

Does High Systolic Blood Pressure Truly Increase Medical Expenditure?

—An Empirical Analysis of the New 2017 ACC/AHA Hypertension Guideline

Kazumitsu Nawata^{1,2}, Moriyo Kimura³

¹Graduate School of Engineering, University of Tokyo, Tokyo, Japan

²Research Institute of Economy, Trade and Industry (RIETI), Tokyo, Japan

³The Public Health Institute, Tokyo, Japan

Email: nawata@tmi.t.u-tokyo.ac.jp, kimuramoriyo@gmail.com

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Abstract

Background: High blood pressure (BP) or hypertension is considered one of the top global disease burden risk factors. In November 2017, the ACC/AHA and other organizations announced a new hypertension guideline of 130/80 mmHg. **Data and Methods:** We evaluate the effects of BP on increases in medical expenditures using transformation tobit models and a dataset containing 175,123 medical checkups and 6,312,125 receipts from 88,211 individuals in three health insurance societies. The sample period was April 2013 to March 2016. We first created a database of combined checkup results and medical expenditures. The power transformation tobit model was then used to remove the effects of other variables, and we investigated the relation between medical expenditures and BP, especially systolic BP (SBP). **Results:** We observed negative effects of SBP on medical expenditures. The results raise uncertainty about the reliability of the new guideline, at least for SBP. Although the simple correlation coefficient of medical expenditures and SBP was positive, the sign of the SBP estimate became negative when a variable representing obesity was included. In terms of other medical checkup items, while LDL is considered the “bad” cholesterol, it reduced medical expenditures. **Conclusion:** Our results did not support the new 2017 ACC/AHA guideline for SBP. A wide and careful range of reviews not only for heart diseases but also for other disease types will be absolutely necessary. New studies to verify the guideline should also be conducted. **Limitations:** The dataset was observational, the sample period only 3 years, and we could not complete a time-series analysis of individuals.

Keywords

Blood Pressure, Hypertension, 2017 ACC/AHA Hypertension Guideline,

1. Introduction

The World Health Organization (WHO) [1] reports that, “Five of the top 10 selected global disease burden risk factors identified by World Health Report 2002: reducing risks, promoting healthy life—obesity, high blood pressure, high cholesterol, alcohol and tobacco.” In terms of blood pressure (BP), the WHO [2] states: “Worldwide, raised blood pressure is estimated to cause 7.5 million deaths, about 12.8% of the total of all deaths. This accounts for 57 million disability adjusted life years (DALYS) or 3.7% of total DALYS.” It also specified “complication of hypertension accounted for 9.4 million deaths in each year” [3]. Lim *et al.* [4] also found that hypertension was one of the three leading risk factors for the global disease burden (GDB) in 2010. Guidelines stated individuals should be treated for high BP or hypertension when their systolic BP (SBP; during the heart beat) is 140 mmHg or more, or their diastolic BP (DBP, when the heart is at rest) is 90 mmHg or more [5]. (For problems with BP measurement errors due to the white-coat effect and other factors, see [6] [7] [8] [9]).

The National Heart, Lung and Blood Institute [10] classified hypertension as Stage 1 (SBP of 140 - 159 mmHg; DBP of 90 - 99 mmHg) and Stage 2 (SBP of 160 mmHg or more; DBP of 100 mmHg). It has been reported that the risk of cardiac diseases increased with BP level in all age groups [11] [12]. WHO and the International Society of Hypertension (ISH) [13] provide guidelines for controlling hypertension WHO-ISH classified hypertension into three categories: Grade 1 (mild) - SBP of 140 - 159 mmHg, DBP of 90 - 99 mmHg; Grade 2 (moderate) - SBP of 160 - 179 mmHg, DBP of 100-109 mmHg; and Grade 3 (severe) - SBP of 180 mmHg or more, DBP of 110 mmHg or more. Based on BP and other risk factors, they concluded that the risk of a major cardiovascular event over a 10-year period was about 20% - 30% in high-risk and 30% or more in high- and very-high-risk groups.

The Prospective Studies Collaboration [14] performed a meta-analysis of individual data for 1,000,000 adults in 61 prospective analyses. They studied 12.7 million person-years at risk. They identified about 56,000 cases of vascular death, including 12,000 stroke, 34,000 ischaemic heart disease (IHD), and other vascular deaths. They found that IHD mortality increased in all age cohorts (from 40 - 49 to 80 - 89) as SBP and DBP increased. Moreover, hypertension lowered quality of life (QOL) [15] [16], and the true cost including indirect cost such as effects on QOL is considered to be much higher than the direct cost. It is estimated that hypertension caused 4.5% of the current GDB [17], suboptimal BP cost \$370 (US \$) billion globally in 2001 [18], and hypertension cost the U.S. about \$51.2 billion per year in 2012-2013 [19] [20]. The Centers for Disease Control and Prevention (CDC) [21] estimated high BP costs the U.S. \$48.6 bil-

lion per year. The medical expenditure for hypertension and related diseases reached as high as 1.85 trillion yen in fiscal year 2015 in Japan [22]. Almost all studies agree that hypertension is a major health risk factor and costly disease.

Race, genetic and environmental factors, and health administrative activities are important factors for BP [7] [23] [24]. For example, Rose [25] compared the distribution of SBP in Kenyan nomads and London civil servants, and found that the former was much lower than the latter. Nawata *et al.* [26] reported that various factors such as age, gender, health conditions and lifestyle strongly affected BP levels in Japan. They found that SBP increased about 5 mmHg with 10 years of increased age, and was 4 mmHg higher in males. These facts raised questions about the results of previous studies. For example, the Prospective Studies Collaboration study [14] selection criteria for the analyses did not clarify the reasons for the 10-year age cohort interval, or the methods for removing effects of individual characteristics other than BP.

