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Original Research

Blood Pressure Differences among Obese, Overweight, and Normal-Weight Adolescents in Enugu Metropolis: A Comparative Study

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Abstract

Background: Hypertension is a major modifiable cardiovascular risk factor, and increasing adolescent obesity is strongly linked to early-onset hypertension and an increased risk of cardiovascular complications in adults. This study compared blood pressure among obese, overweight, and normal-weight adolescents and examined associated anthropometric factors and patterns.
Methodology: This comparative cross-sectional study included 486 adolescents (162 normal-weight, 162 overweight, and 162 obese) from secondary schools in Enugu. The participants were selected via multistage sampling. Anthropometric and blood pressure measurements were obtained via standardized methods, with blood pressure classified by age-, sex-, and height-specific percentiles. The data were analysed via SPSS v26, with significance set at $p < 0.05$.
Results: A significant association was observed between body weight and hypertension ($\chi^2 = 45.5$, $p = 0.0001$), with the prevalence increasing from 3.7% in normal-weight participants to 12.3% in overweight participants and 38.9% in obese participants. Both systolic and diastolic blood pressure differed significantly across the groups ($p = 0.0001$). Systolic blood pressure increased progressively across all categories ($p < 0.05$), whereas diastolic blood pressure was significantly greater in obese participants. Significant positive correlations were found between blood pressure and anthropometric indices, particularly in the overweight and obese groups ($p < 0.05$). Hypertensive participants had significantly higher systolic blood pressure across all groups, with obese hypertensive participants also having higher diastolic pressure.
Conclusion: This study demonstrated that obesity is strongly associated with an increased risk of elevated blood pressure among adolescents. Blood pressure increases progressively with increasing body weight, with obese adolescents being disproportionately affected. Waist circumference has emerged as a key predictor of elevated blood pressure, underscoring the importance of central adiposity in cardiovascular risk stratification. These findings highlight the growing burden of obesity-related elevated blood pressure in adolescents and the need for early detection and intervention.

Keywords: Adolescents; obesity; overweight; hypertension; blood pressure; waist circumference

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Introduction

Hypertension is a major modifiable risk factor for cardiovascular disease (CVD) and contributes substantially to global morbidity and mortality [1,2]. Increasing evidence indicates that elevated blood pressure that originates in childhood often tracks into adolescence and adulthood, thereby predisposing affected individuals to long-term cardiovascular complications [4–7]. Despite this, the diagnosis of hypertension in children and adolescents remains suboptimal, particularly in low- and middle-income settings, where awareness and routine screening practices are still evolving.

The prevalence of hypertension among adolescents ranges from 2% to 20.5%, with a pooled global estimate of 7.6% [8]. Data from the National Family Health Survey-5 further highlight sex-specific prevalence rates of 3.3% in females and 4.6% in males [9]. These findings underscore the growing burden of elevated blood pressure in this age group.

Childhood obesity, a well-recognized global public health concern, has been strongly implicated in the development of hypertension and other cardiometabolic disorders [10]. The World Health Organization estimates that approximately 40 million children under five years of age are overweight worldwide [10]. In Nigeria, the prevalence of childhood obesity ranges from 0.3% to 5%, whereas higher rates of 13–14% have been reported in developed countries [10]. Obesity in adolescence is associated with diminishing self-esteem, increased risk of hypertension, insulin resistance, type 2 diabetes mellitus, and dyslipidemia, with obese adolescents reported to have up to a threefold higher risk of developing hypertension than their nonobese peers [11,12].

Despite the growing recognition of paediatric hypertension, significant knowledge and practice gaps persist. These include under-recognition and under-diagnosis, with studies suggesting that up to 75% of hypertensive children remain undiagnosed [12]. Inadequate screening practices, inconsistencies in diagnostic thresholds, and variability in guideline recommendations further complicate early detection and management [11,13–15]. Additionally, clinician-related factors such as poor adherence to follow-up protocols and inaccuracies in blood pressure measurement techniques contribute to delayed diagnosis [14]. In many settings, both in the primary and secondary health care, including the study environment, there is a paucity of data on adolescent hypertension and limited evidence on long-term outcomes [15].

