

ORIGINAL ARTICLE

# Associations among cardiorespiratory endurance, body mass index and blood pressure in Han Chinese children: results from the 2010 Chinese National Survey On Students' Constitution and Health

Yide Yang<sup>1</sup>, Patrick WC Lau<sup>2</sup>, Jingjing Wang<sup>2</sup>, Bin Dong<sup>1,3</sup>, Lijing Wu<sup>1</sup>, Binh Quach<sup>2</sup>, Del P Wong<sup>4</sup>, Lianguo Fu<sup>5</sup>, Jun Ma<sup>1</sup> and Haijun Wang<sup>1</sup>

The associations among cardiorespiratory endurance (CRE), body mass index (BMI) and blood pressure (BP) in children are still unclear. This study aimed to examine the relationships among CRE, BMI and BP in Chinese children. Data were derived from the 2010 Chinese National Survey on Students' Constitution and Health. An endurance run test was used to determine CRE and children were stratified into low and high/moderate CRE groups. BMI was dichotomized into non-overweight and overweight. Among overweight children aged 7–12 years, the risk of high BP (HBP) was significantly higher in the low CRE group than in the high/moderate CRE group (in boys, odds ratio = 1.13, 95% confidence interval: 1.03–1.24,  $P = 0.010$ ; in girls, odds ratio = 1.18, 95% confidence interval: 1.04–1.33,  $P = 0.010$ ) after adjusting for age, BMI, socioeconomic status and area of residence. However, among all children aged 13–18 years and non-overweight children aged 7–12 years, we did not observe similar results. Higher CRE is associated with lower BP. Overweight children have a significantly higher risk of HBP and low CRE may increase the risk of HBP, independently of BMI, among 7- to 12-year-old overweight children.

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## INTRODUCTION

There is an increasing prevalence of hypertension worldwide in both adults and children.<sup>1,2</sup> It has been estimated that the number of people with hypertension will exceed 1.56 billion by 2025.<sup>3</sup> In China, pediatric blood pressure (BP) and the proportion of children with high BP (HBP) have increased substantially.<sup>4,5</sup> Elevated BP during childhood and adolescence can carry over into adulthood.<sup>6</sup> Moreover, persistently HBP or hypertension is a major risk factor for cardiovascular diseases and contributes to ~54% of stroke cases and 47% of ischemic heart disease cases.<sup>7</sup>

Although the etiology of elevated BP has not been fully elucidated, high body mass index (BMI) and low cardiorespiratory endurance (CRE) are considered to be important risk factors.<sup>8,9</sup> CRE has been used as an important predictor of cardiorespiratory health, because it is relatively easy to measure<sup>10</sup>. The associations among CRE, BMI and BP in the adult population have been well documented in cross-sectional studies and longitudinal studies;<sup>11,12</sup> these studies have

revealed that people with either low fitness (CRE) or high fatness (high BMI or high waist circumference) have a higher risk of hypertension. However, this relationship has been found to be inconsistent in pediatric populations. Musa and Williams<sup>8</sup> have found that both BMI and cardiorespiratory fitness (estimated through the 20-m shuttle run test) are independent predictors of BP in Nigerian children and, of these two factors, BMI has the more important role. Thomas *et al.*<sup>13</sup> have found that the sum of skinfolds is related to BP but that aerobic fitness (estimated by the 20-m shuttle run test) is not related to BP independently of the sum of skinfolds in Welsh children. Similarly, in a US youth study, Kwon *et al.*<sup>14</sup> have found that cardiorespiratory fitness (estimated through the submaximal treadmill test) is not associated with BP in boys, and that the effect of cardiorespiratory fitness on cardiovascular risk factors in girls is possibly mediated by BMI. The conflicting results from these limited studies indicate the need for further studies on the associations between CRE, BMI and BP in children and adolescents.