Many hypertension patients have few or no subjective symptoms. The distribution of BP is close to the normal distribution, and even becomes a statistical example of normal distribution [27], while the definition of hypertension is artificial and may be altered in the future by the accumulation of new medical knowledge.

More recently, the American College of Cardiology (ACC), American Heart Association (AHA), and nine other organizations [28] published the “2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults” (hereafter, 2017 ACC/AHA guideline). Under the new guideline, the threshold for hypertension, requiring treatment with lifestyle changes and medication, is 130/80 mmHg. The 2017 ACC/AHA guideline replaces the term “prehypertension” with “elevated BP” (SBP 120 - 129 mmHg and DBP below 80 mm Hg) and “stage 1 hypertension” (SBP 130 - 139 mmHg or DBP 80 - 89 mmHg). Stage 2 hypertension is defined as SBP of 140 mmHg or more, or DBP of 90 mmHg or more (replacing BP of 160/100 mmHg or more [28] [29] [30]). However, the American Academy of Family Physicians (AAFP), one organization asked to join the publication, announced on December 12, 2017, that “AAFP Decides to Not Endorse AHA/ACC Hypertension Guideline, Academy Continues to Endorse JNC8 Guideline” [31].

As a reason for withholding its endorsement, the AAFP stated that the new guideline lacked a systematic review, and would classify 46% of the U.S. adult population as having hypertension, a 32% increase. Dr. O’Gurek, chair of the AAFP’s Commission on Health of the Public and Science added: “although the guideline’s recommendations were given an evidence quality grade, they weren’t grounded in an assessment of the background resources. Finally, substantial weight was given to the Systolic Blood Pressure Intervention Trial (SPRINT), but other trials were minimized.” Actually, the word “SPRINT” was used many times in the main text of the 2017 ACC/AHA guideline. In the SPRINT [32],

9361 individuals with a SBP of 130 mmHg or higher and an increased cardiovascular risk, but without diabetes, were randomly assigned to a SBP target of less than 120 mmHg (intensive treatment) or a target of less than 140 mmHg (standard treatment). The trial period was from November 2010 to March 2013, and was stopped early after a median follow-up of 3.26 years owing to a significantly lower rate in the intensive treatment group.

As Nawata, Sekizawa and Kimura [33] point out, however, biases such as a publication [34] [35] [36], conflict of interest [37] [38] [39], and termination (or endpoint) biases [40] might exist in randomized clinical trials (RCT). The change of the hypertension guideline will affect the medical system worldwide. As suggested by the AAFP [31], careful and wide-ranging reviews are needed to determine the hypertension guideline. The Action to Cardiovascular Risk in Diabetes (ACCORD) Study Group [41] did a similar trial for 4733 participants with type 2 diabetes. In that study, 491 were recruited from January-June 2001, and an additional 4242 were recruited from January 2003 through October 2005. The researchers concluded that targeting SBP below 120 mmHg did not reduce the rate of composite outcome of fatal and major nonfatal major cardiovascular events compared to below 140 mmHg. The SPRINT research group [32] themselves admitted: “Rates of serious adverse events of hypertension, ... and acute kidney injury, ... were higher in the intensive-treatment group than in the standard-treatment group.” In other words, further investigation as to whether the new guideline is appropriate or not are absolutely necessary. Such research must include not only cardiovascular diseases but also all other (serious) diseases. Since the influence of the AHA/ACC Guideline is so vast, these studies must be done as soon as possible.

In this paper, we analyze the effects of BP (especially SBP) on annual medical expenditures using a dataset containing 175,123 medical checkups and 6,312,125 receipts obtained from 88,211 individuals. The power transformation tobit model [42] is used in the analysis, because the distribution of medical expenditure shows a heavy tail on the right side and many “zeroes” are observed. Although we did not directly analyze heart diseases, medical expenditure is a very important indicator representing the health conditions of an individual. The sample period is from fiscal year 2013 to 2015 (*i.e.*, April 2013 to March 2016).

2. Data and Methods

In this paper, we used an anonymized dataset combining medical checkups and receipts. First, we compared the distributions of medical expenditures for each fiscal year. Various characteristics and health conditions, including BP, affect medical expenditures. To measure the effects of BP correctly, it is necessary to remove the effects of other variables; we therefore employed a regression-type analysis. However, there are problems, as previously identified by Gregori *et al.* [43]. One is that medical expenditures take many zero values (about 20%). The other is that the distribution is asymmetric and has a very heavy tail, and the va-

riance becomes very large. It may not be best to use the ordinary least squares methods in such cases. We therefore used the power transformation tobit model for the analysis.

2.1. Data

Japan employs a public health insurance system for the whole nation, and everyone must join some type of public health insurance organization. Corporations form health insurance societies for employees and their family members. Most employees 40 or older are required to have a medical checkup once a year by the Industrial Safety and Health Act [44], and family members can voluntarily have such checkups. The dataset was created with the cooperation of three health insurance societies (Societies 1 - 3).

Society 1 was formed at a large Japanese corporation with offices and operational centers throughout Japan. Societies 2 and 3 were formed by groups of corporations. The dataset contained information regarding 175,123 medical checkups from 88,211 individuals between fiscal years 2013-2015 (*i.e.*, April 2013 to March 2016). The monthly reports of medical treatments and payments, called “receipts”, are sent from medical institutes to the health insurance associations. Payments are made to the medical institutes after checking the receipts. (According to the Health Insurance Claims Review & Reimbursement Services [45], nearly 99% of receipts were paid as requested in March 2018.) Receipts were classified into five categories: dental; inpatients of DPC hospitals; outpatients and inpatients of non-DPC hospitals; and pharmacies. Of these, we used the sum of DPC, outpatient & non-DPC hospital, and pharmacy receipts as the medical expenditure.

