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BLOOD DONORS AND BLOOD COLLECTION

TRANSFUSION

Trend of blood donors entering the coronavirus pandemic era and challenges: Age-period-cohort analysis using 75.5 million all blood donations data during 2006–2020 in Japan

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Abstract

Background: In Japan, "Blood Donation Promotion 2025," a blood donation target, was established based on a predicted blood donation rate of 5.7% in 2025, which was calculated by the Blood Donation Promotion Study Group (BD research group) of the Ministry of Health, Labor and Welfare using nationwide blood donation data through 2018. However, COVID-19 since 2020 may affect the blood donation rate in Japan.

Method: Data from 75.5 million blood donations from 2006 to 2020 was used. The age-period-cohort model (APC model) was applied to estimate age, period, and birth cohort factors on blood donation rate and to predict the age-specific blood donation rates from 2021 to 2035.

Results: The APC model was highly reproducible for blood donation rates (modified $R^2 = 0.99$). The blood donation rate in 2020 was 6.0% (5.04 million), an increase compared to 2019. Comparing this study with the BD research group, the predicted blood donation rates in 2025 for those 16–19 years old and in 20s are lower (4.8% vs. 5.2% and 5.3% vs. 5.5%) but those among 50s and 60s are higher (7.9% vs. 7.5% and 4.2% vs. 3.9%, respectively).

Discussion: The number of blood donations in 2020 increased despite COVID-19 and it proved that the blood donation promotion was effective. The different age-specific blood donation rates between our study and the report of BD research group infers the effect of COVID-19 on blood donation were differed by age and suggested the need for different approaches to blood donation promotion by generation.

KEYWORDS

age-period-cohort model, blood donations, COVID-19, epidemiology

1 | INTRODUCTION

Transfusion medicine is supported by the blood donation system, and blood donation in Japan is voluntary without receiving any payment or compensation for donating blood. In order to manufacture and supply enough blood products, it is important to predict the demand for blood donations and give a powerful promotion of blood donation, if necessary.

The annual number of blood donations in Japan reached a high of 8.7 million in 1985 and began to decline, falling to 4.99 million in 2006. In recent years,

the number of blood donations has remained almost unchanged at 4.79 million in 2016, 4.73 million in 2017, and 4.73 million in 2018.[1] In Japan, people who are 16–69 years old are eligible for blood donation and the number of eligible population for blood donation in 2000 was 92.1 million. According to the future population prediction, the eligible population is expected to decline to 77.8 million by 2025 and 75.3 million by 2030.[2]

On the other hand, according to the results of the survey of blood transfusion by the Tokyo metropolitan government in 2019, 86.8% of patients requiring blood transfusion were over 50 years old, and 36.4% of all blood products were used for cancer patients.[3] It is also predicted that the elderly population will increase and the number of cancer patients also increase accordingly.[4] Thus, understanding the demand and supply for blood products and predicting the number of blood donations and the target blood donation rate are important.

Based on the data of blood donations up to 2018, the blood donation promotion research group (BD research group) under the Ministry of Health, Labor and Welfare (MHLW) of Japan (Principal Investigator: Junko Tanaka) applied the age-cohort model (AC model) to predict the blood donation rate for the eligible population for blood donation in 2025. Predicted blood donation rate was 5.7% (5.2% for 16–19 years old, 5.5% for 20–29 years old, 4.9% for 30–39 years old, 6.0% for 40–49 years old, 7.5% for 50–59 years old, and 3.9% for 60–69 years old). Also, in 2019, the Japanese Red Cross Society (JRCS) calculated the required blood donation rate in 2027 to be 6.2%–6.6% (6.4%–6.6% for 16–19 years old, 6.6%–6.9% for 20–29 years old, 6.3%–6.6% for 30–39 years old, 7.5%–7.9% for 40–49 years old, 7.1%–7.6% for 50–59 years old and 3.4%–3.8% for 60–69 years old) based on analysis using diagnosis procedure combination (DPC) data and the Delphi method. Based on these results, the MHLW set the blood donation rate target for 2025 at 6.7% to avoid shortages of blood product.

In order to supply blood products without shortages, the JRCS sets *weekly target numbers of blood donations* and manages its inventory. However, immediately after the COVID-19 pandemic started, 3,793 and 6,146 blood donations did not reach the *weekly target numbers of* blood *donations* on February 16–22 and 23–29, 2020, respectively. The global pandemic has been suggested to have an effect on the decline in blood donations. Shan[5] reported that during the 2003 severe acute respiratory syndrome (SARS) epidemic in China, the number of blood donations decreased to one-tenth of the previous average number in April 2003. Therefore, there is a need to assess the effect of the COVID-19 pandemic on the number of blood donations, re-predict future blood donor numbers taking this into account and, furthermore, revise the target values as necessary.

The COVID-19 pandemic affects all ages, therefore we applied the age-period-cohort model (APC model) for analyzing and predicting future blood donation rates.[6] The APC model is used to analyze the variation in age-specific time series data over a period of time, and explains whether the variation is caused by differences in age (age factor), the effect of changing times on all age groups (period factor), or the effect of specific generations only (birth cohort factor) by dividing the data into three categories. The predicted number of blood donations in the COVID-19 era can be calculated by use of the APC model using the period effect of 2020. This research was conducted to understand the changing trends in the number of blood donations during the COVID-19 pandemic and future prospects based on these trends, and to examine the problems of securing the number of blood donations during and after the COVID-19 pandemic.

