Journal of Multidisciplinary Healthcare Dovepress

Open Access Full Text Article

ORIGINAL RESEARCH

Anthropometric Measurements in Predicting Haemorrhagic Stroke Among Bangladeshi Population: The MAGPIE Study

Redoy Ranjan[1,2], Dipannita Adhikary[1], Gie Ken-Dror[1], Md Abdullah Yusuf[3], Adneen Moureen[4], Maliha Hakim[5], Pankaj Sharma[1,6]

[1]Department of Biological Sciences, Royal Holloway University of London, London, UK; [2]Department of Cardiac Surgery, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh; [3]Department of Microbiology, National Institute of Neurosciences and Hospital, Dhaka, Bangladesh; [4]Tuberculosis New Technologies and Diagnostics, USAID's, Dhaka, Bangladesh; [5]Department of Neurology, National Institute of Neurosciences and Hospital, Dhaka, Bangladesh; [6]Department of Clinical Neuroscience, Imperial College Healthcare NHS Trust, London, UK

Correspondence: Pankaj Sharma, Department of Biological Sciences, Royal Holloway University of London, London, UK, Email pankaj.sharma@rhul.ac.uk

Background: Anthropometric measurements used to predict cardiovascular disease vary worldwide but are mostly derived from those of Caucasian ancestry. We sought to undertake such measurements in the little studied Bangladeshi population.

Methods: The MAGPIE (Multidimensional Approach of Genotype and Phenotype in Stroke Etiology) study is a Bangladeshi stroke case–control study that recruited nationwide between January 2022 and June 2024. The univariate analysis was utilised to curtail the risk of independent variables, and a receiver operating characteristic (ROC) curve was employed to identify the cut-off values of Body Mass Index (BMI), Waist Circumference (WC), and Hip Circumference (HC). Furthermore, a multivariate logistic regression (LR) model demonstrated the risk of independent predictors of haemorrhagic stroke (HS) among sexes.

Results: Of a total of 1491 age- and sex-matched study population, 918 were haemorrhagic stroke (61.5%) with female predominance (n=489; 53.3%) and significantly older than men (P=0.003). The BMI (22.9 ±3.0 vs 21.3 ±3.0; P<0.001), WC (84.0 ±7.3 vs 80.8 ±7.3; P<0.001) and HC (90.6 ±7.1 vs 85.5 ±7.7; P<0.001) was significantly higher among women compared to men. A ROC curve demonstrated that the cut-off values of BMI, WC, and HC are 20.6kg/m^2, 78.8cm, and 84.6cm, respectively, in men and 21.1 kg/m^2, 81.5cm, and 88.1cm, respectively, in women haemorrhagic stroke population. Furthermore, an age-adjusted multivariate LR model identified a HC of ≥84.6 cm in men (OR 2.8, 95% CI 1.61–4.97; P <0.001) and a WC of ≥81.5cm in women (OR 1.6, 95% CI 1.01–2.37; P=0.001) as potential independent predictors of haemorrhagic stroke.

Conclusion: Bangladeshi men with a hip circumference of ≥84.6cm have about threefold, and women with a waist circumference of ≥81.1cm have about twofold heightened risk of haemorrhagic stroke.

Keywords: haemorrhagic stroke, body mass index, waist circumference, hip circumference, Bangladesh

Introduction

Haemorrhagic stroke (HS) is an important health issue worldwide due to its high incidence, prevalence, and mortality rate.[1,2] Estimates suggest an incidence rate of approximately 68 per 100,000 individuals annually and the prevalence of haemorrhagic strokes comprises about 20–30% of all stroke cases in Bangladesh, although this country has been little studied.[2–4] Haemorrhagic stroke shows a higher prevalence among males as they are more vulnerable due to risk factors such as hypertension, smoking, and lifestyle differences, emphasising the need for targeted preventive measures to curtail the long-term consequences.[3–6] Furthermore, existing studies suggest that the prevalence of hypertension is 56%,[7] 64%,[8] 65%,[9] and 1.10%–75.0%,[10] among the Bangladeshi population, which is a strong independent predictor of haemorrhagic stroke.[2,4–6] The high mortality rate of 40–50% within the first month of onset for haemorrhagic stroke in Bangladesh is not helped by limited access to advanced medical care, inadequate stroke management facilities, and treatment delays.

