:* Uma das causas para a diminuição das taxas de BP pode ser devido à introdução do programa de doação de sangue BP de 400 ml no Japão.

Palavras-chave: Doadores de sangue. Estudos de séries temporais. Japão.

INTRODUCTION

In Japan, blood donations, which are only conducted by the Japanese Red Cross Society, began in 1965 (one donation volume: 200 ml) and are used for treating diseases and injuries[1]. Therefore, it is important to ensure a stable supply of blood. Considering the physical fitness and nutritional status of the Japanese in 1965, the blood donation volume was determined to be 200 ml once, which was about half that of developed countries in Europe and the United States. The volume was corrected to 400 ml in 1986, due to the improvement of Japanese physical strength and nutritional status.

Many studies have shown that blood donation rates are an index to measure the level of social capital[2-4]. Starting in the late 1980s, blood donation rates have continued to decline in Japan[5], which prompted the view of declining altruism[6]. However, only a few studies have shown that factors other than altruism are related to blood donation rates[7].

This study focused on the cause for decrease in blood donation rates. Thus, the blood donation rate was investigated using an interrupted time series (ITS) analysis[8-11]. The possible cause hypothesized for decrease in blood donation rates was the introduction of the 400 ml blood donation program in 1986.

METHODS

STUDY DESIGN

Blood donation rates (the number of blood donors / total population × 100 :%) were monitored over 48 years (1965–2012) using data from the Welfare Work White Paper in Japan[12].

Prior to analysis, pre- and post- intervention periods were created, in which the intervention factor was the 400 mL blood donation program introduced in 1986. ITS analysis was performed using annual data on blood donation rates, and the trends and impact of introducing the 400 mL blood donation program were investigated.

DATA ANALYSIS OF CLINICAL QUALITY MEASUREMENT

ITS is an analysis used to observe long-term phenomena and evaluates changes due to certain interventions[13-15]. The following linear regression model is used to estimate the level and trend in the dependent variable before intervention, as well as changes in the level and trend following intervention (Equation 1):

$$Y_t = \beta_0 + \beta_1 \times \text{time before intervention t} + \\ \beta_2 \times \text{intervention t} + \beta_3 \times \text{time after intervention t} + e_t \tag{1}$$

In which:
Y_t = the outcome,
t = time in years at time t from the start of the observation period to the last time point in the series.

All "t" is the number of years elapsed since 1965, which was set to 0. Furthermore, intervention is a measure of time t specified as a dummy variable in which the value is 0 (when occurring before intervention) and 1 (when occurring after intervention) and was implemented in the series. In this model:

β_0 = the baseline level of outcome at the beginning of the series;

β_1 = the slope prior to intervention;

β_2 = the change in the level immediately after intervention (pre-intervention = 0, post-intervention = 1);

β_3 = the change in slope from pre- to post-intervention;

$\beta_1 + \beta_2$ = the post-intervention slope;

e_t = the random error term.

STATISTICAL ANALYSIS

Firstly, the ITS data (raw data: between 1956 and 2012) was analyzed using auto regressive moving average model (ARIMA (p, d, q))[16]. Secondly, if there was non-stationarity, autocorrelation[17], or seasonality, the data were re-adjusted and re-analyzed. At the time of analysis, stationarity in the raw series was evaluated using Dickey-Fuller test with no divergence. Durbin-Watson statistic was then used to check for autocorrelation. Next, data were collected (between 1965 and 2012 over 48 years), a sufficiently large number of data

to verify the seasonal variation. Finally, Pearson's correlation coefficient was used to analyze the correlation between the donation rate and the number of blood donors (400 mL), and the total donation volume was clarified. Modeling and statistical tests were carried out using SPSS 25 (USA) and XLSTAT 2018.5 (USA).

The Shikoku Medical College Ethic Screening Committee determined that medical ethical approval was not required since all the data used in this study was already officially released.

RESULTS

The collected data, including blood donation rates (%), are presented in Table 1. The variables are as follows: year, blood donation rate (%), time period (the order from the beginning to the end of this investigation period), phase (pre-investigation (0) and post-investigation (1)), and interact (pre-intervention (0) and post-intervention (same as time period)).