<sup>1</sup>Institute of Child and Adolescent Health, School of Public Health, Peking University Health Science Center, Beijing, China; <sup>2</sup>Department of Physical Education, Hong Kong Baptist University, Hong Kong, China; <sup>3</sup>Centre for Chronic Disease, School of Medicine, The University of Queensland, Brisbane, Queensland, Australia; <sup>4</sup>Sport Science Research Center, Shandong Sport University, Shandong, China and <sup>5</sup>Department of Preventive Medicine, Bengbu Medical College, Anhui, China  
Correspondence: Professor J Ma or Professor H Wang, Institute of Child and Adolescent Health, School of Public Health, Peking University Health Science Center, 38 Xue Yuan Road, Haidian District, Beijing 100191, China.  
E-mail: majunt@bjmu.edu.cn or whjun1@bjmu.edu.cn

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Therefore, the objective of this study was to examine the effects of CRE and BMI on BP, to clarify the relationships among CRE, BMI and BP among Chinese children.

## MATERIALS AND METHODS

### Participants

Data were derived from the 2010 cycle of the Chinese National Survey on Students' Constitution and Health (CNSSCH), a nationally representative cross-sectional survey of students in China that is conducted every 5 years. The participants were selected via stratified multistage sampling among 30 provinces; the selection procedure was the same as that used in the previous CNSSCH and has been described elsewhere in previous publications.<sup>15</sup> All participants had a medical examination before recruitment and those with disease or physical/mental deformities were excluded.<sup>16</sup> The 2010 CNSSCH included 215 280 students of Han ethnicity aged 7–18 years. Of these participants, 1538 were excluded because of an absence of BP or endurance run test results. A total of 213 742 participants of Han ethnicity were included in the present study.

All subjects were recruited from schools and were stratified by gender, age, area of residence (urban or rural) and socioeconomic status (high, intermediate or low) of the school location, as described previously.<sup>15</sup>

All the procedures in this national survey were in accordance with the principles of the Declaration of Helsinki and the survey was approved by six ministries of China, including the Ministry of Education, the General Administration of Sport, the Ministry of Health, the State Ethnic Affairs Commission, the Ministry of Science and Technology, and the Ministry of Finance.<sup>4,16</sup> Informed consent was obtained from both the parents and the students.<sup>4,16</sup>

### Measurements

**Anthropometric measurements.** Body height (cm) and weight (kg) were measured using metal column height measuring stands and lever scales, respectively. Subjects were required to wear only underwear and to stand up straight on the instruments, while they were barefoot and at ease. BMI was calculated as the weight (kg) divided by the square of the height (m<sup>2</sup>). BMI was classified as non-overweight or overweight (including obese) according to the gender- and age-specific cutoff values for 7- to 18-year-old children developed by the Working Group on Obesity in China<sup>17</sup> (Supplementary Table S1).

**BP measurements.** The method of BP measurement was described in a previous study.<sup>16</sup> BP was measured according to the recommendations of the National High Blood Pressure Education Program Working Group in Children and Adolescents.<sup>18</sup> An average of three BP measurements during a single visit was calculated for each child. This method has been described elsewhere.<sup>4</sup>

HBP was defined according to the 95th percentile of age- and gender-specific BP in Chinese children<sup>19</sup> (Supplementary Table S2).

### Cardiorespiratory endurance

CRE was assessed by an endurance run test. Endurance run tests are field tests of fitness and they are one component of the National Fitness Test Battery implemented in China.<sup>20</sup> The validity of endurance run tests has been examined among young people and the correlation of these results with maximal oxygen consumption (VO<sub>2</sub>max) is 0.417 and 0.409 for boys (1000 m run test) and girls (800 m run test), respectively.<sup>21</sup>

In the present study, an 8 × 50 m shuttle run was adopted for children aged 7–12 years regardless of gender. A 1000- and 800-m run tests were adopted for boys and girls, respectively, aged 13–18 years. The measurements were conducted by trained physical education teachers in accordance with the endurance run test protocol. At least two participants were tested together as a group and they were encouraged to run as quickly as possible. The time to complete the endurance run test was recorded in seconds. The participants who had longer endurance run time were regarded as having lower CRE. CRE was categorized by age- and gender-specific percentiles of endurance run time: low CRE (0–20%) and high/moderate CRE (20–100%). A large population cohort study<sup>22</sup> has shown that subjects in the lowest quintile of cardiorespiratory fitness (0–20%) have a significantly higher total mortality and cardiovascular

disease mortality than subjects in the other four quintiles (that is, 20–40, 40–60, 60–80 and 80–100%); thus, we used this health-related cutoff approach for CRE.