Received: 5 November 2024
Accepted: 11 December 2024
Published: 14 December 2024

Efforts to mitigate risk factors are ongoing, focusing on enhancing healthcare infrastructure, increasing public awareness, and promoting preventive measures such as managing hypertension and making lifestyle adjustments.[4,6,11]

Anthropometric measurements such as body mass index (BMI), waist circumference (WC), and hip circumference (HC), are significantly correlated with the risk and severity of haemorrhagic stroke.[12–14] Higher BMI is linked to hypertension (HTN), a potential risk factor for haemorrhagic stroke. Furthermore, a higher WC is a more direct indicator of visceral adiposity and correlates more strongly with stroke risk than BMI.[13–16] Although HC is less frequently studied in isolation, a higher HC might indicate lower visceral fat, which can be protective against metabolic diseases.[14,15] However, the diversity in body measurements associated with hemorrhagic stroke varies globally. In Europe and America, higher BMI and WC are linked to increased stroke risk due to lifestyle factors and higher obesity prevalence.[14,17,18] In Southeast Asia, despite lower BMI, higher WC significantly contributes to stroke risk due to central obesity.[13–16] Region-specific preventive strategies targeting abdominal obesity and specific cut-off values of anthropometric measurements may help in assessing stroke risk across different populations and reducing the risk of haemorrhagic stroke effectively.[14–18]

This is the first study in Bangladesh to determine BMI, WC, and HC for predicting haemorrhagic stroke and observe their distribution patterns in haemorrhagic stroke compared to the control population.

Patients and Methods

The MAGPIE Study

The Multidimensional Approach of Genotype and Phenotype In Stroke Etiology (MAGPIE) study is an age- and sex-matched hospital-based case–control study conducted at the National Institute of Neuroscience and Hospital (NINS&H), Bangladesh. The MAGPIE study recruited adult (age ≥18 years) participants from all eight geographical divisions of Bangladesh between January 2023 and June 2024, whose protocol was published elsewhere.[19] Neuroimaging (CT/MRI) was used to confirm the diagnosis by two independent experts (a neurologist and an intervention radiologist). Ethical clearance was obtained from the institutional review board of the National Institute of Neurosciences and Hospital, Bangladesh (IRB/NINS/2024/358) and the study was conducted according to the Declaration of Helsinki. The study participants provided informed consent, and data were encrypted.

The study population (case and control) was ≥18 years old, and study variables were age, gender, major modifiable risk factors (hypertension, diabetes, smoking, high cholesterol), BMI, WC, and HC. We included all HS cases, either mild to severe, including prior and recurrent stroke (aged ≥18 years) confirmed with CT/MRI brain scans, in the study to avoid selective reporting bias. However, individuals with comorbidities such as neurological disorders (eg, multiple sclerosis, brain tumours), advanced cancer, strokes from other conditions, or those on medications that could significantly affect stroke risk, including experimental therapies, were excluded from the study. Additionally, control subjects also include the adult population (aged ≥18 years) without a prior history of stroke from similar geographic locations and socioeconomic backgrounds to ensure that controls are identical to cases in terms of medication use.

BMI, WC, and HC Measuring Methods

Body circumferences were measured using tape, ideally on bare skin for men and over a single thin layer of clothing for women.[20] The tape should rest snugly against the skin without being so tight it creates an indentation. For accurate waist and hip measurements, the individual should stand upright with shoulders relaxed, position the tape correctly, take a deep breath followed by exhaling fully, relax the abdomen completely, and then record the measurement; perform measurements twice to improve accuracy. To calculate BMI, weight was measured in kilograms using a standard calibrated weighing scale, and height was recorded in centimetres with a measuring tape. To measure WC, we utilised a landmark between the bottom of the ribs and the top of the hips, typically just above the umbilicus. For HC, we positioned the tape measure around the widest part of the hips and stood upright with legs together. For both WC and HC measurements, participants were instructed to exhale naturally before taking the measurements to ensure accuracy.

