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ROC curves of obesity indicators have a predictive value for children hypertension aged 7-17 years

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Abstract

Objective: **The aim of the study is to examine the distribution of integrated covariate and its association with blood pressure (BP) among children in Anhui province, China, and assess the predictive value of integrated covariate to children hypertension.**

Methods: **A total of 2,828 subjects (1,588 male and 1,240 female) aged 7-17 years participated in this study. Height, weight, waistline, hipline and BP of all subjects were measured, obesity and overweight were defined by an international standard, specifying the measurement, the reference population, and the age and sex specific cut off points. High BP status was defined as systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) ≥ 95th percentile for age and gender.**

Results: **Our results revealed that the prevalence of children hypertension was 11.03%, the SBP and DBP of obesity group were significantly higher than that of normal group. Anthropometric obesity indices such as body mass index (BMI) were positively correlated with SBP and DBP. Integrated covariate had a better performance than the single covariate in the receiver-operating characteristic (ROC) curve, the cut-off value; the sensitivity and the specificity of the integrated covariate were 0.112, 0.577, 0.683, respectively.**

Conclusion: **Integrated covariate is a simple and effective anthropometric index to identify childhood hypertension.**

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Key words: *Childhood hypertension. Obesity receiver-operating characteristic (ROC) curve.*

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CURVAS ROC DE LA OBESIDAD EN LOS INDICADORES TIENEN UN VALOR PREDICTIVO PARA NIÑOS DE ENTRE 7 Y 17 AÑOS HIPERTENSIÓN

Resumen

Objetivo: **El objetivo del estudio es examinar la distribución de las covariables integrado y su asociación con la presión arterial (PA) entre los niños en la provincia de Anhui, China, y evaluar el valor predictivo de covariables integrado a los niños la hipertensión.**

Métodos: **Un total de 2.828 sujetos (1.588 macho y 1.240 hembra) de 7 a 17 años participaron en este estudio. Altura, peso, cintura, hipline y BP de todos los sujetos fueron medidos, la obesidad y el sobrepeso se han definido por una norma internacional, especificando la medición, la población de referencia, y la edad y sexo los puntos de corte.La condición de alta presión se define como la presión arterial sistólica (PAS) y/o presión arterial diastólica (PAD) ≥ percentil para edad y sexo.**

Resultados: **Nuestros resultados revelan que la prevalencia de niños la hipertensión fue 11,03%, el SBP y DBP de obesidad grupo fueron significativamente más alta que la de grupo normal. Los índices de obesidad, tales como el índice de masa corporal (IMC) se correlacionaron positivamente con SBP y DBP. Integrated covariable tuvo un mejor rendimiento que la covariable en la curva de características operativas del receptor (ROC), el valor de corte, la sensibilidad y la especificidad de las covariables fueron integrados 0,112, 0,577, 0,683, respectivamente.**

Conclusión: **Integrado covariable es un simple y eficaz para identificar a la niñez índice antropométrico hipertensión.**

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Palabras clave: *Hypertensión. Obesidad infantil de la curva de características operativas del receptor (ROC).*

Introduction

Hypertension is one of the public health which have severely harm to human.[1,2] In recent years, hypertension is prevalence among young adults, previous study showed that the overall prevalence of essential hypertension is vary from 1% to 5%.[3,4] Childhood hypertension can lead to serious health problems,[2,5,6] such as leading to adult hypertension, and adults' left ventricular hypertrophy, which is seen as many as 41% of patients with children hypertension.[7,8] Previous studies showed that overweight and obese children face an approximately threefold higher risk for essential hypertension than do non-obese children.[9,10] The obesity of kids and teenagers had become an important public health problem.[11]

The prevalence of overweight and obesity among children and adolescents is increasing worldwide.[12,13] Appropriate early-stage diagnosis and intervention of hypertension in children and adolescents are important for reducing the risk of hypertension related disorders in adults.[2,6] Identifying hypertension in children and adolescents is more complicated than in adults, because childhood hypertension is based on a set of age, gender, and height specific references in systolic blood pressure (SBP) and diastolic blood pressure (DBP).[4] Thus, a simplify method to diagnostic children hypertension is more important. Many previous studies focus on the relations between the general or central obesity and BP to explore the diagnostic criteria of children hypertension.[14-16]

BMI is widely used as a measurement to define obesity, the potential value to predict BP remains debatable.[17,18] Other measurements, WC and waist-to-height ratio (WHTR), as indicators of abdominal fat mass, may have close relationship with BP in children. Moreover, some studies demonstrated that the ratio of waist circumference to height (WHR) was even superior to waist circumference (WC) and body mass index (BMI) to predict hypertension in children,[19-21] but it remains dispute.