### Statistical analysis

For descriptive statistics, we used means ± s.d. for numerical variables and percentages for categorical variables. Student's *t*-tests were conducted to compare differences in numerical variables between genders and differences in BP across CRE or BMI groups. Pearson's  $\chi^2$ -tests were performed for comparisons of categorical variables. To assess the independent effects of CRE and BMI on BP, participants were further categorized into four BMI–CRE groups: non-overweight and high/moderate CRE, non-overweight and low CRE, overweight and high/moderate CRE, and overweight and low CRE. The differences among the four BMI–CRE groups were assessed via one-way analysis of variance followed by Bonferroni *post-hoc* analyses. A logistic regression model stratified by weight status and adjusted for age, BMI, area of residence and socioeconomic status was performed to compare the risk of HBP among different CRE groups in both boys and girls. A two-sided *P*-value < 0.05 was considered to indicate statistical significance.

## RESULTS

Anthropometric characteristics, area of residence, socioeconomic status, BP and HBP prevalence in children of Han ethnicity are shown in Table 1. The overall prevalence of HBP in Chinese children aged 7–12 years was 11.4% (11.7 in boys and 11.1% in girls), and that in children aged 13–18 years was 15.5% (18.3 in boys and 12.8% in girls). The prevalence of HBP was significantly higher in the older age group (13–18 years) than in the younger age group (7–12 years). The associations of CRE with BMI and other risk factors of HBP, including area of residence, socioeconomic status and age, are presented in Supplementary Table S3.

### Associations of CRE and BMI with BP

Participants with high/moderate CRE had significantly lower BP than their peers with low CRE (*P* < 0.001), as shown in Table 2. In boys aged 7–12 years, diastolic BP (DBP) in low CRE participants was 0.9 mm Hg higher than that of high/moderate CRE participants (*P* < 0.001) and systolic BP (SBP) in the low CRE group was 0.7 mm Hg higher than that in the high/moderate CRE group. DBP and SBP in girls aged 7–12 years were 0.7 and 0.4 mm Hg higher, respectively, in the low CRE participants compared with the high/moderate CRE participants (*P* < 0.001). The corresponding increases in DBP and SBP were 0.7 and 0.3 mm Hg, respectively, in boys aged 13–18 years, and were 0.4 and 0.2 mm Hg, respectively, in girls aged 13–18 years (all *P* < 0.001).

Differences in BP were compared between the two BMI groups of overweight and non-overweight participants (Table 3). In boys aged 7–12 years, DBP and SBP were 4.1 and 7.3 mm Hg higher, respectively, in the overweight group than in the non-overweight group. In girls aged 7–12 years, the increases in DBP and SBP in the overweight group compared with the non-overweight group were 3.5 and 6.1 mm Hg, respectively. These respective values were 3.0 and 7.7 mm Hg for boys aged 13–18 years, and 3.3 and 6.5 mm Hg for girls aged 13–18 years (all *P* < 0.05).

### Combined association of CRE and BMI with BP

To test the combined association of BMI and CRE with BP, a comparison among four BMI–CRE groups was conducted and the results are shown in Table 4. There was an overall significant difference among the four groups. Bonferroni *post-hoc* analysis for multiple comparisons revealed that in the overweight individuals, the high/moderate CRE group had significantly lower SBP and DBP than