Statistical Analysis

We used SPSS v28.0 (IBM SPSS Inc., NY, USA) software to analyse the data and summarised the results using percentage and mean ±SD for categorical and continuous variables, respectively. First, a univariate analysis using appropriate statistical tests was used to curtail the risk patterns in the MAGPIE dataset. This was followed by a receiver operating characteristic (ROC) curve to identify the cut-off values of BMI, WC, and HC in haemorrhagic stroke patients. Furthermore, an age-adjusted multivariate logistic regression (LR) model considering the cut-off values of BMI, WC, and HC demonstrated the likelihood of HS in men and women. A Little's MCAR (Missing Completely At Random) test evaluates missing datasets. We also checked for multicollinearity among independent variables using the collinearity tolerance and variance inflation factor (VIF) value to observe the significant multicollinearity that needed to be addressed.[21] Statistical significance was considered a P value of <0.05.

Results

The MAGPIE study recruited age and sex matched 1491 study population aged ≥18 years with haemorrhagic stroke (n=918 (61.5%); women n=489; 53.3%). Hypertension was significantly higher (76.1% vs 65.6%; P<0.001), but BMI (P=0.002), WC (P<0.001), HC (P<0.001), diabetes (P<0.001), smoking (P=0.004), and high total cholesterol (P<0.001) were significantly lower among HS than control sample (Table 1). Furthermore, among the HS sample, women were significantly older than men (58.8 ±10.2 vs 56.5 ±13.8; P=0.003) (Table 2). Nevertheless, the BMI (22.9 ±3.0 vs 21.3 ±3.0; P<0.001), WC (84.0 ±7.3 vs 80.8 ±7.3; P <0.001), and HC (90.6 ±7.1 vs 85.5 ± 7.7; P<0.001) was significantly higher among women compared to men in haemorrhagic stroke.

In men, a ROC curve demonstrated that the cut-off values of BMI, WC, and HC in HS samples are 20.6kg/m^2, 78.8cm, and 84.6cm, respectively, with an AUROC curve of 0.43 (95% CI 0.38–0.46; P=0.001), 0.42 (95% CI 0.37–0.46; P<0.001), and 0.41 (95% CI 0.36–0.44; P<0.001), respectively (Figure 1). The sensitivity and specificity of BMI, WC and HC were 60.5% and 35.3%, 60.0% and 32.9%, and 52.6% and 33.2%, respectively. Furthermore, the cut-off values of BMI, WC, and HC in women with HS are 21.1kg/m^2, 81.5cm, and 88.1cm, respectively, with an AUROC curve of 0.48 (95% CI 0.43–0.52; P=0.41), 0.44 (95% CI 0.39–0.48; P=0.004), and 0.45 (95% CI 0.41–0.49; P=0.03), respectively (Figure 1). The sensitivity and specificity of BMI, WC and HC were 72.1% and 30.7%, 61.1% and 33.9%, and 58.2% and 35.4%, respectively.

Furthermore, an age-adjusted multivariate LR model identified HC ≥84.6 cm in men and WC ≥81.5 cm in women as a strong independent predictor of HS having an odds ratio of 2.8 (95% CI 1.61–4.97; P<0.001) and 1.6 (95% CI

Table 1 Baseline Characteristics of Study Population (N = 1491)

