Research Paper

Influence of height on blood pressure and hypertension among Bangladeshi adults

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ABSTRACT

Background: Recent studies have reported that height is inversely associated with blood pressure and hypertension. However, there is lack of comprehensive findings from Bangladesh in this regard.
Objective: The purpose of this study was to explore the association between height and blood pressure in a Bangladeshi population.
Setting: Rural and urban sites from seven divisions of Bangladesh.
Participants: Participants were 7932 males and females (aged ≥35 years) evaluated in the 2011 Bangladesh Demographic Health Survey. Participants (n = 7647) who had complete height, weight, systolic and diastolic blood pressure (SBP and DBP) measurements and non-missing medication history, were included in the analysis.
Methods: Hypertension was defined as an SBP over 140 mmHg or/and a DBP over 90 mmHg, or current use of antihypertensive medication. Difference between SBP and DBP was calculated to get pulse pressure (PP). Multivariate linear and logistic regression models were used.
Results: PP decreased linearly with increasing height among males (−0.11, P < 0.05) and females (−0.19, P < 0.05) after adjusting for age, BMI, living region, type of occupation, wealth index, and highest level of education. SBP decreased linearly with increasing height among only females (−0.14, P < 0.05), after adjusting for age, BMI, living region, type of occupation, wealth index, and highest level of education. No association was found between quartiles of height and prevalence of hypertension.
Conclusions: Height was found to be inversely associated with pulse pressure in both sexes. Studies with longitudinal design are needed to investigate the association between shortness with blood pressure and hypertension.

1. Background

Height being related to the risk of disease and mortality was first reported in late 19th century [1]. Data from the insurance industry in the early 20th century indicated that taller people, on average, lived longer in comparison to shorter people [2]. Height has been linked to a range of health problems, from Alzheimer's and heart disease to several cancers. A recent study investigated the association of adult height with 50 diseases using both epidemiological and genetic approaches, and found that

height was associated with 32 diseases and genetically determined height was associated with 12 diseases [3]. However, studies in this arena are mostly focused on cardiovascular disease and only a few studies have examined other illnesses [4].

In 1951 Gertler et al. reported that young men who were at risk for coronary artery disease were about 5 centimetre (cm) shorter than their healthy counterparts [5]. Later, this observation was extended by Paffenbarger and Wing, by studying the risk of developing a fatal stroke among longitudinally followed university students. They found that

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students who suffered from stroke were 2–3 cm shorter than their classmates [6]. Studies from high income settings have investigated the association between blood pressure and height [7–11], but there is lack of credible evidence from low and middle income countries.

Hypertension is a growing threat to Bangladesh's public health. A nationwide survey from Bangladesh in 2011, reported that the prevalence of hypertension was 26.4% among those aged 35 years and older [12]. Epidemiological studies have established modifiable and unmodifiable risk factors for hypertension, including obesity, high salt intake, alcohol consumption, cigarette smoking, sedentary lifestyles, age and family history [13]. However, there are other factors which needs to be explored. Bangladesh is now passing through a nutritional transition [14] and it is expected that average adult height will continue to increase in this country [15], therefore it is imperative to know whether any relationship between height and blood pressure exists in this population.

A study from Bangladesh in 2014 investigated the association of hypertension and height using the data of Bangladesh Demographic Health Survey, 2011 (BDHS, 2011) [16]. However, the study did not portray the whole picture in this arena. First, the study did not investigate the relationship between blood pressure and height. Secondly, it did not show association of hypertension with height by sex. Bangladeshi males are significantly taller than females, therefore the relationship of hypertension and height should be observed by sex [17]. Most previous studies elsewhere that explored this relationship, analysed this association independently among males and females [7–11]. Considering these limitations of the previous report, we reanalysed the data of BDHS, 2011, to comprehensively examine the association between height, blood pressure and prevalence of hypertension in a middle-age Bangladeshi male and female population separately after the adjustment for potential confounders, and to prove following hypothesis.