Table 1. Data collection.

Year	OC	TP	PH	IA	Year	OC	TP	PH	IA	Year	OC	TP	PH	IA
1965	0.4	1	0	0	1981	5.9	17	0	0	1997	4.8	33	1	33
1966	1.0	2	0	0	1982	6.1	18	0	0	1998	4.9	34	1	34
1967	1.6	3	0	0	1983	6.5	19	0	0	1999	4.9	35	1	35
1968	2.0	4	0	0	1984	7.0	20	0	0	2000	4.7	36	1	36
1969	2.2	5	0	0	1985	7.2	21	0	0	2001	4.6	37	1	37
1970	2.3	6	0	0	1986	7.1	22	1	22	2002	4.6	38	1	38
1971	2.5	7	0	0	1987	6.8	23	1	23	2003	4.4	39	1	39
1972	2.7	8	0	0	1988	6.5	24	1	24	2004	4.3	40	1	40
1973	3.1	9	0	0	1989	6.4	25	1	25	2005	4.2	41	1	41
1974	3.5	10	0	0	1990	6.3	26	1	26	2006	3.9	42	1	42
1975	3.4	11	0	0	1991	6.6	27	1	27	2007	3.9	43	1	43
1976	3.7	12	0	0	1992	6.2	28	1	28	2008	4.0	44	1	44
1977	4.1	13	0	0	1993	5.8	29	1	29	2009	4.2	45	1	45
1978	4.4	14	0	0	1994	5.3	30	1	30	2010	4.2	46	1	46
1979	4.8	15	0	0	1995	5.1	31	1	31	2011	4.1	47	1	47
1980	5.3	16	0	0	1996	4.8	32	1	32	2012	4.2	48	1	48

OC: outcomes: blood donation rates (%); TP: time periods; PH: phase: pre-intervention; 0: post-intervention; equation 1: to investigate the effect of introducing the 400 mL blood donation program; IA: Interact: pre-intervention; 0: Post-intervention; time period.

First, the ITS data (raw data: between 1965 and 2012) were analyzed using ARIMA (p, d, q). Based on these results, the most compliant model was ARIMA (0, 0, 0). During this study, a consistent increase in blood donation rates was observed before intervention, and a consistent decrease rate after (Figure 1). In a raw series, ARIMA revealed a significant change in slope between the pre- and post-intervention periods (Table 2). The parameters were as follows: intercept coefficient (initial value) = 0.315, confidence interval (CI) = (0.02, 0.601); slope (pre-intervention) = 0.316, CI = (0.293, 0.340); slope difference = -0.435, CI = (-0.462, -0.408); slope (post-intervention) = -0.119, CI = (-0.135, -0.103); all, $p = 0.000$; goodness-of-fit, $R^2 = 0.963$.