Variables		Haemorrhagic Stroke (N= 918)	Control (N=573)	P value
Age (mean ±SD)		57.7 ±12.0	56.7 ±14.9	0.17
Gender	Men	428 (46.7%)	297 (51.8%)	0.053
	Women	489 (53.3%)	276 (48.2%)	
BMI (mean ±SD)		22.2 ±3.1	22.7 ±3.5	0.002
Waist circumference (mean ±SD)		82.5 ±7.5	84.9 ±9.1	<0.001
Hip circumference (mean ±SD)		88.2 ±7.8	90.5 ±9.3	<0.001
Hypertension		698 (76.1%)	374 (65.6%)	<0.001
Diabetes		128 (13.9%)	157 (27.5%)	<0.001
Smoking		243 (22.4%)	155 (26.5%)	0.004
High total cholesterol		10 (1.1%)	34 (6.0%)	<0.001

Notes: The P-value was reached from the independent *t*-test in continuous variables and the chi-square tests in categorical variables. P <0.05 is considered significant.

Table 2 Gender-Specific Distribution Baseline Characteristics of Study Population

Variables	Haemorrhagic Stroke			Control		
	Men (N= 437)	Women (N=643)	P value	Men (N= 307)	Women (N=278)	P value
Age (mean ±SD)	56.5 ±13.8	58.8 ±10.2	0.003	56.3 ±14.3	57.2 ±15.5	0.48
BMI (mean ±SD)	21.3 ±3.0	22.9 ±3.0	<0.001	22.1 ±3.3	23.3 ±3.6	<0.001
Waist circumference (mean ±SD)	80.8 ±7.3	84. 0 ±7.3	<0.001	83.4 ±9.0	86.4 ±9.0	<0.001
Hip circumference (mean ±SD)	85.5 ±7.7	90.6 ±7.1	<0.001	88.8 ±9.2	92.3 ±9.1	<0.001
Hypertension	337 (78.7%)	360 (73.8%)	0.07	193 (65.4%)	181 (65.8%)	0.92
Diabetes	67 (15.7%)	61 (12.5%)	0.03	85 (28.7%)	72 (26.2%)	0.74
Smoking	160 (37.4%)	0 (0.0%)	<0.001	84 (28.4%)	0 (0.0%)	<0.001
High total cholesterol	5 (1.2%)	5 (1.0%)	0.83	21 (7.1%)	13 (4.7%)	0.23

Notes: The P-value was reached from the independent *t*-test in continuous variables and the chi-square tests in categorical variables. P <0.05 is considered significant.

1.01–2.37; P=0.001), respectively (Table 3). The goodness-of-fit of the prediction model demonstrated by the AUROC curve, sensitivity and specificity are 0.634 (95% CI 0.59–0.67; P <0.001), 70.6% and 49.0%, respectively, in men (Figure S1), and 0.586 (95% CI 0.54–0.62; P<0.001), 69.5% and 49.5%, respectively, in women (Figure S2). Nonetheless, Little's MCAR (Missing Completely At Random) test also observed a *P*-value of 0.85, indicating that the missing data are completely random. Furthermore, the VIF value of the multicollinearity test demonstrated no significant correlation; most VIF values were <2, except for WC and HC among independent variables. The maximum VIF and collinearity toler ance were 2.3 and 0.44 for WC and 2.4 and 0.42 for HC, respectively.

Discussion

This is the first Bangladeshi study to determine the OR of anthropometric measurements on haemorrhagic stroke. The cut-off values for predicting haemorrhagic stroke based on BMI, WC, and HC were 20.6 kg/m2, 78.8 cm, and 84.6 cm,