The aim of the study is to examine the distribution of integrated covariate and its association with blood pressure (BP) among children in a large population in Anhui and to assess the predictive value of integrated covariate to children hypertension.

Methods

A cross-sectional survey with representative sample of children aged 7-17 years was conducted in 2013 from Anhui province, China. A cluster sampling method was used to sample the participants. With city as the sampling unit, first, 2 cities were randomly selected from 22 cities. 5 primary schools were then randomly selected from the cities. Finally, about 2,828 participants aged 7-17 years were selected from 3,000 school children (Response rate was 94.4%). Written consent form was obtained from parents or guardians of the children.

Measurements

All measurements were conducted by a team of trained technicians in each of the selected districts and finished by the same type of apparatus and followed standard procedures. In addition, demographic, socioeconomic data were collected by an interviewer through questionnaire.

BP measurements

All BP measurements were recorded using an aneroid sphygmomanometer with the participants in a comfortable seated position and the right arm fully exposed and resting on a supportive surface at heart level. A bladder was selected with a width covering at least two thirds of the upper arm and a length exceeding the biceps circumference by at least 50%. The cuff was inflated to 20 mmHg over the pressure that occluded the pulse at the wrist, the stethoscope was placed over the antecubital fossa, and the cuff was deflated. The onset of the first Korotkoff sound was used to measure SBP, whereas the fifth was used for DBP. Two readings taken at least 5- to 10-min apart were obtained for each participant, and the mean number of the two measurements was calculated.[22]

Anthropometric measurements

Height, weight, hipline and waistline of children were measured by using a calibrated stationmaster (Shorr Productions, Olney, MD) and scale (Seca model 881, Seca Corporation, Hanover, MD). All anthropometric measurements (weight, height, hipline, waistline) were performed according to standardized method,[23-25] e.g. Height without shoes was measured by Metal column height-measuring by stands to the nearest 0.1 cm. WC was measured midway between the lowest rib and the superior border of the iliac crest with a non-elastic measuring tape at the end of normal expiration to the nearest 0.1cm. Hipline was measured at the widest level over the great trochanters using a plastic flexible tape to the nearest 0.1 cm. Body weight was measured using a SALTER 920 digital weighing scale (SALTER Ltd., Ton bridge, UK) to the nearest 0.1 kg after an overnight fast and with indoor light clothing. BMI was calculated as weight in kilograms divided by height squared in meters ($kg\ m^{-2}$). WHR and WHtR were calculated as WC divided by hipline and WC divided by height, respectively.

Definition

Children hypertension

Children hypertension was defined by China national reference standard: systolic blood pressure or

Table I
Comparison of the obesity indicators between hypertensive and non-hypertensive

Obesity indicators	Male (n = 1,588)			Female (n = 1,240)		
	Non-hypertensive	Hypertensive	p	Non-hypertensive	Hypertensive	p
Weight (kg)[a]	50.26 ± 13.22	59.66 ± 16.33	0.000	46.53 ± 10.25	51.65 ± 12.15	0.000
Waistline (cm)[a]	69.13 ± 9.09	75.62 ± 11.05	0.000	65.71 ± 7.17	68.86 ± 9.08	0.000
BMI (kg/m^2)[a]	20.01 ± 3.57	22.49 ± 4.12	0.000	19.45 ± 3.02	21.13 ± 3.99	0.000
WHR[a]	0.83 ± 0.07	0.85 ± 0.09	0.000	0.78 ± 0.06	0.79 ± 0.06	0.323
WHTR[a]	0.44 ± 0.05	0.47 ± 0.06	0.000	0.42 ± 0.04	0.43 ± 0.06	0.000
Hipline (cm)[a]	83.57 ± 8.65	89.39 ± 10.20	0.000	84.16 ± 7.92	87.54 ± 8.77	0.000

The values in italics demonstrate that p values less than < 0.05 and consider to be statistically significant.
BMI: body mass index; WHR: waist-to-hipline ratio; WHTR: waist-to-height.
[a]Values are given as mean ± SD (standard deviation).

Table II
The comparison of blood pressure between different genders and different groups

Groups	Male (n = 1,588)		Female (n = 1,240)	
	SBP (mmHg)	DBP (mmHg)	SBP (mmHg)	DBP (mmHg)
BMI				
Normal[a]	106.41 ± 11.90	59.71 ± 10.07	104.98 ± 10.75	61.75 ± 8.65
Overweight[a]	113.00 ± 13.06	62.06 ± 10.26	107.41 ± 12.17	61.84 ± 9.85
Obesity[a]	115.94 ± 14.77	63.26 ± 11.18	115.14 ± 12.28	66.50 ± 8.85
P	0.000	0.000	0.000	0.007

The values in italics demonstrate that p values less than < 0.05 and consider to be statistically significant.
[a]Values are given as mean ± SD (standard deviation).

diastolic blood pressure equal or greater than the 95th percentile of the SBP or DBP with the same age and gender is regarded as hypertension.[26]

Children obesity

Obesity and overweight were defined by an international standard, specifying the measurement, the reference population, and the age and sex specific cut off points.[27]

Ethics Statement

The study was approved by the Ethical Review Board of the Wannan Medical College. Research protocols were approved by Wannan Medical College. All subjects provided a written informed consent after the research protocols were carefully explained to them.