Furthermore, much of the literature on hypertension has focused predominantly on adult populations, reinforcing the misconception that hypertension is primarily a disease of older individuals [16,17]. This has contributed to reduced clinical vigilance in younger populations, despite the potential for early-onset hypertension to result in significant long-term health consequences. The diagnosis of hypertension in adolescents often generates considerable concern among caregivers, further emphasizing the need for improved awareness and early detection strategies [7].

Given these gaps, there is a need for context-specific data to inform screening and preventive strategies. Therefore, this study aimed to compare blood pressure levels among obese, overweight, and nonobese adolescents and to identify associated anthropometric and demographic factors. This study also sought to examine age- and sex-related correlates of blood pressure and to interpret findings via standardized blood pressure percentile charts. The findings are expected to contribute to the existing body of knowledge and provide a framework for future research and interventions.

Materials and Methods

Study Area

The study was conducted in the Enugu metropolis, the capital of Enugu State, which is one of the states in the Southeast Geopolitical Zone of Nigeria.

Study Design:
This was a comparative cross-sectional study of 486 adolescents comprising 162 overweight, 162 obese, and 162 normal-weight secondary school adolescents in the Enugu metropolis that was carried out over a seven-month period.

Study population
This comprises secondary school adolescents aged 10- 17 years who are recruited from both public and private schools in the three local government areas of the state of study (LGAs).

Sampling technique
The multistage sampling technique was used to select the students for the study from each of the three local governments in the Enugu metropolis. In the first stage, schools in the three local government areas located in the Enugu metropolis were selected and stratified into private and public schools. The ballot method was used to select the public and private schools that were used in the study. This variable was selected randomly from the three local governments at a ratio of 1:3. 1:4 and 1:3 for Enugu North, Enugu East, and Enugu South, respectively. Ten private and 3 public schools were selected for the study. In the second stage, the required number of students per school was calculated via the ratio of the population in each school to the total population of all the schools via the following formula: [20]

$n_h = (N_h / N) \times n$

where n_h is the sample size for school *h,* N_h is the population size for school *h*, N is the total population size of the schools, and n is the total sample size.

Thus, the number of students enrolled in each school =

$$\frac{\text{Index School Population}}{\text{Total population of selected schools}} \times \text{Total Sample Size}$$

In the third stage, the number allocated to each selected school was spread to cover all cases from junior to senior secondary.

Students (aged 10--17 years) in the selected secondary schools with BMI-for-age Z scores > +1, whose parents/guardians consented to participate in the study, and students who gave assent to participate in the study were included in the study, whereas for controls, age- and gender-matched secondary school students with BMI-for-age Z scores between -2 and < +1, whose parents/guardians consented to participate in the study, and students who gave assent to participate in the study were also included in the study. Students with signs/symptoms suggestive of renal diseases (facial/generalized body swelling, dysuria, passage of blood in urine or scanty urine),

Sample size determination
The desired sample size was calculated via the following formula to compare the proportions of the two groups. [13]

$$n = \frac{[Z_\alpha + Z_{1-\beta}]^2[p_1(1-p_1) + p_2(1-p_2)]}{(p_1 - p_2)^2}$$

where:
n = minimum sample size in each group

Z_α = standard normal deviation corresponding to the 5 percent significance level = 1.96.

$Z_{1-\beta}$ = standard normal deviation corresponding to a power of 80 percent deviation = 0.84.

P_1 = Prevalence of elevated blood pressure in obese adolescents from a previous study [14]

= 13 percent = 0.13.

P2= Prevalence of elevated blood pressure in normal-weight adolescents from a previous study. [14] = 4 percent = 0.04.

p1 – p2 = the smallest difference between the two groups of scientific or clinical importance = 0.09.

Thus, substituting in the formula,
n = 147.

A nonresponse rate of 10% was used. Therefore, 162 overweight, obese, and normal-weight adolescents were recruited for the study, resulting in a total minimum sample size of 486.

Anthropometric measurements
Two measurements were taken for each of the anthropometric indices, namely, weight, height, and waist circumference, and the average of these measurements was taken.

Weight
Each participant was weighed via a sensitive floor weighing scale (SECA® model 756). The scale was placed on a firm horizontal surface and set at zero before any measurement was taken. The accuracy was checked with an object of a known weight after every ten measurements or when the scale was moved from place to place. [21] Weight was measured with the participants in their school uniforms, whose pockets were emptied after the removal of cardigans and sweaters. The participants were asked to stand erect, stand barefoot, and look forward with their arms at their sides. With the measurer standing directly in front of the scale (to eliminate error due to parallax), the weight was recorded in kilograms (kg) to the nearest 0.1 kg. This was recorded in the study proforma.