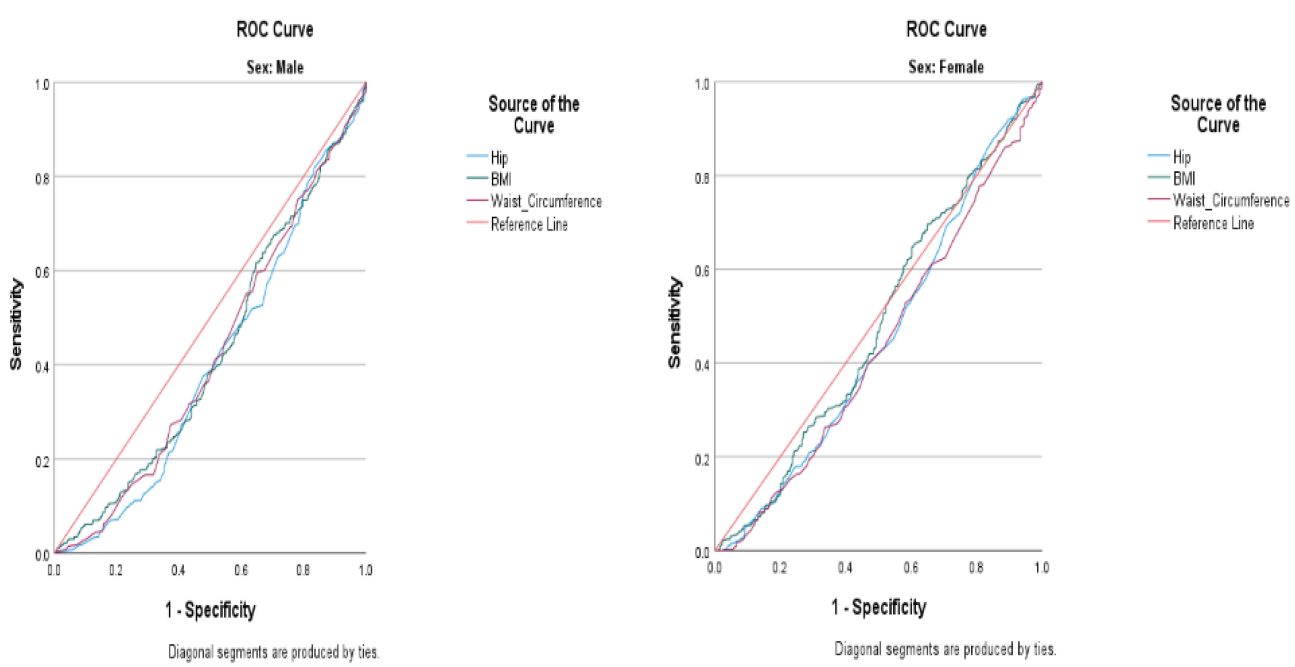

Figure 1 The receiver operating characteristic curve observed the cut-off value for predicting haemorrhagic stroke in men and women.

Table 3 Age-Adjusted Multivariate Logistic Regression Model Predicting Haemorrhagic Stroke Among Sexes Based on the Observed Cut-off Values

Variables		Odds Ratio	P value	95% CI	
				Lower	Upper
Men	BMI ≥20.6kg/m^2	0.92	0.67	0.63	1.34
	Waist circumference ≥78.8cm	0.63	0.11	0.36	1.11
	Hip circumference ≥84.6cm	2.83	<0.001	1.61	4.97
Women	BMI ≥21.1 kg/m^2	0.74	0.12	0.50	1.08
	Waist circumference ≥81.5cm	1.55	0.001	1.01	2.37
	Hip circumference ≥88.1cm	1.07	0.72	0.71	1.62

Notes: Variables entered into model: Age, HTN, Diabetes, Smoking, BMI ≥20.6kg/m^2, Waist circumference ≥78.8cm and Hip circumference ≥84.6cm for men; and Age, HTN, Diabetes, BMI ≥21.1kg/m^2, Waist circumference ≥81.5cm and Hip circumference ≥88.1cm for women.

respectively, for men and 21.1 kg/m2, 81.5 cm, and 88.1 cm, respectively, for women. Furthermore, men with a hip circumference of ≥84.6cm have about 3 times higher risk of haemorrhagic stroke, while women with a waist circumference of ≥81.5cm have about twice the risk compared to control subjects. Nevertheless, haemorrhagic stroke patients are paradoxically associated with significantly lower BMI, WC and HC compared to control subjects.