1.1. Hypothesis

1. There is difference in systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MBP) and pulse pressure (PP) among different height quartiles of Bangladeshi adult males and females.
2. SBP and DBP will decrease with higher height quartiles, MBP will increase with higher height quartiles, and PP will be narrowed down with higher height quartiles of Bangladeshi adult males and females.
3. There is an inverse linear relationship between height and SBP, DBP and PP; and positive linear relationship between height and MBP of Bangladeshi adult males and females.
4. Short height is associated with an increased prevalence of hypertension among Bangladeshi adult males and females.

2. Method

2.1. Study site and design

We used nationally representative data from the 6th Bangladesh Demographic and Health Survey (BDHS), 2011. Secondary analysis of BDHS were done to prove the aforementioned hypothesis. BDHS collect representative sample from all over Bangladesh, covering all the divisions of Bangladesh [18].

2.2. Data source

The Demographic Health Survey (DHS) is a standardised series of surveys routinely conducted in more than 80 developing countries. All data from these surveys are in the public domain of USAID and can be accessed, after registration, from http://www.measuredhs.com. The BDHS is a large, well-established, nationally representative survey based on a multistage cluster random sampling design that provides high-quality information on the health of men, women and children in Bangladesh with an overall response rate of 98%. Unlike other BDHS

surveys, the 2011 BDHS specifically aimed to measure blood pressure for males and females aged 35 years and older [18].

From the 2011 Population and Housing Census, a list of enumeration areas (EAs) was prepared for the sampling frame. The EA was considered as the primary sampling unit in both urban and rural areas. In total, 207 clusters in urban areas and 393 clusters in rural areas were selected to get a total of 600 EAs. In the second phase, households were listed in these EAs. With this design, a total of 18,000 residential households were selected and among those, one-third of the households were randomly selected for measurement of blood pressure. All males and females aged 35 years or older in these selected households were approached to measure blood pressure. Details of the survey design, methodologies, sample size calculation, findings, and questionnaires are available elsewhere [18].

2.3. Assessment of blood pressure and hypertension

Blood pressure measurements were taken by making the participants relax and have them seated straight with the arm supported in a fixed position. The WHO-recommended "LIFE SOURCE® UA-767" Plus Blood Pressure Monitor model was used to measure SBP and DBP. Well trained data collectors measured SBP and DBP three times with an interval of ten minutes between measurements for each participant. The average of the last two measures was used to document the final blood pressure value [18]. Besides, participants were asked if they were taking any prescribed anti-hypertensive drugs to lower blood pressure level. PP was calculated as the difference between SBP and DBP, and MBP was calculated as: MBP = $[2 \times (DBP) + SBP]/3$. In the present study, hypertension was defined as an SBP over 140 mmHg or/and a DBP over 90 mmHg, or current use of antihypertensive medication, or participants with a self-reported physician diagnosis of hypertension [13].

2.4. Assessment of height and height quartiles

Height was measured at the participant's home by trained field research staff. Height was measured only once using a standard clinical height scale. Height (to the nearest 0.1 cm) was measured in participants not wearing shoes [18]. The measured height was categorized in sex-specific quartiles (Q). For men, the height quartiles were Q1$\leq$157.4 cm, Q2 157.5–161.6 cm, Q3 161.7–165.9 cm, and Q4 =>166 cm. For women, the corresponding quartiles were Q1$\leq$145.5 cm, Q2 145.6–149.2 cm, Q3 149.3–153.5 cm, and Q4 =>153.6 cm.

2.5. Assessment of covariates

Information on demographic characteristics such as age, living region and occupation were directly collected using the pre-structured questionnaire. Data related to Socioeconomic status (SES) was collected using the Demographic and Health Survey wealth index, which depends on ownership of selected assets to determine relative wealth. The wealth index was developed through principle components analysis. The body mass index (BMI) was calculated by dividing weight in kilograms by height squared in meters [18].

2.6. Statistical analysis

In this study, we excluded participants with either missing value of body height or missing information on systolic blood pressure, diastolic blood pressure and history of medication for blood pressure. In total, 285 participants (3.5% of the total participants) were excluded from this study. The final analyses included 7647 participants (3771 men and 3876 women).