Height
Height was measured via a stadiometer calibrated to 0.1 centimetres (SECA® stadiometer, model 217, SECA Corp, Hamburg, Germany). The participant stood barefoot on the footplate portion, without headgear such as a cap, during the measurement time. The heels, buttocks, shoulder blades, and occiput were in contact with the vertical board, with the arms vertical on each side of the body and the legs straight. [21] The head was positioned in the Frankfurt plane, with the lower margins of the orbit and the upper margins of the ear canal in the same horizontal plane. [21] At this position, the movable headpiece of the device was lowered until it touched the top of the head of the participant, and the height was read off the stadiometer. [21]

Waist circumference
Waist circumference was measured via a flexible measuring tape with the participant standing erect. The measurement was taken at the end of expiration, midway between the inferior margin of the lowest rib and the highest point of the iliac crest. These landmarks were determined by palpation. The measurements obtained were plotted on the appropriate waist circumference centile chart for age and sex. Waist circumference values greater than or equal to the 90^{th} percentile for age and sex were considered central obesity. [22]

Blood pressure measurement

Blood pressure was measured via an Acosson mercurial sphygmomanometer (DEKAMET MK.3 model, UK) with an appropriately sized cuff. The student was seated quietly in a chair for at least 5 minutes before the BP measurement. The measurement was taken with the feet on the floor, back supported, and arms supported (resting on a table or held up by an observer) at the heart level. An appropriate cuff size was selected by measuring the arm circumference at the midpoint between the acromion and olecranon. A cuff bladder length of 80–100% and width of at least 40% (i.e., a length–width ratio of 2:1) of the measured arm circumference was considered appropriate. [24] The cuff was tied at the midpoint between the acromion and the olecranon process, covering approximately two-thirds of the arm, with the lower border not less than 2.5 cm above the cubital fossa. [24] The palpation method was used initially to obtain the pressure that would occlude the radial pulse, and then the auscultatory measurement method was carried out. The right hand was used for consistency. The brachial artery was palpated, and its position was noted. The cuff was inflated to a pressure of 30 mmHg above the level at which the radial pulse was no longer palpable. The stethoscope was placed over the brachial artery in the cubital fossa, and the pressure in the cuff was deflated at 2–3 mmHg every second until the first Korotkoff sound was heard. [24] This was recorded as the systolic blood pressure (SBP).[145] The pressure in the cuff was continuously lowered until the sounds disappeared completely. This was the fifth Korotkoff sound, and the pressure here was recorded as the diastolic blood pressure (DBP). [24] In situations where the Korotkoff sounds were heard up to the zero mark, the point at which the sound was muffled (fourth Korotkoff sound) was taken as the DBP.[145] Three measurements were taken for each participant with a 2-minute interval between measurements, and the average blood pressure was recorded. Blood pressure (SBP and/or DBP) greater than or equal to the 95th percentile for age, sex, and height according to the CDC blood pressure charts was considered elevated. [24] **Blood pressure was measured on 3 separate occasions, and the average was taken.**

Social class determination

The social class of the study participants was determined via the socioeconomic indices of the parents as described by Oyedeji. [25]

Ethical approval and consent

Ethical approval was obtained from the research and ethics committee of the University of Nigeria Teaching Hospital, Enugu, Nigeria. Reference number NHREC/05/01/2008B-FWA00002458-IRB00002323. Written informed consent was obtained from all parents and/or legal guardians of all the study participants prior to enrollment in the study. All research procedures and ethical standards were conducted in accordance with the Declaration of Helsinki.

Data analysis

The data were analysed via SPSS v 25 software (IBM, USA). Descriptive statistics were performed via frequencies and percentages. Chi-square analysis was used to assess the distribution of elevated blood pressure across the three groups (normal, overweight and obese). Analysis of variance (ANOVA) was used to assess the differences in the mean SBP and DBP between the groups. Independent t-tests were used to compare the mean values of the index parameters (weight, height, WC, etc.) among the different groups. The person's correlation statistic was used to assess the relationships between index parameters and systolic and diastolic BP. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

A statistically significant association was observed between body weight category and hypertension ($\chi^2 = 45.5$, p = 0.0001). The prevalence of hypertension was highest among obese participants (38.9%), whereas it was 12.3% in the overweight group and 3.7% in the normal weight group.