Japan measures medical expenditures in points, paying 10 yen per point to medical institutes. Moreover, the same points are allotted for the same treatments and medicines determined by the government regardless of region and medical institution, with a few exceptions [46]. This means that medical expenditure is a good indicator of the health condition of an individual in Japan. A total of 6,312,125 receipts were summed, and medical expenditures in each fiscal year were calculated. In the analysis, we used the dataset containing 175,123 observations for which both the results of checkups and medical expenditures were available in the same fiscal year.

2.2. Power Transformation Tobit Model

Many studies of medical expenditures use various types of regression analyses [43] [47]. Medical expenditures do not become negative values (left censored), and there exist many zero values. Moreover, the distribution is asymmetric, having a very heavy tail on the right side, and variance is very large. Therefore, analysis by a standard regression model and ordinary least squares methods may not be the best in this case. We therefore used the power transformation model in this analysis. We briefly explain the power transformation tobit model.

1) Tobit model

The standard tobit model (or censored regression model) is given by

$$y_i^* = x_i' \beta + u_i, u_i \sim N(0, \sigma^2), i = 1, \dots, n \quad (1)$$

$$y_i = \begin{cases} y_i^* & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$$

where y_i^* is a latent variable and its value is not observable when it is negative, x_i is a vector of explanatory variables, β is a vector of unknown parameters, and u_i is an error term following the normal distribution with mean 0 and variance σ^2 . For more detail, see Amamya [48].

2) Power transformation

In the tobit model, normality of the error term is assumed. However, the medical expenditures follow the distribution with a heavy tail on the right side, and do not follow normal distribution. Since the medical expenditure takes zero values, we cannot use the log transformation. In this study, we use the power transformation to make the error term cross to the normal distribution. Gregori *et al.* [43] considered the Box-Cox transformation [49], including both log and power transformations. However, the log transformation is not included because of zero values; the power transformation is sufficient in this study. The power transformation is given by:

$$y = M^\alpha, 0 < \alpha \leq 1 \quad (2)$$

where M is the medical expenditure and α is the transformation parameter.

3) Power transformation tobit model

In this paper, we use the power transformation tobit model that combines the tobit model and power transformation. Here,

$$\frac{dy}{dM} = \alpha M^{\alpha-1}. \quad (3)$$

Therefore, the likelihood function to be maximized is obtained by

$$\begin{aligned} \log L(\theta) = & \sum_{M>0} \left\{ -\frac{1}{2} \log(2\pi) - \log(\sigma) - \frac{(y - x'\beta)^2}{2\sigma^2} + \log(\alpha) + (\alpha - 1) \log(M) \right\} \\ & + \sum_{M=0} \log \left\{ 1 - \Phi \left(\frac{x'\beta}{\sigma} \right) \right\} \end{aligned} \quad (4)$$

where Φ is the standard normal distribution function. We consider several different models, and they are explained with the estimation results. Note that when α is given, β and σ^2 are obtained by the standard tobit model. The maximum likelihood estimator (MLE) is calculated by the following scanning method [50]:

- 1) Choose $\alpha_1 < \alpha_2 < \dots < \alpha_m$ from 0.01-1.0 at intervals of 0.01.
- 2) Calculate $\hat{\beta}$ and $\hat{\sigma}^2$ for each α by the tobit maximum likelihood method.

- 3) Choose $\hat{\alpha}$ that maximizes the BC likelihood function.
- 4) Choose α_i in the neighborhood of $\hat{\alpha}$ with an interval of 0.0001, and repeat steps (2) and (3).
- 5) Determine the final estimator.

3. Distributions of Medical Expenditures and Blood Pressures

3.1. Medical Expenditures

Figure 1 shows the distribution of medical expenditures. The distribution is skewed and has a very heavy tail on the right side. The basic statistics (points) are as follows: mean: 13,356, median: 4061, standard deviation (SD): 39,241, skewness: 11.0, kurtosis: 174.0, and maximum: 1,212,291. A total of 20.2% of all observations of medical expenditures are zero. On the other hand, 1.9, 0.4, and 0.16% used more than 100,000, 300,000 and 500,000 points, and their medical expenditures accounted for 30.3, 14.3 and 7.8%, respectively, of total medical expenditures.

3.2. SBP and DBP

Figures 2-4 present the distributions of SBP and DBP, respectively. Excluding observations of BP that are too high (SBP > 300 or DBP > 200) or too low (SBP, DBP < 30), the basic statistics of SBP and DBP of 175,083 observations are given in **Table 1**. Under the 140/90 criterion, 22.8% are diagnosed with hypertension. Under the new guideline of 130/80, this value jumps up to 51.1%, more than a half of observations, suggesting the effect of changing the criterion is quite large.

3.3. Relation between SBP and Medical Expenditures

Figure 5 shows the relation of SBP to average medical expenditures. Average medical expenditures are averages of SBP at intervals of 5 mmHg (*i.e.*, for a SBP

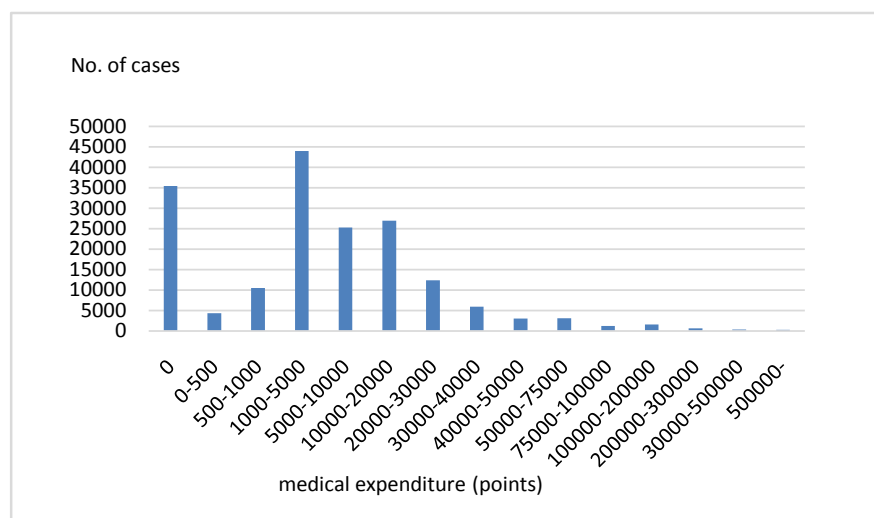


Figure 1. Distribution of medical expenditures.