Categorical variables were described in percentage and compared by Chi-square tests. Continuous variables were presented as mean ± standard deviation (SD) for normally distributed data or median (interquartile range) for skewed data, and compared by sex. Difference in

SBP, DBP, MBP, PP and other quantitative variables among different height quartiles of Bangladeshi males and females was conducted using ANOVA or Welch ANOVA was done based on the result of the Levene's test of homogeneity of variances. However, for skewed quantitative variables, Kruskal Wallis test was done to assess the difference across the height quartiles. Again, according to the output of Levene's test of homogeneity of variances a Games-Howell test or Tukey post-hoc test was done to assess the difference of SBP, DBP, MBP and PP within different quartiles of height. Trend in SBP, DBP, MBP and PP amongst the quartiles of height were assessed by Jonckheere-Terpstra test. Following this, prevalence of hypertension with confidence interval (CI) was calculated across the height quartiles of Bangladeshi men women, and presence of any trend of prevalence of hypertension within the height quartiles was identified by Mantel-Haenszel linear-by-linear association chi-squared test. We used multivariate linear regression models to compare the association of SBP, PP, MBP and DBP with height. Multivariable logistic regression models were used to estimate ORs and 95% CIs, to measure the association between height quartiles and risk of hypertension after adjustment for potential confounders. Models were fitted using height as categorical variable, based on the quartile distribution of height, and the shortest quartile was defined as the referent group. 266 male participants and 551 female participants were excluded from the analysis during ANOVA or Welch ANOVA, Jonckheere-Terpstra test and multivariate linear regression to remove the effect of anti-hypertensive medication on blood pressure. All statistical analyses were performed by using the SPSS version 20. All statistical tests were two-tailed, and the cut-off of significant level was defined as $P < 0.05$. All the statistical analyses were weighted according to the guideline of BDHS [18].

2.7. Ethical considerations

The BDHS received ethical approval from Institutional Review Boards (IRB) of the ICF International and Bangladesh Medical Research Council. Prior informed written consent was obtained from each participant [18]. The analysis presented in this study is based on secondary analysis of existing survey data with all identifying information removed, therefore, no ethical approval was sought.

3. Result

3.1. Characteristics of the participants

Table 1 presents the characteristics of the male and female participants and compare variables according to sex. We included 7647 participants in the analysis. Of 7647, 3771 (49.31%) were males. There were significant differences between Bangladeshi males and females in regard to socio-demographic variables including age, education and occupation. No differences were found for region of residence and wealth index. Male participants were more likely to be older, educated and have a manual job. Clinical characteristics of the respondents such as height, weight, BMI, SBP, DBP, MBP, PP, history of taking anti-hypertensive medication, anti-diabetic medication & hypertensive status significantly differed between males and females. Male participants were taller and heavier compared to female participants. On the other hand, female participants had higher BMI, SBP, DBP, MBP & PP. Female participants were also more likely to be hypertensive, on anti-hypertensive medication and on anti-diabetic medication. Characteristics of participants were also observed across height quartiles (Supplemental Table 1) and it was found that most of the characteristics differ significantly across height quartiles, except for history of anti-hypertensive medication and prevalence of diabetes for both males and females, and occupation of female participants.

3.2. Mean blood pressure according to height quartiles

Table 2 presents mean SBP, DBP, MBP and PP according to height

Table 1
Characteristics of the participants by sex, Bangladesh demographic health survey, 2011.