**Table 1** General characteristics of the participants

Variable	Aged 7–12 years (n = 106 967) mean ± s.d.				Aged 13–18 years (n = 106 775) mean ± s.d.			
	Boys (n = 53 516)	Girls (n = 53 451)	$t/\chi^2$	P-value	Boys (n = 53 181)	Girls (n = 53 594)	$t/\chi^2$	P-value
Age (years)	9.5 ± 1.7	9.5 ± 1.7	0.070	0.943	15.5 ± 1.7	15.5 ± 1.7	1.260	0.207
Area of residence, N (%)								
Urban	26 729 (49.9)	26 685 (49.9)	0.005	0.944	26 559 (49.9)	26 741 (49.9)	0.022	0.882
Rural	26 787 (50.1)	26 766 (50.1)			26 622 (50.1)	26 853 (50.1)		
SES, N (%)								
High	17 745 (33.2)	17 722 (33.2)	0.013	0.994	17 613 (33.1)	17 857 (33.3)	0.695	0.707
Intermediate	17 910 (33.5)	17 874 (33.4)			17 725 (33.3)	17 871 (33.3)		
Low	17 861 (33.4)	17 855 (33.4)			17 843 (33.6)	17 866 (33.3)		
BMI (kg m <sup>-2</sup> )	17.4 ± 3.2	16.6 ± 2.7	43.710	<0.001	20.1 ± 3.2	19.9 ± 2.7	11.410	<0.001
DBP (mm Hg)	62.4 ± 9.9	62.2 ± 9.8	4.410	<0.001	68.5 ± 9.6	66.4 ± 8.8	37.730	<0.001
SBP (mm Hg)	100.3 ± 11.6	99.0 ± 11.4	18.560	<0.001	111.9 ± 11.7	105.3 ± 10.6	95.920	<0.001
HBP, N (%)	6288 (11.7)	5952 (11.1)	9.959	0.002	9756 (18.3)	6841 (12.8)	633.205	<0.001

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; HBP, high blood pressure; SBP, systolic blood pressure; SES, socioeconomic status.

**Table 2** BP change according to different level of CRE (mm Hg)

CRE levels	Aged 7–12 years		Aged 13–18 years	
	DBP	SBP	DBP	SBP
	Mean ± s.d.	Mean ± s.d.	Mean ± s.d.	Mean ± s.d.
<b>Boys</b>				
High/moderate CRE	61.9 ± 9.8	99.9 ± 11.4	68.1 ± 9.6	111.7 ± 11.3
Low CRE	62.8 ± 10.0	100.6 ± 11.7	68.8 ± 9.5	112.0 ± 11.9
<i>t</i>	-9.790	-6.685	-8.426	-2.783
<i>P</i> -value	<0.001	<0.001	<0.001	<0.001
<b>Girls</b>				
High/moderate CRE	61.7 ± 9.7	98.8 ± 11.2	66.2 ± 8.8	105.2 ± 10.4
Low CRE	62.4 ± 9.8	99.2 ± 11.4	66.6 ± 8.7	105.4 ± 10.7
<i>t</i>	-8.096	-3.498	-4.824	-2.577
<i>P</i> -value	<0.001	<0.001	<0.001	<0.001

Abbreviations: BP, blood pressure; CRE, cardiorespiratory endurance; DBP, diastolic blood pressure; SBP, systolic blood pressure.

**Table 3** Comparison of BP between overweight and non-overweight children (mm Hg)

Nutritional status	Aged 7–12 years		Aged 13–18 years	
	DBP	SBP	DBP	SBP
	Mean ± s.d.	Mean ± s.d.	Mean ± s.d.	Mean ± s.d.
<b>Boys</b>				
Non-overweight	61.5 ± 9.7	98.7 ± 10.9	68.1 ± 9.5	110.8 ± 11.3
Overweight	65.6 ± 10.2	106.0 ± 12.1	71.1 ± 9.6	118.5 ± 11.8
<i>t</i>	38.55	59.14	25.89	55.29
<i>P</i> -value	<0.001	<0.001	<0.001	<0.001
<b>Girls</b>				
Non-overweight	61.7 ± 9.6	98.3 ± 11.0	66.1 ± 8.7	104.7 ± 10.4
Overweight	65.2 ± 10.2	104.4 ± 12.4	69.4 ± 9.1	111.2 ± 11.1
<i>t</i>	26.23	38.17	25.04	38.88
<i>P</i> -value	<0.001	<0.001	<0.001	<0.001