2 | METHODS

2.1 | Data sources

Data of all 75.46 million blood donations (4.5–5.3 million per year) during 2006–2020 of the JRCS were used. The approved age for blood donation in Japan is 16–69 years old. Census population (every 5 years) and estimated population (other years) data[7] during 2006–2020 were used as denominators of blood donation rates. Future population projections data (2017 estimates)[2] during 2021–2035 were used to predict the number of blood donations in the future. This research was approved by the Hiroshima University epidemiological research ethics review committee (approval date September 22, 2022, approval number E2022-0147).

2.2 | Data analysis

Based on the data of all blood donations in 2006–2020, the number of blood donations was tabulated by year of donation (2006–2020, 15 years), sex, and age (16–69, 54 classes). Based on population data, blood donation rates were calculated for each year, sex, and age (in 1-year increments) for the period 2006–2020. Next, we estimated

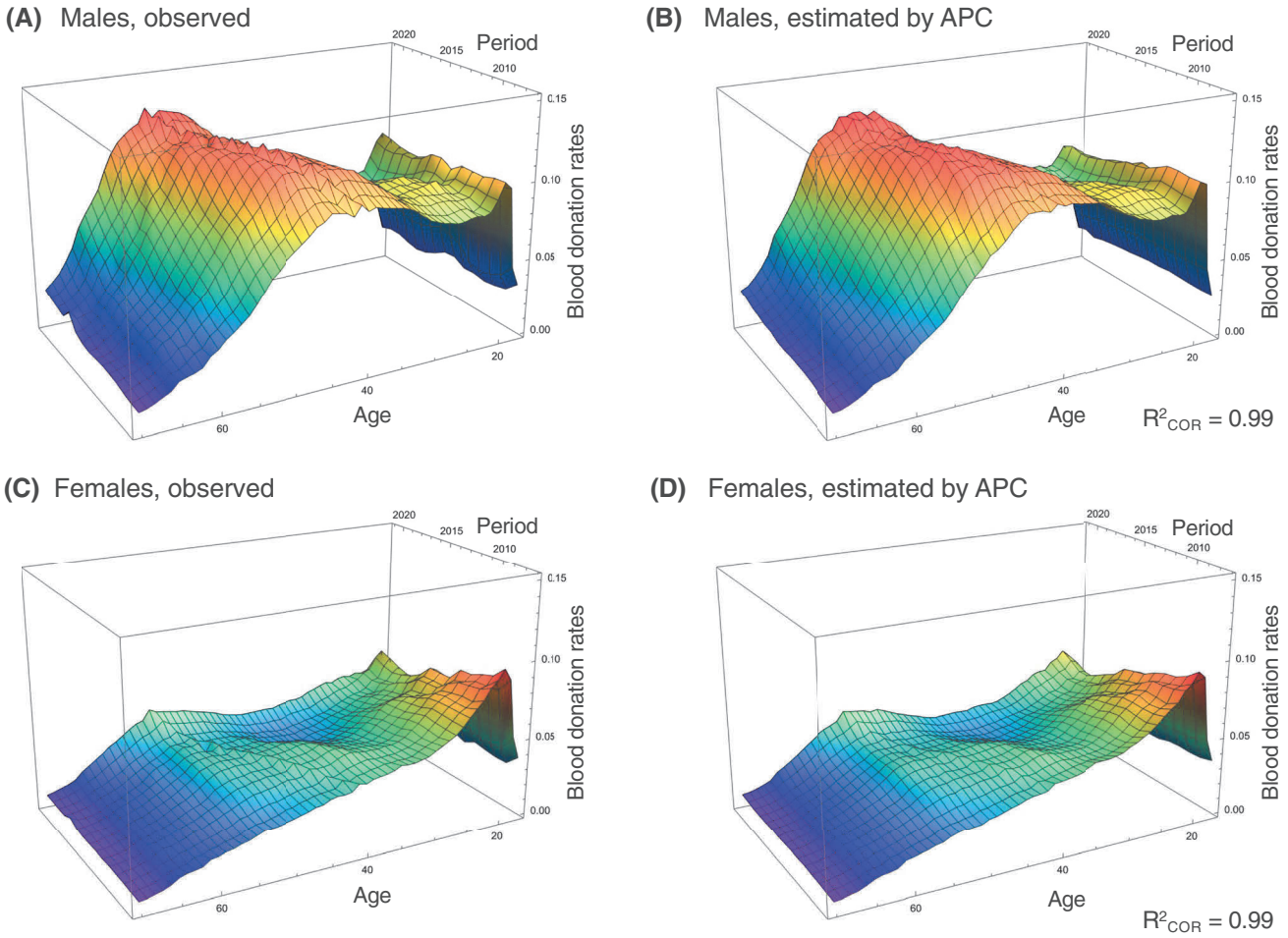


FIGURE 1 Comparison of observed blood donation rates and estimated blood donation rates using the age-period-cohort model. Observed and reproduced blood donation rates from 2006 to 2020 are shown in the 3D graphs: (A). Observed blood donation rate in males; (B). Estimated blood donation rate by age-period-cohort model in males; (C). Observed blood donation rate in females; (D). Estimated blood donation rates by age-period-cohort model in females. [Color figure can be viewed at wileyonlinelibrary.com]

the age factor, period factor, and birth cohort factor of blood donation rates by sex using the APC model.

$$y_{ij} \sim \text{Poisson}\left(\mu_{ij}\right), \log\left(\mu_{ij}\right) = \log\left(P_{ij}\right) + \mu + A_i + P_j + C_k$$

where μ, A_i, P_j, and C_k denote intercept, factor of i-th age group ($i = 16, 17, ..., 69$), factor of j-th time period ($j = 2006, 2007, ..., 2020$) and factor of k-th birth cohort ($k = 1937, 1938, ..., 2004$), respectively. μ_{ij}, y_{ij}, and P_{ij} denote the expected number of donations, the observed number of donors, and the population in i-th age group, and j-th time period, respectively.