Characteristics	Male	Female	P-Value
	N = 3771	N = 3876	
Age, years (Median, IQR)[a]	50 [41–60]	48 [40–58]	<0.001
Age Category			
< 65 years	3054 (81.0)	3270 (84.4)	0.001
≥ 65 years	717 (19.0)	606 (15.6)	
Living region			
Urban	898 (23.8)	890 (23.0)	0.387
Rural	2873 (76.2)	2986 (77.0)	
Wealth Index, n (%)			
Poorest	744 (19.7)	739 (19.1)	0.818
Poorer	739 (19.6)	732 (18.9)	
Middle	739 (19.6)	779 (20.1)	
Richer	766 (20.3)	808 (20.8)	
Richest	783 (20.8)	818 (21.1)	
Education, n (%)			
No education	1422 (37.7)	3406 (87.9)	<0.001
Primary	1060 (28.1)	345 (8.9)	
Secondary	843 (22.3)	103 (2.7)	
College/Higher	447 (11.9)	23 (0.6)	
Occupation, n (%)			
Manual	1847 (49.3)	53 (1.4)	<0.001
Non-manual	1897 (50.7)	3819 (98.6)	
Height, cm (Mean ± SD)	161.54 ± 6.54	149.32 ± 6.09	<0.001
Weight, kg (Mean ± SD)[b]	53.64 ± 10.06	47.66 ± 10.77	<0.001
BMI, kg/m^2 (Mean ± SD)[b]	20.48 ± 3.23	21.24 ± 4.25	<0.001
SBP, mmHg (Mean ± SD)	115.77 ± 18.71	121.14 ± 22.54	<0.001
DBP, mmHg (Mean ± SD)	76.21 ± 11.41	79.54 ± 11.75	0.018
MBP, mmHg (Mean ± SD)	89.39 ± 12.91	93.40 ± 14.25	<0.001
PP (Mean ± SD)	39.55 ± 12.87	41.60 ± 16.21	<0.001
History of medication, n (%)			
For High blood pressure	266 (7.1)	551 (14.2)	<0.001
For High blood glucose[b]	122 (3.4)	155 (4.4)	0.023
Prevalence, n (%)			
Hypertension	724 (19.2)	1230 (31.7)	<0.001
Diabetes[b]	385 (11.1)	422 (12.4)	0.091

Data are mean ± SD for normally distributed data or median (interquartile range) for skewed data, or percentage.
Abbreviation: BMI, body mass index; SD, standard deviation; IQR, Interquartile range; SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP; mean arterial blood pressure; PP, pulse pressure.
[a] Mann-Whitney *U* Test was done because of skewed data.
[b] Number of missing value for weight = 59, number of missing value for BMI = 62, number of missing value for prevalence of diabetes = 777, number of missing value for history medication for diabetes = 545.

quartiles. Mean SBP decreased linearly with increasing height among female (P for trend < 0.001). PP showed the same trends as SBP in both male and female (P for trend < 0.001) participants. Among male participants mean DBP and MBP increased linearly with increasing height. (P for trend < 0.001; P for trend 0.017). However, among females MBP decreased linearly with increasing height (P for trend 0.009). Post hoc analyses showed that taller female individuals had lower SBP and PP than those with shorter height (Q2 vs Q1, P < 0.05; Q3 vs Q1, P < 0.05; Q4 vs Q1, P < 0.05). On contrary, taller male individuals had lower PP than those with shorter height (Q2 vs Q1, P < 0.05; Q3 vs Q1, P < 0.05; Q4 vs Q1, P < 0.05). Taller male individuals have higher DBP than those with shorter height (Q3 vs Q1, P < 0.05; Q4 vs Q1, P < 0.05).

3.3. Association between height and blood pressure

Table 3 shows the results from multivariate linear regression analyses, which were used to explore the associations between height and SBP, DBP and PP after adjustment of potential and available covariates. In the analysis, inverse associations were found between height and SBP and PP among male and female participants (model 1) (all P < 0.05). In the fully adjusted model (model 4), a −0.4 mmHg (95% confidence intervals (CI), −0.52, −0.29) linear change in SBP was found in females.

Table 2
Mean SBP, DBP and PP according to height quartiles by sex, Bangladesh demographic health survey, 2011.

Blood pressure	Height quartile				P for trend
	Q1	Q2	Q3	Q4	
Male					
SBP	115.23 ± 19.72	113.51 ± 16.94	114.30 ± 15.52	113.14 ± 15.92	0.970
DBP	74.60 ± 11.31	74.97 ± 10.95	76.48 ± 10.44[μ]	76.14 ± 11.24[μ]	<0.001
MBP	88.14 ± 13.16	87.81 ± 12.05	89.09 ± 11.33	88.47 ± 12.02	0.017
PP	40.62 ± 13.67	38.53 ± 11.67[μ]	38.82 ± 10.52[μ]	37.00 ± 10.40[μ]	<0.001
Female					
SBP	122.57 ± 23.75	118.06 ± 19.42[μ]	115.94 ± 19.38[μ]	116.50 ± 18.30[μ]	<0.001
DBP	78.23 ± 11.77	78.52 ± 10.70	77.47 ± 11.15	79.11 ± 10.71	0.269
MBP	93.01 ± 14.65	91.69 ± 12.66	90.29 ± 12.98 [μ]	91.57 ± 12.46	0.009
PP	44.34 ± 17.20	39.54 ± 13.70[μ]	38.47 ± 13.33 [μ]	37.39 ± 12.16 [μ]	<0.001