Table 1: Distribution of hypertension by group

Group	Hypertensive n,(%)	Normal n,(%)	Total n,(%)	Chi-square (p-value)
Normal	6(3.7)	156(96.3)	**162(100.0)**	45.5 (0.0001)*
Overweight	20(12.3)	142(87.7)	**162(100.0)**	
Obese	63(38.9)	99(61.1)	**162(100.0)**	

Comparison of Blood Pressure across Groups

There were statistically significant differences in both systolic and diastolic blood pressure across the three weight categories (p = 0.0001), indicating a strong effect of increasing body weight on blood pressure. Table 2

The mean systolic blood pressure increased significantly across all groups, with post hoc analysis confirming significant differences between normal and overweight participants (p = 0.003), normal and obese participants (p = 0.0001), and overweight and obese participants (p = 0.001). This demonstrates a consistent and progressive rise in systolic blood pressure with increasing adiposity. Table 2

For diastolic blood pressure, statistically significant differences were observed between the obese group and both the normal-weight and overweight groups (p = 0.0001). These findings indicate that elevated diastolic pressure is driven primarily by obesity, with a marked increase occurring at higher levels of body weight.

Table 2: Comparison of blood pressure across the different groups

Blood Pressure	Groups			ANOVA	Multiple comparisons (p-value)		
	Normal	Overweight	Obese	(p-value)	Normal Vs Overweight	Normal Vs Obese	Overweight Vs Obese
Systolic BP (mmHg)	105.9 ±11.8	109.9±11.4	114.3±12.7	0.0001*	0.003*	0.0001*	0.001*
Diastolic BP (mmHg)	68±9.9	68.1±9	75.3±9.8	0.0001*	0.912	0.0001*	0.0001*

*statistically significant (p<0.05); all values are presented as the mean ± standard deviation

Correlation ***between*** *Anthropometric Parameters and Blood Pressure*

Significant positive correlations were observed between blood pressure and anthropometric indices, particularly among overweight and obese participants. Table 3

In the obese group, systolic and diastolic blood pressure were significantly positively correlated with weight (r = 0.409; r = 0.311), height (r = 0.311; r = 0.264), BMI (r = 0.359; r = 0.263), and waist circumference (r = 0.343; r = 0.230) (p < 0.05 for all). Table 3

In the overweight group, systolic blood pressure correlated significantly with weight (r = 0.189) and BMI (r = 0.187), whereas diastolic blood pressure correlated with BMI-for-age Z score (r = 0.243) and waist circumference (r = 0.158) ($p < 0.05$). Table 3

A strong positive relationship between systolic and diastolic blood pressure was also observed across all groups ($p < 0.05$).

Table 3: Pearson's correlation of blood pressure with other parameters

Blood Pressure	Parameters	Normal	Overweight	Obese
Diastolic BP vs	Weight	-0.001	0.151	0.311*
	Height	-0.017	0.134	0.264*
	BMI	0.021	0.077	0.263*
	Z score: BMI-for-age	0.017	0.243*	-0.159*
	WC	-0.122	0.158*	0.230*
	Systolic Bp	0.445*	0.306*	0.460*
Systolic BP vs	Weight	0.069	0.189*	0.409*
	Height	0.032	0.11	0.311*
	BMI	0.075	0.187*	0.359*
	Z score: BMI-for-age	0.062	0.117	-0.188*
	WC	0.039	0.139	0.343*
	Systolic Bp	0.445*	0.306*	0.460*

Comparison of Hypertensive and Normotensive Participants

Compared with normotensive participants, hypertensive participants in the normal-weight group had significantly greater systolic (123.25 ± 15.41 mmHg) and diastolic (83.45 ± 7.67 mmHg) blood pressures (p = 0.000).

In the overweight group, hypertensive participants demonstrated significantly greater systolic blood pressure (121.70 ± 13.47 mmHg vs 108.18 ± 10.07 mmHg; p = 0.000) and a significant difference in waist circumference (p = 0.031).