BMI has a potential correlation with haemorrhagic stroke risk, which is higher in slimmer individuals compared to overweight or obese individuals, supported our study findings.[12–15,22,23] Furthermore, a Nordic collaborative study[24] suggested that underweight individuals had an elevated risk for subarachnoid haemorrhage, especially in smokers and hypertensive men, indicating a modifying effect of risk factors on the BMI-subarachnoid haemorrhage (SAH) association. Furthermore, studies found that women with lower BMI levels have an increased risk of hemorrhagic stroke compared to men, a finding discordance to current study results.[15,17,22–24] However, this study findings emphasised the importance of weight management in reducing the risks of haemorrhagic strokes, highlighting the need for tailored risk assessment based on the observed BMI cut-off points among the Bangladeshi population.

Although the optimal cut-off values of WC and HC for predicting haemorrhagic stroke are elusive, the cut-off values for cardiovascular disease (CVD) risk vary across different populations.[15,18,25] Studies have shown that the new WC cut-off values for predicting atherosclerotic CVD for non-diabetic patients were 84cm and 76cm for non-obese men and women, whereas WC was 93 and 87 cm for obese men and women.[15–18] Furthermore, studies have shown disparities in using American, European, and Asian cut-offs for Africans, suggesting the need for indigenous African-based cut-offs predicting CVD.[26] Nonetheless, an Iranian study suggests that locally defined WC values of 90cm for men and 97cm for women are more accurate in predicting cardiovascular disease and metabolic syndrome than internationally recommended cut-off values.[27] Among Finnish participants, the hazard ratio (HR) was 1.2 in women with WC ≥87.5 cm and 1.4 in men with WC ≥ 100.5 cm to predict haemorrhagic stroke.[15] A recent study by Lopez-Lopez et al[18] found that men with a waist circumference of ≥89 cm had an HR of 1.8 for predicting cardiovascular morbidity and mortality, while women with a waist circumference of ≥86 cm had an HR of 1.5 among Colombians. Furthermore, in predicting CVD, women with a WC of ≥80 cm had an HR of 1.3 in the Arabian population,[28] and an odds ratio (OR) of 1.78 among Africans,[29] like our study findings. While risk prediction for hemorrhagic strokes is consistent across different ethnicities worldwide, the cut-off values for waist circumference (WC) vary by gender and ethnicity, supporting our study findings.

The specific cutoff values for HC in haemorrhagic strokes were not directly provided in the context, but existing studies found that larger HC is associated with an increased risk of hemorrhagic strokes. A hip circumference of ≥102cm in men and ≥88cm in women is considered high and associated with increased CVD risks.[14,16,29] The observed variations in WC and HC across different genders and ethnicities prompted an investigation to establish cut-off values that can predict the risk of hemorrhagic strokes in the Bangladeshi population. Higher waist and hip circumferences indicate metabolically active excess visceral fat, increasing the risk of chronic inflammation, arterial stiffness, and cardiovascular disease.[18,27–30] However, the differences in WC and HC among sexes in predicting haemorrhagic stroke in the current study are due to anatomical differences in bone structure, as women generally have a wider pelvis than men, contributing to a larger hip circumference.

Strength and Limitations

As with all studies, some limitations need to be acknowledged, especially the hospital-based observational nature of the study; however, utilising an age- and sex-matched control reduces the risk of outcome bias. Furthermore, we only evaluated adult haemorrhagic stroke patients from Bangladesh, so our results are not applicable to children or those of other ancestries. Bangladesh is a diverse country with populations spread across rural and urban regions. Although the current study included patients from all eight divisions within Bangladesh, representing a nationwide study, recruiting from every narrower geographical setting is challenging. Finally, we do not have data on treatment outcomes or the details of the brain lesions that prevent evaluating potential differences in mortality or morbidity among the study population.