Second, we found that the raw series was stationarity using the Dickey-Fuller test without divergence. Since the time series plot of blood donation rate did not diverge, it was considered that the donation rate was either "having unit root" or "satisfying stationarity". Here, as it was found by the Dickey-Fuller test that the blood donation rate had "no unit roots", it could be judged that the donation rate satisfied the stationarity legally. It was also confirmed that the raw series was autocorrelated using Durbin-Watson statistics. Since seasonality was not established, the raw series was converted to a logarithmic series and a single moving average was obtained. The adjusted model was ARIMA (1, 0, 0) with the following parameters: intercept
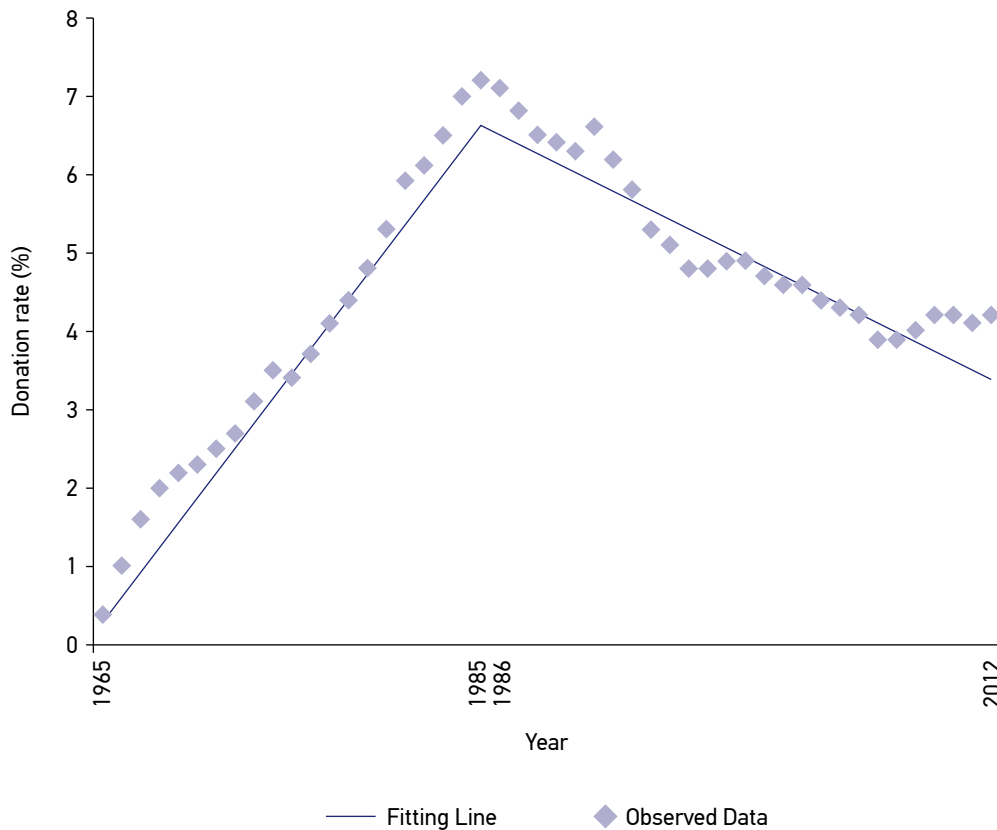

Figure 1. Time series data with regression lines for the pre- and post–intervention periods.

(initial value) = - 0.699, CI = (-0.838, -0.560); slope (pre-intervention) = 0.136, CI = (0.085, 0.187); slope difference = -0.165, CI = (-0.247, -0.083); slope (post-intervention) = -0.029, CI = (-0.070, 0.012); all, $p = 0.000$ (except for slope (post-intervention), $p = 0.170$); goodness-of-fit, $R^2 = 0.930$ (Table 3). Therefore, an increase and decrease in blood donation rates was observed before and after intervention, respectively.

Finally, Pearson's correlation coefficient was used to analyze the correlation between the donation rate and number of blood donors (400 mL) and was found to be -0.9480 ($p < 0.001$). The total donation volume between 1986 and 2012 was nearly constant every year (1,845,000 (minimum) – 2,167,000 liters (maximum)) (Table 4).

DISCUSSION

ITS analysis is a powerful quasi-experimental design for assessing the longitudinal impact of an intervention. In this study, the intervention was the 400 mL blood donation program introduced in 1986. Using this analysis, our results suggest that one of the causes for decrease in blood donation rates may be due to the introduction of the 400 mL blood donation program in Japan.

Table 2. Interrupted time series analysis; ARIMA (0, 0, 0).

	Coefficient;	95%CI	p
	initial value or slope (SE)		
Intercept	0.315 (0.146)	0.029 ~ 0.601	< 0.001
Slope pre-intervention	0.316 (0.012)	0.293 ~ 0.340	< 0.001
Slope differences	-0.435 (0.014)	-0.462 ~ -0.408	< 0.001
Slope post-intervention	-0.119 (0.008)	-0.135 ~ -0.103	< 0.001

Goodness-of fit: R2 = 0.963; 95%CI: 95% interval of confidence.

Table 3. Interrupted time series analysis (adjusted; ARIMA (1, 0, 0)).