Compared with normotensive participants, hypertensive participants in the obese group had significantly greater weight (p = 0.007), height (p = 0.011), and waist circumference (p = 0.003), as well as markedly elevated systolic (123.57 ± 10.57 mmHg) and diastolic (82.62 ± 8.93 mmHg) blood pressure (p = 0.000 for both).

Table 4: **Comparison of Hypertensive and Normotensive Participants**

Blood Pressure Parameters		**Hypertensive (Mean ± SD)**	**Normal (Mean ± SD)**	**p value**
Normal	Weight	53.25 ± 5.16	52.25 ± 8.78	0.621
	Height	163.40 ± 6.00	162.95 ± 7.44	0.798
	Z score: BMI-for-age	–0.08 ± 0.73	-0.17 ± 0.89	0.663
	WC	66.35 ± 2.80	68.25 ± 4.66	0.078
	Systolic BP	123.25 ± 15.41	103.49 ± 8.81	0.000*
	Diastolic BP	83.45 ± 7.67	65.85 ± 8.14	0.000*
Overweight	Weight	64.40 ± 9.77	68.35 ± 10.33	0.109
	Height	161.40 ± 8.05	164.75 ± 8.88	0.113
	Z score: BMI-for-age	1.65 ± 0.26	1.57 ± 0.27	0.192
	WC	76.75 ± 6.93	80.10 ± 6.37	0.031*
	Systolic BP	121.70 ± 13.47	108.18 ± 10.07	0.000*
	Diastolic BP	69.75 ± 13.62	67.91 ± 8.25	0.396
Obese	Weight	84.94 ± 12.28	79.55 ± 12.22	0.007*
	Height	164.67 ± 6.27	161.70 ± 7.65	0.011*
	Z score: BMI-for-age	2.62 ± 0.44	3.06 ± 3.49	0.323
	WC	93.12 ± 9.07	88.92 ± 8.42	0.003*
	Systolic BP	123.57 ± 10.57	108.38 ± 10.25	0.000*
	Diastolic BP	82.62 ± 8.93	70.62 ± 7.09	0.000*

*statistically significant ($p<0.05$)

Discussion

Principal Findings

This study revealed that elevated blood pressure was markedly more prevalent among obese participants (38.9%) than among overweight (12.3%) and normal-weight adolescents (3.7%). In addition, both systolic and diastolic blood pressure progressively increased with increasing body weight and adiposity indices. Obesity was also associated with stronger correlations between anthropometric parameters and blood pressure.

Comparison with Previous Studies

The observed prevalence obtained in the current study is consistent with the findings of Nkeh et al. [25], who reported an identical prevalence among adolescents. The similarity in age range and study design (cross-sectional) likely explains this concordance. The significantly greater prevalence of elevated blood pressure among obese adolescents in this study aligns with the findings of previous reports. Bonita et al. [26] reported a prevalence of 30% among obese adolescents, whereas another study reported rates of 18.2% and 31.4% among overweight and obese individuals, respectively [27]. In contrast, data from the United States reported lower prevalence rates of 9.43% in obese children, increasing to 14.7% among those with severe obesity [28]. These variations may reflect differences in population characteristics, environmental exposures, dietary patterns, and genetic predispositions.

Pathophysiological Mechanisms

The greater burden of elevated blood pressure observed among obese adolescents may be explained by several biological mechanisms. Obesity is associated with hyperinsulinaemia, activation of the sympathetic nervous system, and increased sodium retention, all of which contribute to elevated blood pressure. Additionally, chronic low-grade inflammation and the release of adipokines further exacerbate vascular dysfunction and increase peripheral resistance [28]. These mechanisms collectively support the observed relationship between adiposity and elevated blood pressure.

Relationship between Anthropometry and Blood Pressure

This study demonstrated a positive association between increasing body weight and both systolic and diastolic blood pressure. This finding is consistent with previous evidence indicating that weight gain is directly proportional to increases in blood pressure; for example, a 1 kg increase in body weight has been associated with an increase in systolic blood pressure of approximately 0.7 mmHg [29]. Similar associations have been reported by Yusni et al. [31], Luisa et al. [32], and Kringel et al. [33].