Abbreviations: BP, blood pressure; DBP, diastolic BP; SBP, systolic BP.

the low CRE group ( $P < 0.05$ ). In overweight boys aged 7–12 years, the DBP and SBP in the low CRE group were 1.6 and 1.7 mm Hg higher, respectively, than those in the high/moderate CRE group ( $P < 0.05$ ). In addition, the corresponding increases in DBP and SBP in girls aged 7–12 years were 1.6 and 1.5 mm Hg, respectively ( $P < 0.05$ ). In overweight boys aged 13–18 years, the increases in DBP and SBP were 1.1 and 1.2 mm Hg, respectively, in the low CRE group compared with the high/moderate CRE group ( $P < 0.05$ ). In addition, the corresponding increases in DBP and SBP in girls aged 13–18 years were 1.2 and 2.1 mm Hg, respectively ( $P < 0.05$ ). In non-overweight individuals, the significant differences in DBP and SBP between the high/moderate and low CRE groups were not consistent. In 7- to 12-year-old and 13- to 18-year-old non-overweight girls, the DBP values in the low CRE group were 0.6 and 0.3 mm Hg higher than those in the high/moderate CRE peers ( $P < 0.05$ ), respectively. The magnitude of the differences in SBP and DBP between high/moderate CRE individuals and low CRE individuals was substantially greater in the overweight group than in the non-overweight group.

### Independent effect of CRE on HBP

The results comparing the risk of HBP among the four CRE-BMI groups are listed in Table 5. Overall, overweight children had a higher risk of HBP (ranging from 20.4 to 35.9%) than non-overweight children (ranging from 8.4 to 16.0%). To explore the independent effect of CRE on HBP, we excluded the effect of BMI by adjusting for this parameter. Boys aged 7–12 years in the overweight and low CRE group had a significantly higher risk of HBP than their overweight and high/moderate CRE peers (odds ratio = 1.13, 95% confidence interval: 1.03–1.24,  $P = 0.010$ ). In non-overweight boys aged 7–12 years, there was no significant difference among the CRE groups. Similarly, in girls aged 7–12 years, the risk of HBP for the overweight and low CRE group was 1.18 (odds ratio = 1.18, 95% confidence interval: 1.04–1.33,  $P = 0.010$ ) relative to the overweight and high/moderate CRE group. For non-overweight girls aged 7–12 years, there was no difference in HBP risk between the high/moderate CRE and low CRE groups ( $P > 0.05$ ).

**Table 4 Differences in BP among BMI-CRE groups (mm Hg)**

Gender	BMI-CRE group	Aged 7–12 years (n = 106 967)			Aged 13–18 years (n = 106 775)		
		n	DBP	SBP	n	DBP	SBP
Boys	Non-overweight and high/moderate CRE	35 318	61.5 ± 9.6	98.7 ± 10.9	37 654	68.1 ± 9.5	110.9 ± 11.3
	Non-overweight and low CRE	6390	61.7 ± 10.0	98.6 ± 10.7	7804	68.1 ± 9.5	110.0 ± 11.4
	Overweight and high/moderate CRE	7490	65.0 ± 10.1	105.4 ± 12.0	4884	70.7 ± 9.7	118.0 ± 11.6
	Overweight and low CRE	4318	66.6 ± 10.2 <sup>a</sup>	107.1 ± 12.3 <sup>a</sup>	2839	71.8 ± 9.5 <sup>a</sup>	119.2 ± 12.0 <sup>a</sup>
Girls	non-overweight and high/moderate CRE	38 560	61.6 ± 9.6	98.2 ± 11.0	39 559	66.1 ± 8.7	104.7 ± 10.4
	Non-overweight and low CRE	8423	62.2 ± 9.8 <sup>b</sup>	98.4 ± 11.1	9160	66.4 ± 8.5 <sup>b</sup>	104.8 ± 10.5
	Overweight and high/moderate CRE	4190	64.7 ± 10.1	103.9 ± 12.3	3282	69.0 ± 9.0	110.5 ± 10.9
	Overweight and low CRE	2278	66.3 ± 10.2 <sup>a</sup>	105.4 ± 12.5 <sup>a</sup>	1593	70.2 ± 9.3 <sup>a</sup>	112.6 ± 11.5 <sup>a</sup>

Abbreviations: BMI, body mass index; BP, blood pressure; CRE, cardiorespiratory endurance; DBP, diastolic BP; SBP, systolic BP.