Conclusion

In Bangladesh, the cut-off values for predicting haemorrhagic stroke were 20.6 kg/m2 BMI, 78.8 cm WC, and 84.6 cm HC for men and 21.1 kg/m2 BMI, 81.5 cm WC, and 88.1 cm HC for women. Additionally, men with a hip circumference of ≥84.6 cm and women with a waist circumference of ≥81.1 cm have approximately three times and two times higher risk of haemorrhagic stroke, respectively.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Mondal MBA, Hasan ATMH, Khan N, Mohammad QD. Prevalence and risk factors of stroke in Bangladesh: a nationwide population-based survey. *eNeurologicalSci*. 2022;28:100414. doi:10.1016/j.ensci.2022.100414
2. Islam MN, Moniruzzaman M, Khalil MI, et al. Burden of stroke in Bangladesh. *Int J Stroke*. 2013;8(3):211–213. doi:10.1111/j.1747-4949.2012.00885.x
3. Sadat A, Podder V, Biswas R. Stroke strikes in Bangladesh: current insights and future directions. *Cureus*. 2023;15(4):e37882. doi:10.7759/cureus.37882
4. Venketasubramanian N, Mannan M. Stroke burden and stroke services in Bangladesh. *Cerebrovasc Dis Extra*. 2021;11(2):69–71. doi:10.1159/000517234
5. Riaz BK, Chowdhury SH, Karim N, Feroz S, Selim S, Rahman R. Risk factors of hemorrhagic and ischemic stroke among hospitalized patients in Bangladesh - A case control study. *Bangladesh Med Res Counc Bull*. 2016;41(1):29–34. doi:10.3329/bmrcb.v41i1.30231
6. Hasan ABMK, Mandal MA, Moniruzzaman M, Shill SK, Ali MY. Sociodemographic status of hemorrhagic stroke patients: a study in a tertiary care hospital of Bangladesh. *Med Res Chronicles*. 2021;8(6):490–495. doi:10.26838/MEDRECH.2021.8.6.564
7. Hanif AAM, Shamim AA, Hossain MM, et al. Gender-specific prevalence and associated factors of hypertension among elderly Bangladeshi people: findings from a nationally representative cross-sectional survey. *BMJ Open*. 2021;11:e038326. doi:10.1136/bmjopen-2020-038326
8. Parvin S, Akter S, Hossain M, et al. Residential variations in hypertension prevalence and trends among adults in Bangladesh. *Res Health Serv Reg*. 2024;3:3. doi:10.1007/s43999-024-00040-2
9. Hypertension Study Group. Prevalence, awareness, treatment and control of hypertension among the elderly in Bangladesh and India: a multicentre study. *Bull World Health Organ*. 2001;79(6):490–500.
10. Chowdhury MZI, Rahman M, Akter T, et al. Hypertension prevalence and its trend in Bangladesh: evidence from a systematic review and meta-analysis. *Clin Hypertens*. 2020;26:10. doi:10.1186/s40885-020-00143-1
11. Mamin FA, Islam MS, Rumana FS, Faruqui F. Profile of stroke patients treated at a rehabilitation centre in Bangladesh. *BMC Res Notes*. 2017;10(1):520. doi:10.1186/s13104-017-2844-x
12. Shiozawa M, Kaneko H, Itoh H, et al. Association of body mass index with ischemic and hemorrhagic stroke. *Nutrients*. 2021;13(7):2343. doi:10.3390/nu13072343
13. Cong X, Liu S, Wang W, et al. Combined consideration of body mass index and waist circumference identifies obesity patterns associated with risk of stroke in a Chinese prospective cohort study. *BMC Public Health*. 2022;22(1):347. doi:10.1186/s12889-022-12756-2
14. Pillay P, Lewington S, Taylor H, Lacey B, Carter J. Adiposity, body fat distribution, and risk of major stroke types among adults in the United Kingdom. *JAMA Network Open*. 2022;5(12):e2246613. doi:10.1001/jamanetworkopen.2022.46613
15. Hu G, Tuomilehto J, Silventoinen K, Sarti C, Männistö S, Jousilahti P. Body mass index, waist circumference, and waist-hip ratio on the risk of total and type-specific stroke. *Arch Intern Med*. 2007;167(13):1420–1427. doi:10.1001/archinte.167.13.1420