Statistical Analysis

Independent sample t-tests were used to compare the related obesity index and blood pressure between male and female. Pearson's partial correlation coefficient was used to determine an association between variables and to verify significance. Analysis of variance (ANOVA) was performed to compare blood pressure level according to BMI. Multiple logistic regression modules were used examined risk factors. ROC was used to compare the predictive value of anthropometric parameters to childhood hypertension and to determine the cutoff values. All analyses were performed by SPSS 13.0 (SPSS Inc., Chicago, IL, USA). $P < 0.05$ were considered statistically significant.

Results

A total of 2,828 subjects aged 7-17 years were conducted in our study, 56.15% (n = 1,588) were males, 59.87% (n = 1,693) were residing in urban areas. Mean age was 12.52 ± 1.83 years.

The prevalence of children hypertension were 11.03 % (males: 10.64%, females: 11.53%), the related obesity index was showed in table I; our results revealed that the related obesity index of children with hypertension was higher than hat of those childhood without hypertension. SBP and DBP of the obesity group were higher than over-weight group and normal group, differences of SBP and DBP among BMI groups are statistically significant ($P < 0.05$) (table II).

The correlations between the different anthropometric parameters and blood pressure are presented in

Table III
Relationship between SBP and DBP among anthropometric parameters and the differences among correlation coefficients

Variables	SBP		DBP		p
	Correlation coefficient (r_1)	p	Correlation coefficient (r_2)	p	
Weight	0.454	0.000	0.287	0.000	0.000*
Waistline	0.374	0.000	0.221	0.000	0.000*
Hipline	0.420	0.000	0.298	0.000	0.000*
BMI	0.351	0.000	0.203	0.000	0.000*
WHR	0.054	0.004	-0.022	0.248	0.153*
WHTR	0.161	0.000	0.064	0.000	0.000*

The values in italics demonstrate that P values less than < 0.05 and considered to be statistically significant.
*r_1 compared to r_2.
SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; WHR: Waist-to-hipline ratio; WHTR: Waist-to-height.

table III. All anthropometric parameters except WHR were significantly ($P < 0.05$) correlated with SBP and DBP in all students, males and females. Weight had the highest correlation with SBP and hipline had the highest correlation with DBP, The positive correlations observed between SBP among anthropometric parameters are stronger than DBP. The Z-test[28] among all correlations indicated differences are statistically significant except WHR ($P < 0.05$).

The AUCs of the anthropometric indices and integrated covariates in the prediction of children hypertension are shown in table IV. Of all students, the AUC of integrated covariates was significantly higher than that of anthropometric indices such as BMI, WC in the prediction of children hypertension. BMI, age and hipline were selected from many anthropometric indices by the multiple logistic regression analysis. Then BMI, age and hipline were put into binary logistic regression model to identify independent risk factors for children hypertension and integrated covariates were made, as showed in table V. The single covariate in the area under the receiver-operating characteristic (ROC) curves is less than integrated covariates, and the optimal cut-off point of the integrated covariates is 0.08, at which the sensitivity is 0.64 and the specificity is 0.73. As showed in table VI.

Discussion

Our results show that traditional obesity anthropometric indices are positively associated with childhood hypertension. In all students, males and females the AUC of integrated covariates was significantly higher

Table IV
Comparison of the AUC (area under the curve) of anthropometric parameters

Variables	Male (n = 1,588)				Female (n = 1,240)			
	AUC	SE	p	95% CI	AUC	SE	p	95% CI
BMI	0.679	0.023	0.000	0.635-0.723	0.629	0.025	0.000	0.580-0.628
Waist	0.676	0.023	0.000	0.631-0.722	0.594	0.026	0.000	0.543-0.646
Hipline	0.682	0.022	0.000	0.638-0.723	0.608	0.026	0.000	0.558-0.658
Weight	0.672	0.023	0.000	0.627-0.717	0.629	0.026	0.000	0.577-0.680
WHR	0.577	0.024	0.001	0.529-0.624	0.527	0.027	0.299	0.474-0.580
WHTR	0.635	0.025	0.000	0.586-0.683	0.570	0.027	0.006	0.517-0.624
Integrated covariates	0.700	0.022	0.000	0.656-0.744	0.631	0.025	0.000	0.582-0.680

The values in italics demonstrate that P values less than < 0.05 and considerd to be statistically significant.
AUC: Area under the Curve; SE: Standard error.