	Coefficient;	95%CI	p
	initial value or slope (SE)		
Intercept	- 0.699 (0.071)	- 0.838 ~ - 0.560	< 0.001
Slope pre-intervention	0.136 (0.026)	0.085 ~ 0.187	< 0.001
Slope differences	- 0.165 (0.042)	- 0.247 ~ - 0.083	< 0.001
Slope post-intervention	- 0.029 (0.021)	- 0.070 ~ 0.012	0.170

Goodness-of fit: R2 = 0.963; 95%CI: 95% interval of confidence.

Based on our analysis, the donation rate consistently increased between 1965 and 1985 prior to the 400 mL blood donation program. The slope of the fitted line was 0.316 (adjusted, 0.136). However, the donation rate consistently decreased between 1986 and 2012 after the 400 ml blood donation program was implemented. The slope of the fitted line was -0.119 (adjusted, -0.029). This suggests that the blood donation rate may have decreased due to the 400 ml blood donation program. In this study, the slope after the intervention presented significant difference in the ARIMA (0, 0, 0) model (Table 2) and no significant difference in the ARIMA (1, 0, 0) model (Table 3). In addition, ARIMA (0, 0, 0) model ($R^2 = 0.963$) was more fit than ARIMA (1, 0, 0) model ($R^2 = 0.930$). This was probably because ARIMA (1, 0, 0) model had excessively incorporated the rise in blood donation rates since 2009 on into the model, causing goodness-of-fit to decrease. There is also a strong inverse correlation between the decrease in the blood donation rate and increase in the number of 400 ml blood donations (Pearson's correlation coefficient = -0.9480, $p < 0.001$). This result suggests that the implementation of the 400 ml blood donation program may have decreased the blood donation rate. Furthermore, despite the decrease in blood donation rate, the total donation volume between 1986 and 2012 was nearly constant every year. Therefore, there was no risk of shortage in blood supply.

Table 4. Changes in blood donation rate, number of blood donors, blood donation volume.

Year	OC	NBD	TDV	Year	OC	NBD	TDV
1986	7.1	617	1,845	2000	4.7	2,726	2,076
1987	6.8	1,049	1,861	2001	4.6	2,727	2,088
1988	6.5	1,251	1,859	2002	4.6	2,752	2,133
1989	6.4	1,447	1,892	2003	4.4	2,766	2,078
1990	6.3	1,600	1,938	2004	4.3	2,686	2,018
1991	6.6	1,813	2,160	2005	4.2	2,760	1,960
1992	6.2	1,903	2,167	2006	3.9	2,761	1,842
1993	5.8	2,062	2,117	2007	3.9	2,932	1,887
1994	5.3	2,356	2,022	2008	4.0	3,030	1,970
1995	5.1	2,642	1,940	2009	4.2	3,160	2,070
1996	4.8	2,662	1,917	2010	4.2	3,270	2,070
1997	4.8	2,665	1,935	2011	4.1	3,300	2,020
1998	4.9	2,710	2,095	2012	4.2	3,320	2,040
1999	4.9	2,768	2,129				

OC: Outcomes: blood donation rates (%); ML: milliliter; NBD: number of blood donors (400 mL) (thousands unit); TDV:Total donation volume (1,000 liters unit).

When using ITS, the upper limit effect may affect the possible outcomes[18]; however, we did not observe any upper limit effects in our study. If the upper limit effect was present, the blood donation rate would be 7.2% (1985) from 1986, and the slope of the regression line would be zero. However, the slope of the regression line was negative (< 0).

Some studies have shown that the decline in blood donations was due to the decline in altruism[2-4,6]. However, in this study, we found that one of the causes for the decline in blood donation rates might be due to the 400 mL blood donation program.

Our study has several limitations. Firstly, we did not investigate other intervention factors[19] (e.g., the promotion of high-unit formulations, efficiency of inventory adjustments). In future studies, confounding factors should be controlled. Secondly, since blood donation rates vary among different regions and age groups, future studies should stratify the analyses by these categories[20,21].

CONCLUSION

One of the causes for the decrease in blood donation rates may be due to the introduction of the 400 mL blood donation program in Japan.

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