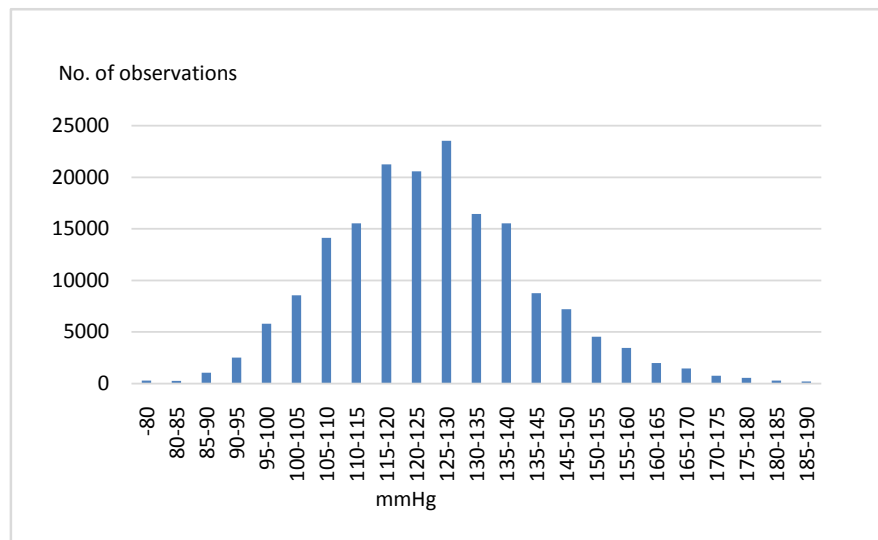


Figure 2. Distribution of SBP.

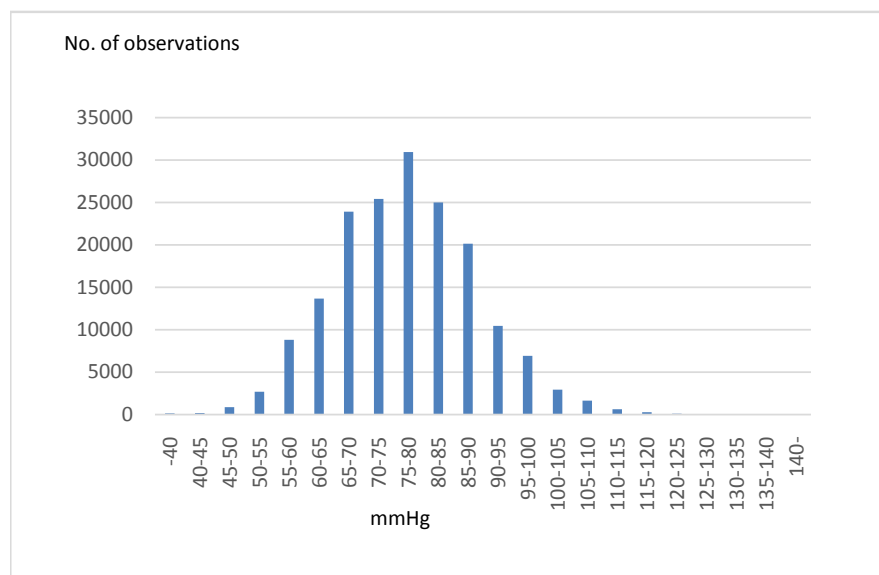


Figure 3. Distribution of DBP

Table 1. Summaries of SBP and DBP.

	SBP	DBP
Mean	125.7	77.7
Median	125	78
Maximum	278	172
Minimum	38.5	30
SD	17.1	12.0
Skewness	0.521	0.282
Kurtosis	4.128	3.454
Observations	175,083	

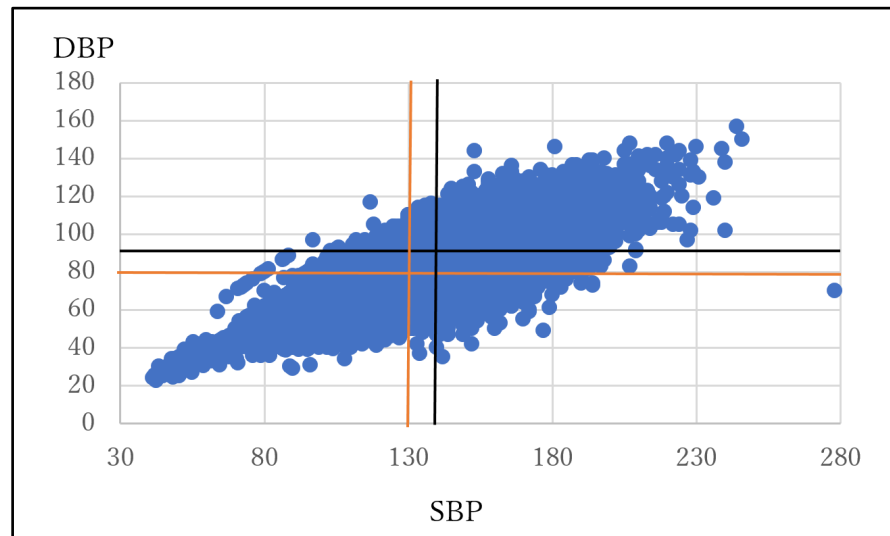


Figure 4. Relationship of SBP and DBP, and 130/80 and 140/90 criteria

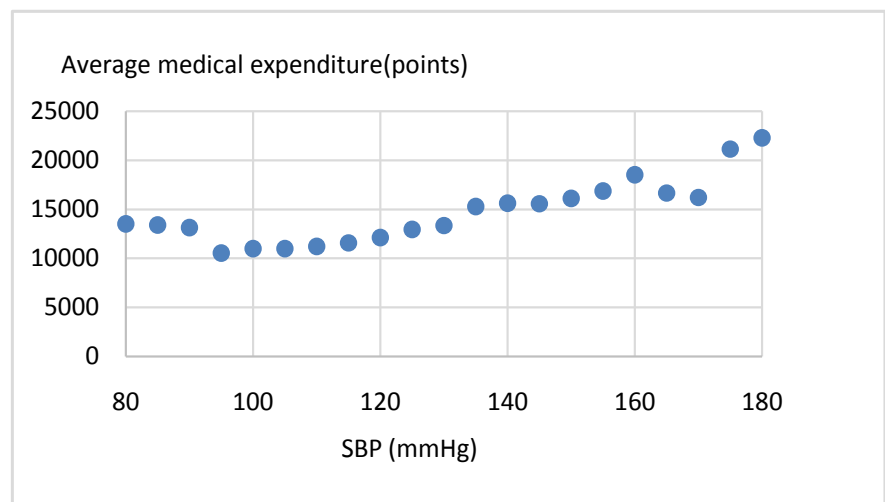


Figure 5. Relationship of average medical expenditure and SBP.

value of 130 mmHg, average medical expenditures of observations between 127.5 - 132.5 mmHg). The figure shows an upward trend, and the correlation coefficient between SBP and average medical expenditure between 80 - 180 mmHg is 0.843. This result seems to support the new guideline. But the question is whether this relation is a true or spurious one.

As already mentioned, various factors affect medical expenditures and BP. **Figure 6** shows the relationships between the average medical expenditures at intervals of 5 years by gender. As an individual ages, medical expenditure increases, and there is a difference between males and females. Nawata *et al.* [26] pointed out that BP is strongly affected by age and gender. SBP increases by 5 mmHg over a 10-year aging period, and the SBP of males is about 4 mmHg higher than that of females. BP becomes higher as an individual grows older. In the next section, we conduct the analysis by the transformation tobit model.

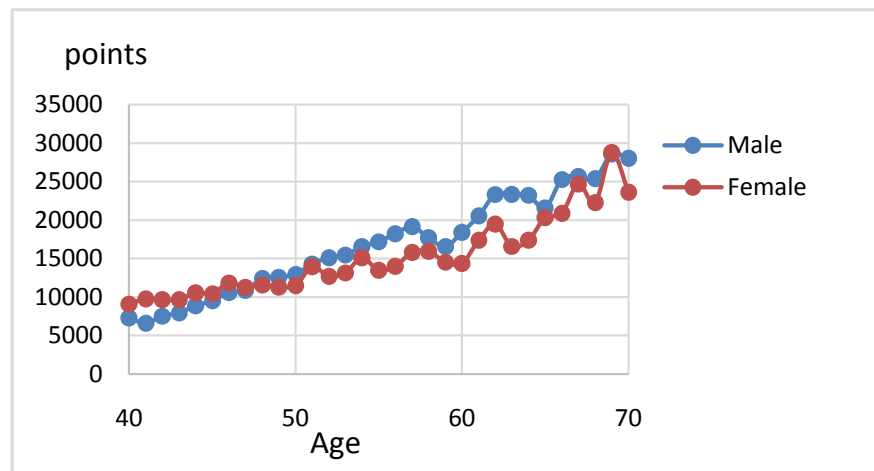


Figure 6. Medical expenditures by age and gender.

4. Results of Analysis by the Power Transformation Model Models and Explanatory Variables

Regression models are used to remove the effects of various factors. We first consider the following the power transformation tobit model in Equation (1).

Model A:

$$\begin{aligned}
 y_i^* = & \beta_1 + \beta_2 Age + \beta_3 Female + \beta_4 Height + \beta_5 BMI + \beta_6 SBP + \beta_7 DBP \\
 & + \beta_{10} HDL + \beta_9 LDL + \beta_{10} Triglyceride + \beta_{11} GGP + \beta_{12} AST + \beta_{13} ALT \\
 & + \beta_{14} Boold_Sugar + \beta_{14} Urine_sugar + \beta_{15} Urin_protein \\
 & + \beta_{16} F_year14 + \beta_{17} F_year15 + \beta_{18} Society2 + \beta_{19} Socitey3 + u
 \end{aligned} \quad (5)$$

Besides *SBP* and *DBP* (mmHg), the following explanatory variables are used. *Age*, *Female* (1: if female, 0: otherwise), *Height* (cm), *BMI* (= height (m)/weight (kg)²), *HDL* (high density lipoprotein cholesterol blood, mg/dL), *LDL* (low-density lipoprotein cholesterol, mg/dL), *Triglyceride* (mg/dL), *GGP* (γ -glutamyl transferase, U/L), *AST* (aspartate aminotransferase, U/L), *ALT* (alanine aminotransferase, U/L), *Blood_sugar* (mg/dL), *Urine_sugar* (integers of 1-5, sugar in urine increasing with number; 1 is normal, 5 is worst), *Urine_protein* (same as *Urine_sugar*), *F_year 14* (1: fiscal year 2014, 0: otherwise), *F_year 2015* (1: fiscal year 2015), *Society 2* (1: Society 2, 0: otherwise) and *Society 3* (1: Society 3, 0: otherwise) where U/L is units per liter.

For all explanatory variables, objectively measured values could be obtained from medical checkup data. This model did not include variables related to anamnesis, currently treated diseases, or individual lifestyles. For example, hypertension is an important risk factor of diabetes [51]. Suppose that the relation may be “hypertension => diabetes => medical expenditure”. In this case, if a variable representing diabetes is included, the relation of “hypertension => medical expenditure” could not be observed. In econometric terms, we used the reduced form so as not to miss any possible effects of BP.

Age, *Female* and *Height* represent basic individual characteristics; *BMI*

represents obesity; while *HDL*, *LDL* and *Triglyceride* represent lipid concentration in the blood. If lipid concentration is abnormal (too high or too low), an individual is diagnosed as dyslipidemia. Lipoproteins are proteins that carry cholesterol through the blood. LDL cholesterol makes up most of the body's cholesterol, and HDL cholesterol absorbs cholesterol and carries it back to the liver [52]. Triglyceride is the most common type of fat in the body, and stores excess energy [53]. Although our bodies need lipids to build cells, too much could be a problem [54].

Currently, dyslipidemia is mainly hyperlipidemia, where the lipid concentration is too high. WHO [55] warned: "Raised cholesterol increases the risks of heart disease and stroke. Globally, a third of ischemic heart disease is attributable to high cholesterol. Overall, raised cholesterol is estimated to cause 2.6 million deaths (4.5% of total) and 29.7 million disability adjusted life years (DALYS), or 2.0% of total DALYS." LDL and HDL cholesterol are classified as "bad" and "good". LDL (bad) cholesterol contributes to fatty buildups in arteries, and raises the risk factor for chronic coronary heart disease, heart attack and stroke. On the other hand, HDL (good) cholesterol removes LDL cholesterol from the arteries [52] [53]. *GGP*, *AST* and *ALT* are mainly related to liver functions; *Blood_sugar* and *Urine_sugar* are important indicators of diabetes; and *Urine_protein* represents the condition of the kidneys [56].

We first excluded observations with missing values in explanatory variables. We then excluded the following observations: *BMI* too high (over 100); *SBP* too high (over 300) or too low (under 30); *DBP* too high (over 200) or too low (under 30); *SBP-DBP* becomes zero or negative; *HDL* too high (over 500); *LDL* too high (over 500); *Triglyceride* too high (over 1000); *GGT* too high (over 1000); *ALT* too high (over 500); *AST* too high (over 500); and *Blood_sugar* too high (500). Excluding observations with missing values in explanatory variables, we used 173,498 ($M > 0$: 138,407, and $M = 0$: 35,091) observations for the estimation of the model. Among these observations, 20.2% of medical expenditures were zero, and 79.8% were positive values.

Model A assumes that the effects of BP are continuous. However, it is possible that BP affects health conditions only if it becomes higher than certain threshold values (hereafter, threshold value hypothesis; criteria such as 140/90 and 130/80 are obviously based on this hypothesis). Therefore, we consider the model using dummy variables of SBP. Note that we analyzed only SBP as the SPRINT.

Model B:

$$\begin{aligned}
 y_i^* = & \beta_1 + \beta_2 \text{Age} + \beta_3 \text{Female} + \beta_4 \text{Height} + \beta_5 \text{BMI} + \beta_6 \text{SBP130} \\
 & + \beta_7 \text{SBP140} + \beta_8 \text{SBP160} + \beta_9 \text{SBP180} + \beta_{10} \text{DBP} + \beta_{11} \text{HDL} \\
 & + \beta_{12} \text{LDL} + \beta_{13} \text{Triglyceride} + \beta_{14} \text{GGP} + \beta_{15} \text{AST} + \beta_{16} \text{ALT} \\
 & + \beta_{17} \text{Boold_Sugar} + \beta_{18} \text{Urine_sugar} + \beta_{19} \text{Urin_protein} \\
 & + \beta_{20} \text{F_year14} + \beta_{21} \text{F_year15} + \beta_{22} \text{Society2} + \beta_{23} \text{Socitey3} + u
 \end{aligned} \tag{6}$$

SBP130 (1: if $SPB \geq 130$, 0:otherwise), *SBP140* (1: if $SPB \geq 140$, 0:otherwise), *SBP160* (1: if $SPB \geq 160$, 0:otherwise) and *SBP180* (1: if $SPB \geq 180$, 0:otherwise)

are dummy variables representing threshold values. **Table 2** presents a summary of the explanatory variables.

Table 3 lists the result of estimations for Model A. **Figure 7** shows the distribution of the medical expenditures after the power transformation ($y = M^{0.4088}$). The distribution is much closer to the normal distribution, suggesting usefulness of the model for analyzing this dataset. Since the sample size was quite large, all variables except F_year 14 were significant at the 1% level. The estimates of *Age*, *Female*, *Height*, *BMI*, *Triglyceride*, *GGT*, *AST*, *ALT*, *Blood_suger*, *Urine_suger*, *Urine_protein*, and *F_year15* were positive, with these variables making medical

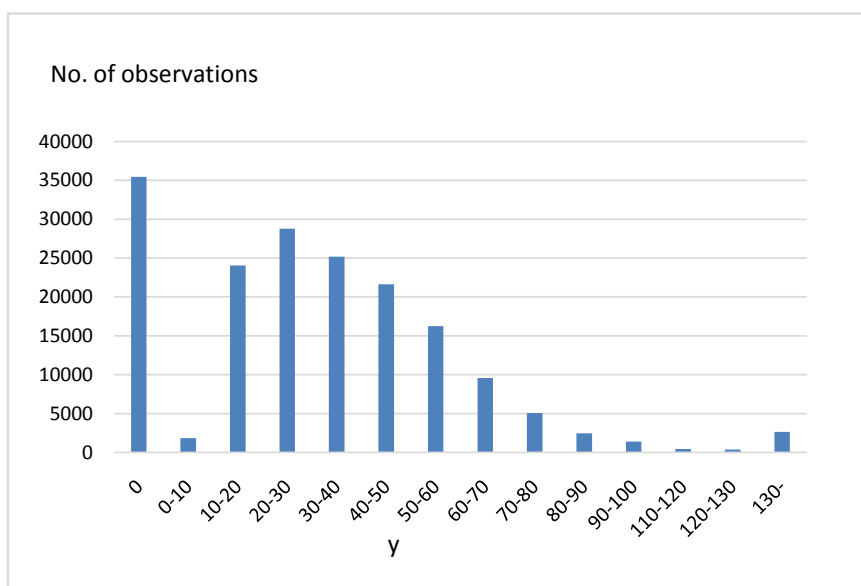


Figure 7. Distribution medical expenditures after the transformation ($y = M^{0.4088}$).

Table 2. Explanatory variables.

Variable	Mean	SD	Variable	Mean	SD
Age	50.25	7.76	AST	23.46	10.56
Female	1:25.0%, 0:75.0%		ALT	24.77	17.40
Height	166.86	8.16	Urine_sugar	1:96.49%, 2:0.71%, 3:0.94%, 4:0.74%, 5:1.12%	
BMI	23.69	3.77	Urine_protein	1:91.58%, 2:4.78%, 3:2.60%, 4:0.79%, 5:0.25%	
SBP	125.72	17.09	Fiscal year	2013: 27.7%, 2014:31.2%, 2015: 41.1%	
DBP	77.70	11.95	Societies	1: 65.5%, 2:16.1%, 18.4%	
HDL	61.31	16.59	BP130	1:37.9%, 0:62.1%	
LDL	124.57	31.70	BP140	1:18.4%, 0:81.6%	
Triglyceride	126.74	94.37	BP160	1:3.55%, 0:96.43%	
Blood_sugar	63.41	48.81	BP180	1:0.55%, 0:99.45%	
GGT	44.44	49.17			

SD: Standard deviation.

Table 3. Result of estimation (Model A).

Variable	Estimate	SE	t-value
α	0.4088	0.0007	623.62**
Constant	-59.9797	2.0011	-29.974**
Age	0.9576	0.0105	91.299**
Female	11.0988	0.2111	52.571**
Height	0.0857	0.0100	8.565**
BMI	1.3286	0.0199	66.796**
SBP	-0.0566	0.0054	-10.425**
DBP	0.0316	0.0079	3.997**
HDL	-0.0427	0.0042	-10.144**
LDL	-0.1128	0.0020	-55.931**
Triglyceride	-0.0026	0.0007	-3.638**
Blood_sugar	0.0236	0.0012	19.913**
Urine_sugar	5.0889	0.1067	47.692**
Urine_protein	4.2282	0.1007	41.986**
GGT	0.0179	0.0013	13.650**
AST	0.0770	0.0080	9.576**
ALT	0.0653	0.0057	11.463**
F_year14	0.1263	0.1608	0.786
F_year15	0.9614	0.1460	6.585**
Society2	-5.5580	0.1736	-32.016**
Society3	-5.3787	0.1618	-33.243**
σ	26.9985	0.2294	117.67**
logL		-1,552,289	
No. of observations		M > 0: 138407, M = 0:3501, Total: 173,498	

SE: standard error, **: significant at 1% level.

expenditures higher. The effects of most of these variables were as expected. On the other side, the estimates of *LDL*, *HDL*, *Society 2* and *Society 3* were negative. Although LDL Cholesterol is called “bad” and HDL “good” [53], higher levels of both LDL and HDL cholesterols reduced medical expenditures in our study. Hence further studies are necessary to determine the roles and functions of cholesterols, especially LDL cholesterol. This is one important finding of this study.

The medical expenditures of Societies 2 and 3 were lower than those of Society 1. Society 1 was formed by one large corporation, while Societies 2 and 3 were formed by groups of smaller corporations. Although the reason why cannot be

elucidated, it might be necessary to check and revise the healthcare system in Society 1. Although the sign of DBP was positive and significant, the estimate of SBP was -0.0566 , and its t-values were -10.42 and significant at any reasonable significance at any reasonable level. This means that higher SBP reduced medical expenditures.

Table 4 presents the estimation results of Model B, which contained the threshold value dummies for SBP. The values of estimations for variables other than BP were very similar to those of Model A. For the SBP dummy variables, *SBP130*, *SBP140* and *SBP180* dummies were not significant even at the 5% level, despite the fact that the sample size was quite large. Only the *SBP160* dummy was significant at the 1% level, but the estimated value was negative. Although it was not significant at the 5% level, the estimate of DBP becomes a negative value in this model. These findings do not support the threshold value hypothesis, at least for SBP.

5. Discussion

The effects of BP on medical expenditures are mixed. Higher DBP makes them higher, but higher SBP makes them lower. We evaluated the relations between medical expenditures and high SBP or SBP hypertension. As shown in **Figure 5**, there exists an upward trend between SBP and average medical expenditures.

We consider a simple regression model of Equation (1) that is given by:

Model C:

$$y_i^* = \beta_1 + \beta_2 SBP + u \quad (7)$$

Then we get (standard errors are in parentheses),

$$y_i^* = 13.264 + 0.1308SBP, \hat{\alpha} = 0.4094(0.0007) \\ (0.466) (0.00367) \quad (8)$$

The estimate of *SBP* is positive, and its t-value is 35.70 and significant at any reasonable significance level. As shown in **Figure 6**, age and gender might affect medical expenditures. We add *Age* and *Female*, and consider the model:

Model D:

$$y_i^* = \beta_1 + \beta_2 Age + \beta_3 Female + \beta_4 SBP + u \quad (9)$$

The estimation results of this model are given by:

$$\hat{\alpha} = 0.4088(0.0007) \\ y_i^* = -24.016 + 0.8508Age + 5.8150Female + 0.0747SBP \quad (10) \\ (0.5665) (0.0100) (0.15468) (0.00359)$$

Although the size is almost half that of the previous case, the estimate of *SBP* is still positive, and the t-value is 20.86 and significant at any reasonable level.

We then add *BMI*, representing obesity, and consider the model,

Model E:

$$y_i^* = \beta_1 + \beta_2 Age + \beta_3 Female + \beta_4 SBP + \beta_5 BMI + u$$

Table 4. Result of estimation (Model B).

Variable	Estimate	SE	t-value
α	0.4089	0.0007	625.23**
Constant	-62.0945	2.0300	-30.588**
Age	0.9446	0.0104	90.919**
Female	11.1871	0.2111	52.991**
Height	0.0868	0.0100	8.680**
BMI	1.3088	0.0198	66.067**
SBP130	0.0421	0.1644	0.256
SBP140	-0.2291	0.1970	-1.162
SBP160	-1.3446	0.3487	-3.856**
SBP180	0.3567	0.7030	0.507
DBP	-0.0188	0.2287	-0.082
HDL	-0.0440	0.0042	-10.456**
LDL	-0.1124	0.0020	-55.857**
Triglyceride	-0.0029	0.0007	-3.935**
Blood_sugar	0.0240	0.0012	20.277**
Urine_sugar	5.0627	0.1065	47.556**
Urine_protein	4.2229	0.1007	41.942**
GGT	0.0179	0.0013	13.595**
AST	0.0759	0.0080	9.432**
ALT	0.0664	0.0057	11.642**
F_year14	0.1205	0.1644	0.733
F_year15	0.9640	0.1460	6.604**
Society2	-5.5515	0.1736	-31.981**
Society3	-5.3967	0.1618	-33.362**
α	27.031	0.2287	118.21**
logL		-1552309	
No. of observations		M > 0:138407, M = 0:3501, Total:173498	

SE: standard error, **: significant at 1% level.

The estimation result is given by:

$$\hat{\alpha} = 0.4085(0.0007)$$

$$y_i^* = -58.963 + 1.0416Age + 9.0088Female - 0.0250SBP + 1.7028BMI \quad (11)$$

(0.6973) (0.0101) (0.1554) (0.0035) (0.0186)

In Model E, the coefficient of *SBP* becomes negative and significant at the 1% level. Muntner *et al.* [57] analyzed data from the US National Health and Nutri-

tion Examination Survey (NHANES). They pooled data from the 2011-2012 and 2013-2014 NHANES cycles of adult participants, 20 years of age and older ($n = 10,907$). They declared that, "Implementation of the 2017 ACC/AHA hypertension guideline has the potential to increase the prevalence of hypertension and use of antihypertensive medication among U.S. adults. This should translate into a reduction in CVD events." Although age, gender, race, smoking, total and HDL-cholesterol, and diabetes were included, "obesity" was not considered in their analysis. The correlation coefficient of *SBP* and *BMI* is 0.307 in this study. The relation between obesity and hypertension has been recognized for more than a half century [58], and many studies have been conducted. For details, see the review works of Kotchen [59], Jiang *et al.* [60] and Leggio *et al.* [61]. Jiang *et al.* [60] declared that: "The mechanisms underlying obesity-associated hypertension or other associated metabolic diseases remains to be adequately investigated." They furthermore contended that, "There is no single cause to explain all the cases of obesity worldwide." The relation between BP and obesity should be carefully studied.

The results of this study suggest that the risks of hypertension might be spurious, and other factors such as obesity might be affecting health condition. Moreover, BP has been found to affect not only heart diseases but also various other health conditions such as kidney diseases [32] [62]. The influences of the new guideline of 130/80 are so large that careful reviews of various studies including analyses of various factors and diseases (not only heart diseases) affected by BP levels are absolutely necessary to determine whether or not the new guideline is appropriate.

6. Conclusions

In this study, we mainly evaluated the effects of BP on medical expenditures by the transformation tobit models using a dataset containing 175,123 medical checkups and 6,312,125 receipts obtained from 88,211 individuals obtained from three health insurance societies. Medical expenditure is a very good indicator of an individual's health condition, because under the current Japanese national health insurance system, most medical institutes receive the same amount for the same treatments and medicines, independent of region. We first considered a model that included various health information factors for individuals obtained in yearly medical examinations. Although the estimate of DBP had a positive value, that of SBP became negative and the absolute t-value was larger than 10, suggesting that the new guideline for SBP was not supported.

We then theorized that threshold values and BP might affect health condition only if BP exceeded those values (threshold value hypothesis). We used SBP dummies to check the threshold value hypothesis, but the results did not support the hypothesis for SBP. While the estimates of most other variables had expected signs, LDL cholesterol, considered "bad", showed the opposite result. It is likely we will need additional studies for the evaluation of cholesterols.

We then evaluated the relation between medical expenditures and SBP. Medical expenditures and SBP were positively correlated, and if the simple model only contained SBP, the estimate became a positive value. Although the size of the coefficient was almost cut in half, the sign did not change if age and gender variables were considered in the model. However, when BMI, representing obesity, was added, the estimate of SBP became negative and significant at the 1% level.

It is possible that the relation between SBP and medical expenditures might be spurious, and the correlation of SBP and BMI might affect the result. The relation between BP and obesity should be carefully studied. Moreover, the effect of the new 2017 ACC/AHA guideline, the first comprehensive hypertension clinical practice guideline since 2003 [30], is so large that a careful and wide range of reviews of various studies, not only of heart diseases but for other types of diseases as well, are absolutely necessary. New studies verifying the guideline should also be conducted.

In this paper, we evaluated medical expenditures, not the risks of BP on heart diseases. Evaluation of the effects of BP on heart diseases and other important diseases is needed. It will also be necessary to analyze a larger and longer time-range dataset from various insurance societies to make the analysis more precise. These are subjects to be studied in future.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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