[μ]$P < 0.05$ for the comparison with shortest quartile of height, by using Games-Howell test for post hoc analysis.
Abbreviation: Q, Quartile; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure.

For males the relationship was found insignificant in the fully adjusted model (model 4). Each centimetre increase in height was associated with a reduction of 0.11 mmHg for males (P value < 0.05) and 0.19 mmHg for females (P value < 0.05) in PP. No association was found between height and DBP, and MBP after adjusting for potential factors among males and females.

3.4. Association between height and hypertension

Table 4 displays the unadjusted, age-adjusted and multivariate-adjusted odds ratios (ORs) and 95% CIs for hypertension according to quartiles of height among males and females. For males, no model provides a significant result. However, for females the unadjusted analysis (model 1) showed that increased height was associated with significantly decreased likelihood of hypertension (the highest vs shortest quartile: OR, 0.75; 95% CI, 0.62, 0.90). Adjustments for potential and available confounders materially changed the significant relationship. Addition to that, prevalence of hypertension according to quartiles of height are shown in Supplemental Fig. 1 and Supplemental Fig. 2 for males and females respectively. Only for females, there was a significant descending linear association between height quartile and prevalence of hypertension.

4. Discussion

In the nationwide survey, we found that increasing height was associated with lower SBP and PP but not with DBP among females, independent of potential confounders. On the other hand, among males association was only found with PP independent of potential confounders. No association was found between height and prevalence of hypertension among the survey population after adjustment of potential confounders, but a descending linear trend of prevalence of hypertension was observed across quartiles from lower to higher for female participants.

Analysis of BDHS 2011 participants, who were not taking antihypertensive medications confirmed that, a significant association is present between adult stature and PP which was also replicated in study from China, USA, Finland, Spain and UK [7,8,11,19,20]. Reports from the Framingham Heart study showed that PP was superior to SBP and DBP to predict Coronary Heart Disease (CHD). High PP is a marker for large artery stiffness, which is the main pulsatile force that contributes to vascular aging from middle age onwards [21]. The underlying mechanism is that due to large artery stiffness, SBP rises and DBP falls, resulting an increase in PP [22]. Though our analysis did not show the relationship between height and CHD, based on the findings of Framingham heart study we could argue that Bangladeshi people with shorter height and with high PP might be at risk of CHD.

Evidence on biological plausibility of high PP and SBP and short stature is scarce, however, a 2016 study from China with similar evidence suggested that the dynamic effect of the arterial tree is reflected on the relationship between height and hypertension. The reflected waves reach at the central aorta at a normal pulse wave velocity in the late systole and/or early diastole. Individuals with short stature have short length of arterial tree, therefore in short persons, the reflected waves have greater possibility to reach the central aorta earlier and augment central pressure and PP in the late systole, when compared to a taller person [7]. Besides, the most common explanation is that impaired foetal and infancy development due to malnutrition might influence non-communicable diseases such as hypertension and diabetes in later life, which is also known as "thrifty phenotype hypothesis" [23,24]. Studies argued that the

Table 3
Regression coefficients (95% CIs) of blood pressure components for each centimetre increase in height by sex, Bangladesh demographic health survey, 2011.