Furthermore, the obese adolescents in this study had significantly greater systolic blood pressure than did their overweight and normal-weight counterparts. Although diastolic blood pressure did not differ significantly between the normal-weight and overweight groups, it was significantly elevated among obese adolescents, suggesting a threshold effect of adiposity on vascular resistance.

Role of Central Obesity

Waist circumference has emerged as an important marker of elevated blood pressure risk. In normal-weight adolescents, anthropometric indices (weight, height, and waist circumference) are interrelated but do not significantly influence blood pressure. However, in overweight adolescents, increased body size and central fat accumulation are associated with increased blood pressure. This relationship became more pronounced in obese adolescents, where anthropometric indices showed strong positive correlations with both systolic and diastolic blood pressure.

This finding is consistent with the study by Niba et al. [34], which demonstrated a strong association between waist circumference and elevated blood pressure among adolescents in Cameroon. Central adiposity is therefore a critical determinant of cardiovascular risk and may be a more sensitive predictor of elevated blood pressure than general adiposity measures.

Subgroup Analysis by Weight Category

Among normal-weight adolescents, hypertensive and normotensive participants had similar anthropometric characteristics, suggesting that elevated blood pressure in this group may not be driven by body size but possibly by other factors, such as genetics, diet, or physical inactivity.

In the overweight group, anthropometric indices were also comparable between hypertensive and normotensive individuals, although a trend toward greater blood pressure was observed. In contrast, among obese adolescents, hypertensive individuals consistently presented higher values of weight, body mass index, and waist circumference, alongside elevated blood pressure. These findings underscore the significant role of obesity in increasing blood pressure risk.

Public health implications

These findings highlight the need for early identification of adolescents at risk of elevated blood pressure, particularly those with obesity. Preventive strategies should include routine blood pressure screening in schools, promotion of healthy dietary practices (including reduced sodium intake), encouragement of regular physical activity, and weight management interventions. Early lifestyle modification is critical for reducing the long-term cardiovascular burden associated with elevated blood pressure in adolescents [28].

Limitations

The study is limited by the fact that confounders were not adjusted for by the use of multivariate analysis. Blood pressure measurements were obtained at a single time point; repeated measurements over time would improve diagnostic accuracy and allow assessment of trends. The cross-sectional design limits causal inference between obesity and elevated blood pressure. Potential residual confounding factors (e.g., dietary intake, physical activity, family history) were not fully explored

Conclusion

This study demonstrated that obesity is strongly associated with an increased risk of elevated blood pressure among adolescents. Blood pressure increases progressively with increasing body weight, with obese adolescents being disproportionately affected. Waist circumference has emerged as a key predictor of elevated blood pressure, underscoring the importance of central adiposity in cardiovascular risk stratification. These findings highlight the growing burden of obesity-related elevated blood pressure in adolescents and the need for early detection and intervention.

Recommendations

Regular blood pressure measurements should be incorporated into school health programs, particularly for adolescents who are overweight or obese, to facilitate early detection of elevated blood pressure. In addition, **t**argeted interventions focusing on weight reduction through healthy dietary practices and increased physical activity should be prioritized among adolescents. Schools and caregivers should promote reduced salt intake, balanced diets, and healthy lifestyle behaviours to mitigate modifiable risk factors. Waist circumference should be routinely assessed alongside BMI in clinical and school settings as a simple and effective predictor of elevated blood pressure risk. Government and health authorities should implement policies that encourage physical activity in schools and regulate access to unhealthy foods among adolescents.

Declaration

Ethical approval and consent

Ethical approval was obtained from the research and ethics committee of the University of Nigeria Teaching Hospital, Enugu, Nigeria. Reference number NHREC/05/01/2008B-FWA00002458-IRB00002323. Written informed consent was obtained from all parents and/or legal guardians of all the study participants prior to enrollment in the study. All research procedures and ethical standards were conducted in accordance with the Declaration of Helsinki.

Consent for publication:

Not applicable.

Availability of data and materials: Data are provided within the manuscript or supplementary information files.

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Authors' contributions
NON conceived and designed this study, whereas NON, ICN, UE and JMC helped in the critical revision of the article. NON also performed the data analysis/interpretation.

Patient and public involvement
It was not appropriate or possible to involve patients or the public in the design, conduct, report, or dissemination of plans for our research.

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Supporting Information Files
The files, including the raw data and SPSS files, are submitted to the online submission system.

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