<sup>a</sup>Overweight and high/moderate CRE significantly different from overweight and low CRE.

<sup>b</sup>Non-overweight and high/moderate CRE significantly different from non-overweight and low CRE.

**Table 5 Logistic regression results for the association of BMI and CRE with risk of high BP<sup>a</sup>**

Gender	Age group	BMI group	CRE group	High BP (%)	OR <sup>a</sup>	95%CI <sup>a</sup>		P-value
						Lower	Upper	
Boys	Aged 7–12 years	Non-overweight	High/moderate	8.8	1 (ref)			
			Low	8.4	0.91	0.83	1.00	0.056
		Overweight	High/moderate	20.4	1 (ref)			
	Aged 13–18 years	Non-overweight	High/moderate	16.0	1 (ref)			
			Low	15.7	0.99	0.93	1.06	0.819
		Overweight	High/moderate	30.4	1 (ref)			
Girls	Aged 7–12 years	Non-overweight	High/moderate	9.5	1 (ref)			
			Low	9.9	1.01	0.93	1.09	0.803
		Overweight	High/moderate	20.7	1 (ref)			
	Aged 13–18 years	Non-overweight	High/moderate	11.6	1 (ref)			
			Low	11.8	1.03	0.96	1.11	0.365
		Overweight	High/moderate	22.2	1 (ref)			
		Low	27.3	1.12	0.97	1.29	0.126	

Abbreviations: BMI, body mass index; BP, blood pressure; CI, confidence interval; CRE, cardiorespiratory endurance; OR, odds ratio; SES, socioeconomic status.

<sup>a</sup>Adjusted for age, BMI, SES and area of residence.

In 13- to 18-year-old children, the risk of HBP was not significantly different between the high/moderate CRE group and the low CRE group ( $P > 0.05$ ).

## DISCUSSION

Our study principally showed that in 7- to 12-year-old overweight children, low CRE was associated with an increased risk of HBP independent of BMI. However, in 7- to 12-year-old non-overweight children and 13- to 18-year-old children, no such associations between CRE and HBP were observed.

### Prevalence of pediatric HBP

The overall prevalence of HBP in Chinese children aged 7–12 years and those aged 13–18 years was 11.4% and 15.5%, respectively. HBP is becoming a common chronic disease in Chinese children and this condition should warrant increased attention. Substantial evidence has shown that pediatric BP is associated with BP in later life and administering an appropriate intervention in early life is quite important.<sup>6</sup> It has also been demonstrated in other populations that a higher BMI, that is, overweight or obese status, leads to a higher BP

or risk of hypertension. In a Japanese population, overweight and obese subjects have been found to have an approximately twofold greater risk of hypertension than that of normal-weight subjects.<sup>23,24</sup> Although there is no clear explanation for the mechanism underlying the relationship between overweight/obese status and hypertension, recent research has implied that excessive sympathetic nervous system activity, insulin resistance (insulin/leptin) and inflammation (C-reactive protein) may have an important role.<sup>25</sup>

### CRE, BMI and BP/HBP

According to our results, irrespective of BMI, subjects with high/moderate CRE had more favorable BP profiles than their low CRE peers across age and gender strata. In addition, being overweight and having low CRE had a combined effect of increasing BP. These findings were consistent with those of similar studies<sup>26,27</sup> that did not adjust for BMI. The study of Wang *et al.*<sup>26</sup> in Wuhan, China, has found that fitness (estimated by the 20-m shuttle run test) and the fatness (waist circumference or BMI) are associated with cardiovascular risk (metabolic risk score) in children. A study by Ogunleye *et al.*<sup>27</sup> evaluating 5983 school children aged 10–16 years

from eastern England using a 20-m shuttle run test has reported similar results.