	SBP		DBP		PP		MBP	
	Coefficient (95% CI)	P value	Coefficient (95% CI)	P value	Coefficient (95% CI)	P Value	Coefficient (95%CI)	P Value
Male								
Model 1	−0.09 (−0.18, −0.01)	0.02	0.10 (0.05, 0.16)	<0.001	−0.20 (−0.26, −0.14)	<0.001	0.22 (−0.13, 0.59)	0.216
Model 2	−0.01 (−0.10, 0.06)	0.666	0.10 (0.04, 0.15)	<0.001	−0.12 (−0.18, −0.06)	<0.001	0.34 (−0.02, 0.7)	0.069
Model 3	−0.06 (−0.14, 0.02)	0.152	0.06 (0.01, 0.12)	0.01	−0.12 (−0.18, −0.06)	<0.001	0.09 (−0.26, 0.44)	0.617
Model 4	−0.08 (−0.17, 0.00)	0.066	0.02 (−0.02, 0.08)	0.15	−0.11 (−0.17, −0.05)	<0.001	−0.1 (−0.47, 0.27)	0.6
Female								
Model 1	−0.40 (−0.52, −0.29)	<0.001	0.03 (−0.25, 0.10)	0.23	−0.44 (−0.52, −0.36)	<0.001	−0.11 (−0.18, −0.03)	0.003
Model 2	−0.14 (−0.25, −0.02)	0.017	0.07 (0.004, −0.03)	0.037	−0.21 (−0.29, −0.13)	<0.001	−0.01 (−0.09, 0.06)	0.706
Model 3	−0.15 (−0.26, −0.03)	0.01	0.05 (−0.005, 0.12)	0.07	−0.21 (−0.29, −0.13)	<0.001	−0.01 (−0.08, 0.06)	0.797
Model 4	−0.14 (−0.26, −0.01)	0.029	0.05 (−0.019, 0.12)	0.158	−0.19 (−0.27, −0.1)	<0.001	−0.01 (−0.09, 0.06)	0.757

Model 1: Unadjusted.
Model 2: Adjusted for age.
Model 3: Adjusted for age and BMI.
Model 4: Adjusted for age, BMI, Prevalence of diabetes, Living region, Type of occupation, Wealth index and highest level of education.
Abbreviation: Q, Quartile; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; CI, confidence interval.

Table 4
Unadjusted, age-adjusted and multivariate-adjusted ORs (95% CIs) of hypertension according to height quartiles by sex, Bangladesh demographic health survey, 2011.

	Height quartile			
	Q1	Q2	Q3	Q4
Male				
No of cases	968	966	929	908
Model 1	1.00 (Ref)	0.88 (0.70, 1.11)	0.97 (0.78, 1.22)	0.97 (0.77, 1.22)
Model 2	1.00 (Ref)	0.96 (0.76, 1.22)	1.09 (0.87, 1.38)	1.16 (0.91, 1.47)
Model 3	1.00 (Ref)	0.92 (0.73, 1.17)	0.96 (0.75, 1.22)	1.00 (0.78, 1.28)
Model 4	1.00 (Ref)	0.90 (0.70, 1.15)	0.84 (0.65, 1.09)	0.88 (0.67, 1.14)
Female				
No of cases	992	949	983	952
Model 1	1.00 (Ref)	0.73 (0.61, 0.89)	0.72 (0.60, 0.87)	0.75 (0.62, 0.90)
Model 2	1.00 (Ref)	0.86 (0.71, 1.05)	0.92 (0.76, 1.12)	0.98 (0.81, 1.20)
Model 3	1.00 (Ref)	0.85 (0.69, 1.04)	0.90 (0.73, 1.10)	0.90 (0.73, 1.11)
Model 4	1.00 (Ref)	0.91 (0.73, 1.13)	0.92 (0.74, 1.15)	0.93 (0.75, 1.17)

Model 1: Unadjusted.
Model 2: Adjusted for age.
Model 3: Adjusted for age and BMI.
Model 4: Adjusted for age, BMI, Living region, Type of occupation, Wealth index and Highest level of education.
Abbreviation: Q, Quartile.

individuals who were raised in low socio-economic conditions during childhood were associated with increased SBP and/or DBP in adulthood [25] or to have adverse cardiovascular risk factors during adulthood [26–29]. Stefan et al. provided additional evidence and explained the relationship between height and cardiometabolic risk [15]. This study reported that taller persons have good pulmonary function; lower heart rates and increased parasympathetic activity; larger coronary vessel diameter; lower blood cholesterol and triglyceride concentration; all of which reduce the risk of CVD among taller people in comparison to shorter people [15].

Our analysis also highlighted a divergent association between height and SBP among female only which is concurrent with the findings from Brazilian studies [9,30]. Possible biological plausibility of the divergent association between height and SBP among females is that the calibre of coronary arteries in females is smaller than males which might increase the risk of having higher SBP among females [15]. However, studies from other part of the world found the divergent association between height and SBP in both males and females, but showed that the dose dependent relationship is much stronger in females compare to males [7,8,19,31].

Like the study in China, our results did not find a conclusive relationship between shorter height and increased prevalence of hypertension among males and females. However, this result might have been different if analyses could be adjusted by the major contributors of hypertension, such as smoking, unhealthy diet, and physical inactivity. Height might not be directly related to smoking, unhealthy diet, and physical inactivity, but it is directly related with socio-economic status of the participants. People with lower socioeconomic status tend to be shorter than those with higher socioeconomic status [32]. People with lower socio-economic status are also more prone to unhealthy lifestyle such as smoking, unhealthy diet and physical inactivity [33]. Therefore, our analysis could be mediated by smoking, unhealthy diet, and physical inactivity. It should also be noted that the average height of Bangladeshi people might already be relatively low, thus limiting our ability to see the

difference in prevalence of hypertension across different quartiles of height.

Average heights of men and women in USA are 177 cm and 163 cm respectively [8], whereas the average height of Bangladeshi men and women are 161 cm and 149 cm respectively (Table 1). Average height of Chinese male and female are almost 5 cm higher than Bangladeshi males and females [7]. Therefore, it might have been easier for studies from USA and China to find the significant differences in prevalence of hypertension across different quartiles of height. Moreover, an analysis from the University of Tuebingen showed that the average height in developed countries increased substantially in the last 140 years, over the last 140 years the average height of Dutch men increased by 17.4 cm, whereas in the last 140 years, average height of Bangladeshi men increased by only 0.6 cm [34].

Another major limitation of the study is an absence of childhood nutrition data, because the underlying association between height and hypertension could be mediated by nutrition during childhood. Height is not only an imperative marker of malnutrition in childhood, but also a marker of mothers' nutrition during pregnancy [35]. Some studies have already reported that malnutrition during critical periods in early life might increase the risk of developing hypertension [36]. Due to the lack of childhood nutrition data of the respondents, it was not possible to explore whether height itself or malnutrition had an effect on hypertension in adulthood. Another major limitation was the use of cross-sectional data to establish the causal association between height and hypertension. One of the strengths of the study was that it involved all 7 divisions of Bangladesh which enhanced the generalizability of the result. In addition, BDHS uses standard questionnaires and medical measurements to collect quality assured data on demographics, socioeconomic status, and medical history of diseases which enhanced the reliability of our results [18].

5. Conclusion

Although this study did not find a significant relationship between height quartiles and prevalence of hypertension, height was found to be inversely associated with pulse pressure in both sexes. This evidence is important since it could provide a possible explanation for short stature being an independent risk factor for cardiovascular disease in middle aged older Bangladeshi adults. Future investigations preferably with longitudinal design is needed to further clarify our understanding of the potential association between height and the risk of developing hypertension and possibly CVDs.

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Availability of data and material

Data may be made available upon request to the ICF International, Maryland, USA.

Authors' information

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Consent for publication

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Declaration of Competing Interest

The authors declare that they have no competing interests.

CRediT authorship contribution statement

Md. Tauhidul Islam: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Md. Shahjahan Siraj:** Data curation, Formal analysis, Writing - review & editing. **Md. Zakiul Hassan:** Writing - review & editing. **Mohammad Nayem:** Writing - review & editing. **Dipankar Chandra Nag:** Writing - review & editing. **Md. Aminul Islam:** Writing - review & editing. **Rafiqul Islam:** Writing - review & editing. **Tapas Mazumder:** Writing - review & editing. **Sohel Reza Choudhury:** Writing - review & editing. **Ali Tanweer Siddiquee:** Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijchy.2020.100028.

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