16. Furukawa Y, Kokubo Y, Okamura T, et al. The relationship between waist circumference and the risk of stroke and myocardial infarction in a Japanese urban cohort: the Suita study. *Stroke*. 2010;41(3):550–553. doi:10.1161/STROKEAHA.109.569145
17. Becerril-Gaitan A, Ding D, Ironside N, et al. Association between body mass index and functional outcomes in patients with intracerebral hemorrhage. *Neurology*. 2024;102(2):e208014. doi:10.1212/WNL.0000000000208014
18. Lopez-Lopez JP, Gonzalez AM, Lanza P, et al. Waist circumference cut-off points to identify major cardiovascular events and incident diabetes in Latin America: findings from the prospective urban rural epidemiology study Colombia. *Front Cardiovasc Med*. 2023;10:1204885. doi:10.3389/fcvm.2023.1204885
19. Ranjan R, Adhikary D, Barman S, et al. Multidimensional approach of genotype and phenotype in stroke etiology: the MAGPIE study. *Health Sci Rep*. 2024;7:e70227. doi:10.1002/hsr2.70227
20. Casadei K, Kiel J. Anthropometric measurement. In: *StatPearls [Internet]*. Treasure Island (FL): StatPearls Publishing; 2024.
21. Hosmer DW, Lemeshow S, Sturdivant RX. *Applied Logistic Regression*. 3rd ed. Hoboken, NJ: John Wiley & Sons; 2013.
22. Song DK, Hong YS, Sung YA, Lee H. Body mass index and stroke risk among patients with diabetes mellitus in Korea. *PLoS One*. 2022;17(9):e0275393. doi:10.1371/journal.pone.0275393
23. Kim SH, Lee YS, Lee SM, Yoon BW, Park BJ. Body mass index and risk of hemorrhagic stroke in Korean adults: a case-control study. *J Prev Med Public Health*. 2007;40(4):313–320. doi:10.3961/jpmph.2007.40.4.313
24. Rautalin I, Kaprio J, Ingebrigtsen T, et al. Obesity does not protect from subarachnoid hemorrhage: pooled analyses of 3 large prospective Nordic cohorts. *Stroke*. 2022;53(4):1301–1309. doi:10.1161/STROKEAHA.121.034782
25. Kim KS, Oh HJ, Choi YJ, et al. Reappraisal of waist circumference cut-off value according to general obesity. *Nutr Metab*. 2016;13:26. doi:10.1186/s12986-016-0085-y
26. Bolanle AA. Waist circumference disparity: a comparison of American, European and Asian cut-off among Africans. *J Appl Biotechnol Bioeng*. 2017;4(3):605–608.
27. Talaei M, Thomas GN, Marshall T, et al. Appropriate cut-off values of waist circumference to predict cardiovascular outcomes: 7-year follow-up in an Iranian population. *Intern Med*. 2012;51(2):139–146. doi:10.2169/internalmedicine.51.6132
28. Al-Lawati JA, Barakat NM, Al-Lawati AM, Mohammed AJ. Optimal cut-points for body mass index, waist circumference and waist-to-Hip ratio using the Framingham coronary heart disease risk score in an Arab population of the Middle East. *Diab Vasc Dis Res*. 2008;5:304–309. doi:10.3132/dvdr.2008.044
29. Ringane MC, Choma SSR. The optimal WC cut-off points for the prediction of subclinical CVD as measured by carotid intima-media thickness among African adults: a cross-sectional study. *BMC Cardiovasc Disord*. 2021;21(1):575. doi:10.1186/s12872-021-02389-5
30. Shuang P, Yang J, Li C, et al. Effect of BMI on central arterial reflected wave augmentation index, toe-brachial index, brachial-ankle pulse wave velocity and ankle-brachial index in Chinese elderly hypertensive patients with hemorrhagic stroke. *J Stroke Cerebrovasc Dis*. 2021;30(9):105945. doi:10.1016/j.jstrokecerebrovasdis.2021.105945