However, further analysis has shown that low CRE increases the risk of HBP independently of BMI in overweight children aged 7–12 years. Crump *et al.*<sup>28</sup> have performed a cohort study confirming that low physical fitness (aerobic capacity) is associated with a subsequent increased risk of hypertension, even after adjusting for BMI and other potential confounders. However, our study showed that in 13- to 18-year-old children, the effect of low CRE on the risk of HBP was dependent on BMI. After adjusting for BMI, the difference in HBP risk between the low and high/moderate CRE groups was no longer significant. Similar to our results, Kwon *et al.*<sup>14</sup> have reported that in adolescents aged 12–19 years involved in NHANES 1999–2002, cardiorespiratory fitness was associated with SBP, but this result was no longer significant after adjusting for BMI.

There are several differences between our study and other similar studies. First, in our study, the CRE was measured by using an endurance run test, which was a common CRE test in the CNSSCH from 1985 to 2010. However, different measures of CRE (for example, the 1.6-km endurance run test, 20-m shuttle run test, submaximal treadmill test or 3-min step test) have been used in other studies. In addition, the discretization of CRE variables (for example, into two categories, quartiles or quintiles, or applying specific cutoff values) was different among studies. In the present study, the discretization of CRE was based on a large population cohort study of the relationship between CRE and cardiovascular risk, which showed that those with low CRE (the lowest quintile, 0–20%) had an unusually higher risk of mortality (relative risk=3.44 and 4.65 for men and women, respectively) and risk of cardiovascular disease,<sup>22</sup> and those results have been confirmed by another large cohort study.<sup>29</sup>

The mechanism underlying the association between CRE and BP has not been fully elucidated. One possible reason for this association is that the benefits of CRE are mediated by circulating endothelial progenitor cells that are involved in vascular repair and that improve vascular function,<sup>30</sup> because these processes are significantly improved after exercise training.<sup>31,32</sup> Another possible reason is that higher CRE is associated with lower arterial stiffness and greater arterial distensibility and compliance, which may influence BP in adults and children.<sup>33–35</sup> Exercise training can decrease SBP or DBP through neurohormonal adaptations, such as decreases in the levels of renin, angiotensin and plasma norepinephrine, which may be mediated by improved CRE.<sup>36</sup>

As high/moderate CRE is significantly associated with low BP in overweight or obese 7- to 12-year-old children but not in 13- to 18-year-old children, our results highlighted the importance of exercise intervention in early life to improve the BP profile. Our results also indicated that an exercise intervention may reduce the risk of HBP without changing BMI. Although the exact reason for the adverse effect of obesity on BP in young children and especially among adolescents is unclear, one plausible explanation for this phenomenon might involve the relatively short duration of obesity for young children. However, further study is needed to evaluate this possibility.

Our results suggested that high CRE, independently of BMI, may explain the additional beneficial effect of increased CRE on HBP risk in 7- to 12-year-old overweight children. Physical activity interventions are commonly used in weight management to improve CRE and these interventions are relatively safe and inexpensive compared with anti-hypertension treatment. Notably, weight control is a widely accepted and highly beneficial intervention, but achieving an adequate level of CRE may provide an additional health benefit, in particular in 7- to 12-year-old overweight children.

## Strengths and limitations

Our study was a nationally representative study that consisted of Chinese children and adolescents ranging from 7 to 18 years old, which examined the effects of CRE and BMI on BP to produce generalizable results. Our findings implied that the increasing CRE may improve the BP profiles of overweight children. Thus, our findings may provide a new perspective and direction for future interventions. However, several limitations should also be considered when interpreting our results. This was a cross-sectional study that cannot prove a causal relationship. Therefore, a further longitudinal, prospective study in the pediatric population should be conducted to confirm this relationship. