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The Association between Height and Hypertension in Indonesia☆

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ABSTRACT

There is growing interest in the influence of early-life conditions on the development of disease. Among diseases in adulthood, hypertension is particularly important for the developing world because considerably more people there are and will be afflicted with the disease than in the developed world and hypertensives there are often unaware of their disease status. We employed height as a proxy for the influence of early-life conditions and estimated the relation between height and hypertension status in Indonesia. We analysed 9,597 men and 10,143 women, aged 25–70. We employed a linear probability model to relate height to hypertension status by sex and age. When we controlled for an array of covariates, a 10 cm increase in height was related to an approximately 7% point reduction in the likelihood of being hypertensive for both men and women. This is about a quarter of the prevalence of hypertension in Indonesia. This relation was linear and stronger among older individuals. In addition, the pre- and post-pubertal environments (measured by leg and trunk lengths, respectively) contributed similarly to hypertension. Further evidence suggests that women are more likely to be hypertensive at older ages because they are on average shorter than men.

1. Introduction

Hypertension is a major risk factor for coronary heart disease, heart failure, cerebrovascular disease, and chronic renal failure and is an important health issue worldwide. Ezzati et al. (2002) argued that it is the single most important cause of morbidity and mortality. Although hypertension is a global-scale threat to health, it is a greater threat to developing than to developed countries. Kearney et al. (2005) estimated the total number of hypertensives in 2000 at 972 million, which consisted of 333 million in developed countries and 639 million in developing countries. They projected that, by the year 2025, the total number of hypertensives was expected to increase by 24% to 413 million in developed countries and by as much as 80% to 1.15 billion in developing countries. Therefore, there is a compelling need to focus on developing countries.

Because hypertension is a major risk factor for coronary heart disease, it is worth considering the foetal origins hypothesis proposed by Barker (1995): foetal undernutrition in middle to late gestation programs later coronary heart disease. Inspired by this hypothesis, researchers have extended the period of early-life conditions beyond pregnancy and the outcome of interest beyond coronary heart disease (Currie and Almond, 2011; Currie and Vogl, 2013). For example, Currie and Vogl (2013) reviewed *inter alia* studies on the relation of height with socioeconomic status outcomes, such as schooling, income, and expenditure. To relate early-life conditions to later-life outcomes, researchers have used many measures, subjective or objective and self-reported or measured. In this endeavour, measured height in adulthood is widely used as a proxy for early-life conditions (Steckel, 2009). Height is objective, easily measurable, readily available, comparable across time and space, and most of all, sensitive to early-life conditions. Given a person's genetic factors, an individual is taller if his growth environment provides sufficient nutrition and healthcare and is free of disease, heavy workload, and extreme weather conditions (Silventoinen, 2003).

At first sight, relating adult height to Barker's hypothesis seems unjustified because the hypothesis highlights intrauterine growth whereas adult height is influenced by factors beyond intrauterine conditions. However, invoking Barker's hypothesis is reasonable because ample evidence suggests that adult height is strongly predicted by birth length (Eide et al., 2005; Sørensen et al., 1999). This justification is reinforced by Horikoshi et al. (2013), who

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Table 1
Descriptive Statistics.

	Men	Women
Continuous Variable	Mean (SD)	Mean (SD)
Height (cm)	161.9 (6.2)	150.4 (5.7)
Sitting Height (cm)[a]	81.9 (6.3)	76.6 (6.1)
Leg Length (cm)[a]	78.7 (6.8)	72.9 (6.6)
Systolic Blood Pressure (mmHg)	130.8 (18.3)	129.9 (22.7)
Diastolic Blood Pressure (mmHg)	80.8 (11.0)	81.2 (11.4)
Weight (kg)	58.3 (10.7)	53.8 (11.0)
Age	40.9 (11.9)	41.3 (12.1)
Days of Vigorous Activities during the Past 7 Days	2.51 (2.95)	0.92 (2.17)
Per Capita Salt Consumption in the Household (Rp.)	0.83 (1.51)	0.83 (1.41)
Ln(Household Wealth)	17.14 (1.94)	17.18 (2.02)
# of Men Aged 16+ in the Household	2.21 (1.46)	2.09 (1.44)
# of Women Aged 16+ in the Household	2.11 (1.40)	2.34 (1.48)
# of Boys Aged 15- in the Household	0.75 (0.86)	0.76 (0.87)
# of Girls Aged 15- in the Household	0.70 (0.84)	0.74 (0.87)
Discrete Variable	%	%
No Hypertension	71.7	69.5
Hypertension	28.3	30.5
Unmarried	12.8	19.7
Married	87.2	80.3
No or Elementary School	43.1	54.3
Junior High School	17.1	15.8
Senior High School	28.3	20.5
College or Above	11.6	9.4
Not Working	6.7	36.3
Working	93.3	63.7
No Smoking	25.0	96.2
Previous Smoking	5.3	0.6
Current Smoking	69.7	3.2
Rural Residence	47.3	46.2
Urban Residence	52.7	53.8
N	9597	10,143

[a] The sample size was 4457 for men and 4905 for women; these variables were available only for individuals aged 40+.

located genetic links between intrauterine growth and adult height. Based on this justification, we used height as a proxy for early-life conditions, related it to hypertension status in adulthood, and relied on Barker's hypothesis in the interpretation of the relation. In a sense, we went back to basics because hypertension takes centre stage here—unlike in many previous studies that were inspired by the hypothesis but investigated outcomes other than coronary heart disease. Our focus on Barker's hypothesis, however, does not exclude other hypotheses. For example, in their review, Batty et al. (2009) listed four mechanisms linking increased height with lower risk of coronary heart disease (increased pulmonary function, increased coronary vessel diameter, increased insulin-like growth factor, genetic factors), which are not necessarily determined in utero. We later discussed how Barker's hypothesis could be combined with others to understand the relation between height and hypertension.

The relation is empirically ambiguous. Physiologically, a positive relation is expected according to Poiseuille's law, which states that the resistance to flow in a vessel is directly proportional to the length of the vessel. An apt example of this law is provided by the giraffe, which exhibits the highest blood pressure (BP) among 47 species of terrestrial mammals (White and Seymour, 2014). Biologically, a negative relation is expected according to Barker's hypothesis—better conditions in early life (taller height) result in better health outcomes in later life (less hypertension). Given that Barker's hypothesis has been challenged, however, ambiguity in the relation looms larger. For example, Huxley et al. (2004) reviewed 79 studies and found that most studies did not find any relation between birthweight and subsequent blood pressure. In addition, Sohn (2016b) reported that the taller died earlier in the US, thereby challenging the notion that the taller are healthier. Therefore, it is not surprising to observe that results concerning the relation between height and hypertension in medicine vary depending on population, sex, height classifications, sample sizes, empirical models, and covariates (Florêncio et al., 2004; Hoque et al., 2014; Kannam et al., 1994; Langenberg et al., 2003; Law et al., 1993; Olatunbosun and Bella, 2000; Puchner et al., 2015; Sichieri et al., 2000; Voors et al., 1982). However, these studies suffered from important limitations. Regarding the data, their sample sizes were often small and nationally unrepresentative, and self-reported height was used. Regarding the empirical methods, multivariate analyses, if used at all, controlled for only a small number of potential confounders. Regarding the populations of interest, the focal populations were mostly from developed countries. Regarding the results, most did not go beyond simply estimating the relation between height and hypertension.

Similar but rare attempts in economics have been made, while addressing some of the limitations in medicine. However, as hypertension was only one of the many health outcomes in these studies, the same standard specifications were applied to many diseases, regardless of the special characteristics of each disease. For example, Huang et al. (2013) did not control for a weight-related variable because their standard specification without a weight-related variable was more suitable for their set of health outcomes. As demonstrated below, including a weight-related variable is critical when estimating the relation between height and hypertension. Perelman (2014) did include a weight-related variable (a dummy variable to indicate obesity) but used self-reported height and hypertension status. He argued that self-reported height was accurate, citing a Spanish study (Spijker et al., 2012), but not everyone agrees with this (e.g. Danubio et al., 2008). Even excluding systematic bias, measurement error in self-reported height attenuates the relation between height and hypertension (i.e. attenuation bias). More importantly, he asserted that self-reported morbidity did not differ largely from physician-reported values. This may be the case for other diseases but not for asymptomatic diseases, particularly hypertension. Pereira et al. (2009) reviewed studies published from March 2001 to August 2007 and estimated that, among patients with measured hypertension in all countries, only 46.2% of men and 58.5% of women reported prior diagnoses of hypertension by healthcare professionals. These proportions were smaller in developing than in developed countries (Ibrahim and Damasceno, 2012). Furthermore, Huang et al. (2013) and Perelman (2014) applied a single specification to many diseases, thereby missing many interesting details. We attempted to address all of these limitations. Specifically, in addition to the baseline relation between height and hypertension, we examined age and cohort heterogeneity in the relation, the relative importance of leg vs. trunk length, and the role of sex difference in height in accounting for the sex difference in hypertension. We controlled for a weight-related variable and drew on measured height.

The country of interest in this study is Indonesia. In addition to its developmental stage, the country is of particular interest regarding the relation between height and hypertension. First, hypertension is a serious health issue in Indonesia. Hypertension is widespread, particularly among older people. Almost half of people aged 50+ were hypertensive. To make matters worse, most hypertensives are unaware that they are hypertensive. Sohn (2015c) reported that, among hypertensive men aged 40+ in Indonesia, only 23.4% were aware that they were hypertensive; the corresponding figure for women was 37.0%. Second, Indonesia belongs to the region where the mean population heights were the shortest in the world from 1810 to 1989 (Baten and Blum, 2012). This feature helps one determine whether a population that has long been exposed to adverse conditions can still exhibit a negative relation between height and hypertension. It is possible to see no relation if the population has adapted to the environment. Third,