The APC model has methodical drawbacks, which is called the identification problem. There are various approaches to solving the identification problem, such as imposing constraints or using modeling (Bayesian, time series) methods.[8] We assumed that two effects of the birth cohort factor, 1963 and 1964, would be the same to overcome this problem by Barrett's technique.[9] We set the baseline of each factor as 16 years old (age factor), the year 2006 for time period (period factor) and 1963 and 1964 for birth year cohorts (birth cohort factor), respectively. Each factor was estimated by the maximum likelihood method. The modified determination coefficient R^2_{COR}[10] was used to compare observed and estimated blood donation rates (see Appendix A for details).

Finally, predicted blood donation rates during 2021–2035 were calculated based on estimated age, period, and birth cohort factors. It was assumed that the period factor after the year 2020 and the birth cohort factor after the year 2004 remained unchanged. Future population predictions were used to calculate the predicted number of blood donations during 2021–2035.

JMP Pro ver. 15 (SAS Institute, Cary, NC, USA) was used for statistical analysis.

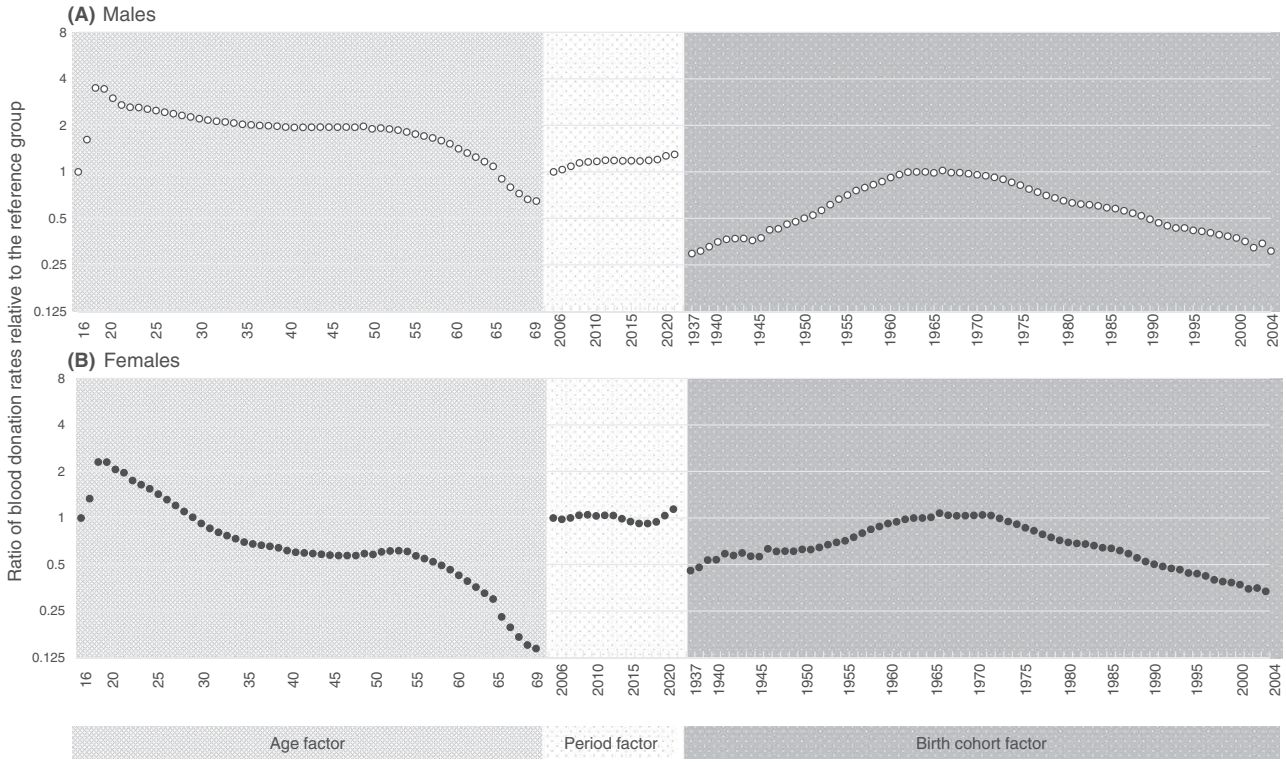


FIGURE 2 Age factor, period factor, and birth cohort factor on blood donation rates using the age-period-cohort model. Age factor, period factor, and birth cohort factor of blood donation rates by sex. (A). Male; (B). Female. The baselines are age factor 16 years old, period factor 2006 and birth cohort factor 1963 and 1964.

3 | RESULTS

3.1 | Comparison of observed blood donation rates and estimated blood donation rates using the age-period-cohort model

Figure 1 shows 3D graphs of blood donation rates by sex for the period 2006–2020. The observed blood donation rates for males (A) and females (C) are compared with the estimated blood donation rates from the APC model (B and D). Observed blood donation rates are closely reproduced by estimated blood donation rates in both sexes with very high modified determination coefficients ($R^2_{COR} = 0.99$).

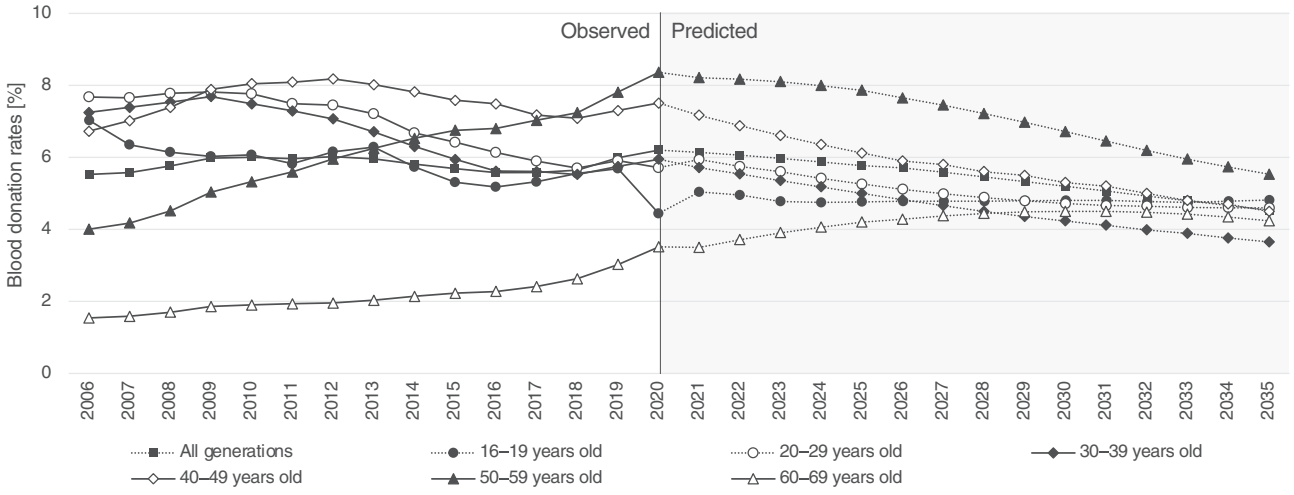
3.2 | Age factor, period factor, and birth cohort factor on blood donation rates

The age factor, period factor, and birth cohort factor of the APC model are shown in Figure 2. For both males and females, the ratio of blood donation rates peaked at 18 years old, and the relative ratio of blood donation rates tended to decrease with increasing age. For males, the rates remained flat from 30 to 59 years old, with a sharp decline in the 60s. For females, the blood donation rate was the rate remained flat from 35 to 50 years old, and decline in the 50s. The period factor did not change significantly, but it increased in 2020, the year of the COVID-19 pandemic, from the previous year. Blood donation rates for both males and females tended to be higher for birth cohorts born in the 1960s and 1970s and lower for other birth years.

3.3 | Observed blood donation rates by age group for 2006–2020 and predicted blood donation rates by age group using age-period-cohort model for 2021–2035

The observed blood donation rates by age group for 2006–2020 and predicted blood donation rates for 2021–2035 are shown in Figure 3. In terms of observed blood donation rates, those 16–19 years old decreased by 1.3% from 5.7% in 2019 to 4.4% in 2020, those aged 20–29 years old decreased by 0.2% from 5.9% in 2019 to 5.7% in 2020, and those aged 30–39 years old and older increased by 0.2%–0.6%. Therefore, the effect of the COVID-19 pandemic on the decline in blood donation behavior was apparent in 16–19 years old and 20s.

As the BD research group predicted the blood donation rates up to 2025, we confirmed how the predicted value in 2025 changed from their study to the current



	Observed															Predicted						
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
All generations	5.5	5.6	5.8	6.0	6.0	6.0	6.0	6.0	5.8	5.7	5.6	5.6	5.6	6.0	6.2	6.1	6.1	6.0	5.9	5.8	5.2	4.5
16–19 years old	7.0	6.3	6.1	6.0	6.1	5.8	6.2	6.3	5.7	5.3	5.2	5.3	5.6	5.7	4.4	5.0	5.0	4.8	4.8	4.8	4.8	4.8
20–29 years old	7.7	7.7	7.8	7.8	7.8	7.5	7.5	7.2	6.7	6.4	6.1	5.9	5.7	5.9	5.7	5.9	5.7	5.6	5.4	5.3	4.7	4.6
30–39 years old	7.2	7.4	7.5	7.7	7.5	7.3	7.1	6.7	6.3	5.9	5.6	5.6	5.5	5.8	6.0	5.7	5.5	5.4	5.2	5.0	4.2	3.7
40–49 years old	6.7	7.0	7.4	7.9	8.0	8.1	8.2	8.0	7.8	7.6	7.5	7.2	7.1	7.3	7.5	7.2	6.9	6.6	6.4	6.1	5.3	4.5
50–59 years old	4.0	4.2	4.5	5.0	5.3	5.6	6.0	6.3	6.5	6.8	6.8	7.0	7.2	7.8	8.4	8.2	8.2	8.1	8.0	7.9	6.7	5.5
60–69 years old	1.5	1.6	1.7	1.9	1.9	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.6	3.0	3.5	3.5	3.7	3.9	4.1	4.2	4.5	4.2

Blood donation ratio [%]

FIGURE 3 Observed blood donation rates by donor's age group in 2006–2020 and predicted blood donation rates by donor's age group based on age-period-cohort model in 2021–2035.

study. The blood donation rate for all age groups in 2025 was 5.8% in current research and 5.7% in BD research group, an increase of 0.1%. Comparing blood donation rates by age group, those 16–19 years old decreased 0.4% from 5.2% to 4.8%; those 20–29 years old decreased 0.2% from 5.5% to 5.3%; those 30–39 years old increased 0.1% from 4.9% to 5.0%; those 40–49 years old increased 0.1% from 6.0% to 6.1%; and those 50–59 years old increased 7.5% to 7.9%. The number of blood donations between 60 and 69 years old increased by 0.3%, from 3.9% to 4.2% (Figure 4). As for the number of blood donations, there was a decrease in the 16–19 years old and 20–29 years old and an increase from the 30–39 years group onwards. (Table 1).

3.4 | Number of observed blood donations by donor's age group in 2006–2020 and predicted blood donations by donor's age group using the age-period-cohort model in 2021–2035

The observed number of blood donations and the predicted number of blood donations based on the APC model are shown in Figure 5, Table 2. Number of blood donations was 5.04 million in 2020, an increase of 0.11 million from 4.93 million in 2019. The predicted number of blood donations from 2021 to 2035 was 4.93 million in 2021, 4.49 million in 2025, 3.90 million in 2030 and 3.28 million in 2035, with a yearly decrease.

4 | DISCUSSION

We conducted the analysis to clarify the factors related to the number of blood donations and predicted the future trend of blood donations, using nationwide blood donation data including the COVID-19 pandemic era by the APC model. The predicted number of blood donations (blood donation rate) is calculated to be 4.49 million (5.8%) in 2025, 3.90 million (5.2%) in 2030, and 3.28 million (4.5%) in 2035. The predicted blood donation rate in 2025 is not significantly different from the prediction by BD research group which only used blood donation data before the COVID-19 pandemic era (the predicted blood donation rate and number of blood donations are 5.7% and 4.40 million, respectively). However, by age group, the predicted blood donation rate decreased for those 16–19 years old and 20–29 years old, while it increased for those 50–59 years old and 60–69 years old, suggesting that the factor of the COVID-19 pandemic on blood donation behavior varies by age group.

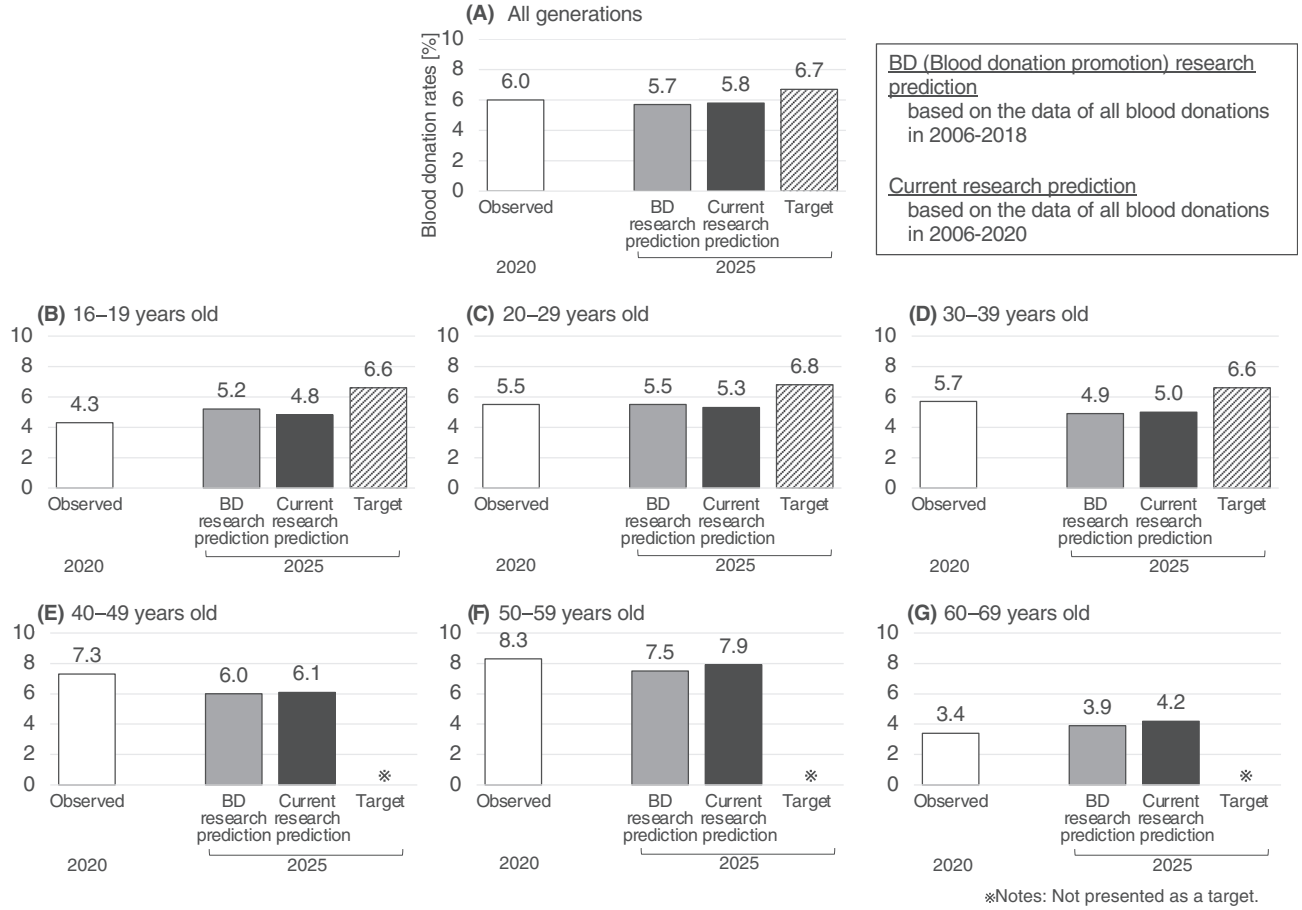


FIGURE 4 Observed blood donation rate in 2020, estimated blood donation rate using age-cohort model based on the observed number of blood donations through 2018, predicted blood donation rate using age-period-cohort model based on the observed number of blood donations through 2020, and target blood donation rate for blood donation promotion 2025. From left to right: observed blood donation rate in 2020, estimated blood donation rate using age-cohort model based on the observed number of blood donations through 2018, predicted blood donation rate using age-period-cohort model based on the observed number of blood donations through 2020, and target blood donation rate for blood donation promotion 2025. (A). all generations; (B). 16–19 years old; (C). 20–29 years old; (D). 30–39 years old; (E). 40–49 years old; (F). 50–59 years old; and (G). 60–69 years old.

Several methods to predict the number of blood donations have been suggested. Akita et al applied a Markov model to blood donation data and estimated that the number of blood donations in their 20s and 30s would decrease year by year, and that the number of blood donations would be 4.77 million in 2025.[11] Takanashi et al simulated the demand and supply of blood products in Japan based on the proportion of blood donation to the total suitable age population and the future population and reported a shortage of 1.01 million blood donations in 2027.[12] Abe et al. estimated that raising the ratio of blood donations to the total population to 5% would ensure that the required number of blood donations would be available until 2060.[13] Tanaka et al. found that blood donation behavior is characterized by age factor and birth cohort factor.[14]

However, since the COVID-19 pandemic affect blood donors' behavior among all generations in that era, regardless of age or birth cohort, we applied the APC model to analyze and predict the number of blood donations to consider the period factor. As a consequence, the period factor on blood donation rates in 2020 did not decrease despite the COVID-19 pandemic occurred, and the number of blood donations in 2020 was 5.04 million, 0.11 million more than the 4.93 million donations in 2019. That is, in focusing on the total number of blood donations, behavioral restrictions did not relate to it. In fact, as the observed number of blood donations decreased by up to 9.4% against the target number of blood donations in late February 2020, the JRCS strongly encouraged the public that blood donation was not an unnecessary outing and repeatedly communicated blood donations and blood donor cooperative organizations through letters, e-mails, phone calls and social media (Twitter, Facebook, Instagram, and YouTube). It also

TABLE 1 Estimated number of blood donations and blood donation rates by age group for 2006–2020 and predicted number of blood donations and blood donation rates by age group based on age-period-cohort model for 2021–2035.

		All generations	16–19	20–29	30–39	40–49	50–59	60–69
2020	Observed number of blood donations and donation rate in 2020, *n* (%)	5,037,920 (6.0)	203,467 (4.3)	705,192 (5.5)	827,843 (5.7)	1,364,830 (7.3)	1,386,032 (8.3)	550,556 (3.4)
2025	Predicted number of blood donations and donation rate by blood donation promotion research group, *n* (%) (Using data 2006–2018)	4,399,457 (5.7)	225,473 (5.2)	659,030 (5.5)	623,999 (4.9)	934,147 (6.0)	1,369,233 (7.5)	587,574 (3.9)
	Predicted number of blood donations and donation rate by current research group, *n* (%) (Using data 2006–2020)	4,490,460 (5.8)	204,923 (4.8)	631,472 (5.3)	635,009 (5.0)	959,693 (6.1)	1,433,922 (7.9)	625,442 (4.2)
	Change of prediction, *n* (%)	+91,003 +0.1	−20,550 −0.4	−27,558 −0.2	+11,010 +0.1	+25,546 +0.1	+64,689 +0.4	+37,868 +0.3

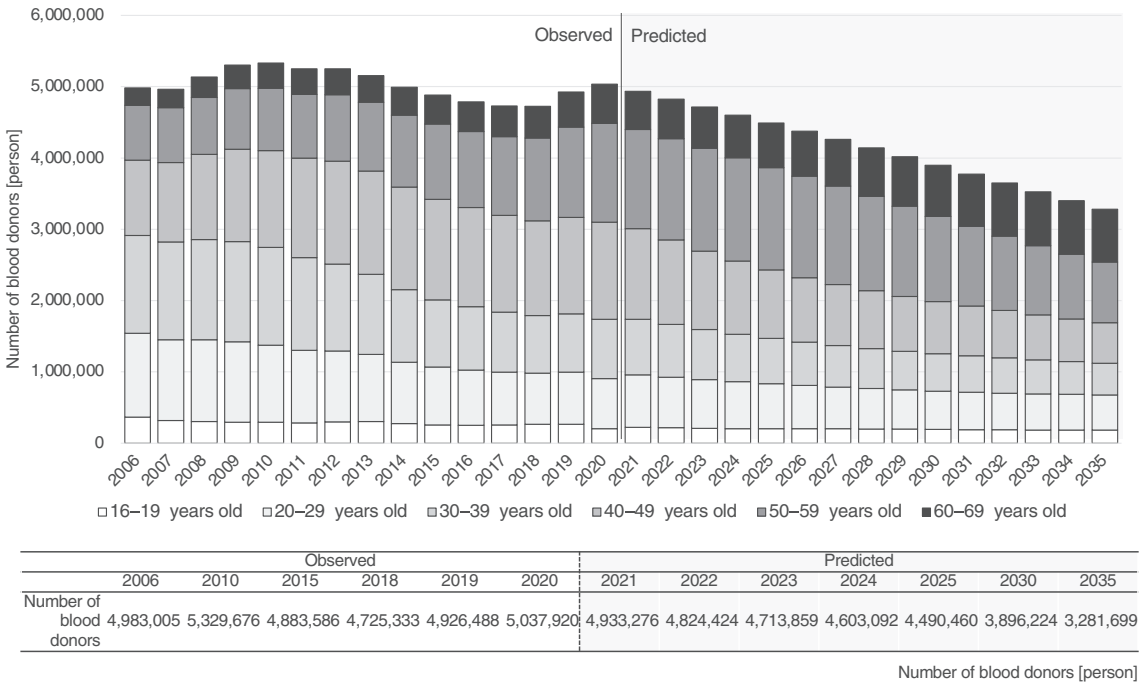


FIGURE 5 Observed number of blood donations by donor's age group in 2006–2020 and predicted number of blood donations by donor's age group based on age-period-cohort model in 2021–2035.

requested that media outlets such as television, radio, and newspapers to call for active cooperation in blood donation.[15] Furthermore, the MHLW requested each prefectural government to promote awareness of blood donation practices and to secure blood donation sites through mobile blood donations in shopping malls, and so forth.[16] As a result, the annual number of blood donations in 2020 are not expected to have decreased.

Previous studies have shown that the persistence rate of blood donation is high for middle-aged and older men.[17]

TABLE 2 Observed number of blood donations by donor's age group in 2006–2020 and predicted number of blood donations by donor's age group based on age-period-cohort model in 2021–2035.

Year		Observed							Predicted by APC model						
		2006	2010	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035
Both sex	**All generations**	**4,983,005**	**5,329,676**	**4,788,211**	**4,728,837**	**4,725,333**	**4,926,488**	**5,037,920**	**4,933,276**	**4,824,424**	**4,713,859**	**4,603,092**	**4,490,460**	**3,896,224**	**3,281,699**
Male	16–19 years old	188,588	155,957	149,854	151,983	154,734	153,761	111,882	124,258	119,145	112,032	110,905	111,127	106,145	101,229
	20–29 years old	657,010	640,309	487,253	466,862	450,971	453,124	420,362	444,413	429,388	417,988	400,573	383,716	318,649	292,083
	30–39 years old	922,680	949,515	646,594	613,689	588,538	588,948	571,836	549,170	523,014	495,711	472,027	450,622	376,209	316,863
	40–49 years old	762,958	1,006,254	1,058,076	1,032,769	1,007,164	1,009,254	995,579	931,459	869,158	808,084	752,191	703,806	539,635	422,228
	50–59 years old	527,227	630,735	801,720	841,166	879,349	951,630	1,019,790	1,016,597	1,033,013	1,044,902	1,047,316	1,035,387	859,158	612,169
	60–69 years old	154,238	240,301	314,091	326,997	343,138	376,929	421,288	403,867	421,140	439,051	456,796	475,550	537,984	553,419
Female	16–19 years old	178,012	139,818	101,582	105,625	110,999	112,037	91,585	101,206	97,890	94,715	93,797	93,796	89,630	85,107
	20–29 years old	519,822	440,505	287,489	271,396	265,026	276,177	284,830	288,368	277,927	268,570	257,934	247,755	214,945	200,599
	30–39 years old	448,625	419,120	241,957	227,624	219,654	230,762	256,007	229,104	216,987	204,855	194,038	184,387	149,671	125,218
	40–49 years old	291,304	353,417	335,195	324,471	321,940	341,181	369,251	339,009	315,873	293,816	273,727	255,886	192,869	146,980
	50–59 years old	243,739	243,850	261,565	265,941	280,794	318,627	366,242	376,347	387,350	395,658	400,259	398,534	336,817	239,017
	60–69 years old	88,802	109,895	102,835	100,314	103,026	114,058	129,268	129,478	133,539	138,478	143,527	149,892	174,511	186,787

However, our study showed that the age factor was the highest around the 20 years old, and decreased monotonically at later ages, with no tendency to be higher among the middle-aged and older age groups. On the other hand, the birth cohort in 1960–1974 was highest in the birth cohort factor. One of the reasons for the high birth cohort factor in 1960–1974 is *the school blood donation program*.[14] In Japan, high school blood donation used to be widely practiced, and many of current middle-aged and older blood donations had experienced their first blood donation at a school blood donation bus when they were in high school.[18] However, the number of school blood donations has been decreasing year by year. The reason is the promotion of 400 mL blood donation and the difficulty of securing classroom time. Therefore, alternative measures to school blood donation program are needed to encourage first-time donations. Currently, the MHLW or JRC is creating blood donation awareness materials for young people and conducting "Kids' Blood Donation (simulated blood donation)" aimed at spreading knowledge about blood donation from the elementary and junior high school age. In addition, efforts are being made to bring young children into contact with blood donation at an early age through such activities as the "My Blood, Everyone's Blood" picture book for young children. On the other hand, the fact that the age effect peaked at around 20 years old suggests that many high school and college/university students who used to donate blood have stopped donating since they started working and that it is important to encourage them to continue donating blood after they enter the workforce and to increase the number of multiple blood donations.

Comparing the predicted blood donation rate in 2025 by BD research group[14] and our study, there was a 0.4% decrease for those 16–19 years old and a 0.2% decrease for those 20–29 years old. In terms of the number of blood donations, they have predicted a drop of 20,550 for the 16–19 years old and a drop of 27,558 for the 20–29 years old. These reasons are thought to be due to the fact that school was closed and opportunities to get out of the home were greatly reduced. By age group, the 18–29 years old tends to have a lower rate of going out during declared emergencies than other age groups.[19] However, those in their 30s and older were increased. In specially, there was a 0.4% increase for those in the 50–59 years old, and a 0.3% increase for those in the 60–69 years old. One possible reason for this fact is that the JRCS has been giving priority to repeat blood donations by calling them directly when a shortage of blood donations is expected.[20] The JRCS established the Repeat Blood Donor Club (nicknamed "Love Blood") in 2006 to ask for their continued cooperation in blood donation and to improve services for blood donations. When there is a shortage of blood donations, it is possible to call for blood donations through the Love Blood. Many of the blood donors in Love Blood were between the 40 years old and 69 years old, who are frequent multiple donors, and it is thought that they responded well to the call and donated blood even in the event of the COVID-19 pandemic. Thus, it is clear that the change of blood donation rate in the COVID-19 era differed by age group. Therefore, it is necessary to strongly encourage younger people to donate blood, even more so than before the COVID-19 pandemic, because of the birth cohort who are 40–69 years old in current have a high blood donation rate, and when the group becomes out of eligible blood donation age, the overall blood donation rate can be expected to decrease rapidly. Therefore, increasing the blood donation rate among 16–29 years old is a emargency issue. It has been reported[17] that young people who donate blood twice in the same year in which they donate blood for the first time have a higher persistent blood donation rate in subsequent years. Thus, it is also important to take measures to secure new blood donations and to encourage them to continue donating blood every year.

During the research period, the number of blood donations reached a low of 4.73 million in 2018 and continued to increase until 2020. However, the number of blood donations is predicted to decrease to 4.49 million by 2025, 3.90 million by 2030, and 3.28 million by 2035. The rapid decrease is also thought to be due to the fact that a elder people those with high blood donation rates will no longer be able to donate blood. On the other hand, the number of blood donations falls sharply when the birth cohorts who are avid blood donors turn 69 years old or older. The United States and Canada have removed the upper age limit for blood donation. It may be valuable that discuss the removal of upper age limit in Japan to avoid the rapid decrease in blood donations. Alternatively, the annual supply of blood products in 2020 is approximately 4.92 million units, which is approximately 80,000 units less than the 5 million units supplied in 2019. In order to ensure that blood products are delivered to those in need of transfusion without excesses or shortages, targets for the number of blood donations need to be set taking into account demand.

This research has several limitations. Period effects include both of a decrease in blood donor trends due to the effect of the COVID-19 pandemic and an increase due to the JRCS awareness-raising campaign, but these cannot be individually disaggregated and verified. In addition, the affected frequency limits for different types of blood donation could not be taken into consideration.

5 | CONCLUSIONS

In this research, the future number of blood donations until 2035 was predicted using the APC model in order to understand the trend changes in the number of blood donations during the COVID-19 pandemic and the future prospects based on these trends. The results showed that the observed number of blood donations in 2020 was 5.04 million, an increase of 0.11 million compared to 2019, despite the COVID-19 pandemic, the expected number of blood donations in 2025 was projected to be 4.49 million, 0.09 million more than the BD research group of 4.40 million. The blood donation rate by age group decreased in the 16–19 years old and 20–29 years old and increased in the 50–59 years old and 60–69 years old. In order to secure blood donor numbers during and after the COVID-19 pandemic, different approaches to blood donation promotion by generation are needed.

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CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflict of interest with respect to this research study and paper.

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APPENDIX A: CRITERIA FOR GOODNESS OF FIT

Usually, determination coefficient R^2 is used for simple and multivariate regression analysis because of assumption of variance. We used modified determination coefficient as follows.[9]

$$R^2_{COR} = \frac{\left(\sum \left(r_{ij} - \overline{r}\right)\left(\widehat{r}_{ij} - \overline{\widehat{r}}\right)\right)^2}{\sum \left(r_{ij} - \overline{r}\right)^2 \sum \left(\widehat{r}_{ij} - \overline{\widehat{r}}\right)^2}$$

as criteria of goodness of fit, where r_{ij} means blood donation rate, symbol "hat" means estimator and symbol "bar" means average. $R^2{}_{\mathrm{COR}}$ has a similar character with R^2 such as $0 \leqq R^2{}_{\mathrm{COR}} \leqq 1$.