Table V
Detecting risk factors of hypertension with binary logistic regression

Covariates	B	SE	Waldχ^2	OR	OR 95% CI	p
Weight	0.224	0.009	12.952	1.032	1.014-1.050	0.000
Age	-0.201	0.042	22.663	0.819	0.755-0.889	0.000
Hipline	0.192	0.014	8.613	1.041	1.014-1.070	0.000
Constant		0.899	27.194			0.000

The values in italics demonstrate that P values less than < 0.05 and considerd to be statistically significant.
SE: Standard error.

Table VI
The comparison between single covariates and integrated covariates of the diagnostic value for hypertension

Variables	*AUC*	*SE*	*p*	*AUC 95% CI*
Single covariates (BMI)	0.655	0.017	0.000	0.622-0.688
Integrated covariates	0.668	0.017	0.000	0.635-0.701

The values in italics demonstrate that P values less than < 0.05 and considerd to be statistically significant
AUC: Area under the Curve; SE: Standard error.

than that of anthropometric indices in the prediction of children hypertension, integated covariate is a simple and effective anthropometric index to identify children hypertension.

Our results on the correlations between the anthropometric parameters and blood pressure are in line with previous studies, which showed the BMI and WC had a association with hypertension.[15,29] A study in South Asian adults found that WHtR had stronger association than BMI in prediction of hypertension,[30] However, our study showed that weight is better index than WHtR for perceiving childhood hypertension. The main problem of the study in South Asian adults was gender imbalance (0.395:0.605), which may decreased the representativeness of sample and also affected the result of study.

The possible reason maybe that there is an ethnic difference among different populations. In our study, most of participants were Han Chinese (98%). Additionally, South Asian people are thinner than Han Chinese of the same age. Some researcher found that identified optimal cutoffs of WHtR were not always equal to 0.5 from different regions.[19]

However, the study in Chinese adults in Beijing also found that the superiority of WHtR over weight in their association with hypertension. The participants in our study were children aged 7-17 years, which were the most important diversity compared to the study made in China. It is also well-known that WHtR is a simple alternative anthropometric index to measure abdominal obesity.[32] But some indices such as weight and height were not to be constant, especially the index of weight were increased by a wide margin with age. The tendency of variances of weight were not included in WHtR, the early age nutritional environment is closely associated with body stature, weight was the most direct index for the growth of children and had the strongest association with obesity in children. So the maximal area under the curve is weight not WHtR.

Most of the studies have analyzed the single covariate evaluation of hypertension diagnosis value by BMI, waistline. But the significance to the diagnosis of hypertension by integrated covariates has not been reported. The integrated covariates united three obesity indices to assess diagnosis value for childhood hypertension by ROC curve. With regard to the currently recommended cutoff, integrated covariates had the strongest association with children hypertension, in both men and women, compared to the BMI, and hipline et al. The integrated covariates area under the ROC curve is greater than the single covariate. It may be that the children hypertension is reflected by many anthropometric indices include height, weight, waistline, hipline and age. Integrated covariates are comprehensive enough variable for the diagnostic value of children hypertension; it can provide us with more accurate hypertension diagnosis value point.

There are several practical advantages of using integrated covariates for countries to prevent the epidemic tendency of children hypertension. First, it is easy to identify those at children hypertension risks with several anthropometric measurements. Second, the integrated covariates were united with several obesity indices, the diagnosis value for childhood hypertension are significantly higher than any other single index.

Despite being based on a very large study, our results have several limitations. First, the integrated covariate is a better marker of children hypertension in investigated children than the BMI. However, body composition of other children in different district may be different, so larger cross-sectional and prospective studies are needed to identify the applicability of integrated covariates for other district. Second, this is a cross-sectional analysis of an observational study. Relationships between variables cannot be interpreted as causal. In addition, the study population that was examined in the present report may not have been representative of the overall Chinese children population. Last, although we had information on several indicators of socioeconomic position, some of which we did not include in the final model, we cannot rule out the possibility of residual confounding.

Thus, the association between anthropometric indices and childhood hypertension, diagnostic indices should take into account. Serological indicator such as low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) should be further study.

Public health implication

The study explored the discriminating power of integrated covariates for childhood hypertension in Chinese. Our results support the needs for childhood hypertension intervention. Integrated covariates is easy and cheap to measure, So integrated covariates can be served as a standard screening tool for better comparisons of epidemiological data between different studies.

Conclusion

Obesity index, including body mass index and waistline, etc, is not only an important evaluation indicator of children obesity, but also have influence on the prevalence of childhood hypertension. Thus, a simple and effective anthropometric index to identify childhood hypertension in the early period has great significance to improve and promote children health.

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Conflict of interest

Authors declare that they have no conflict of interest.

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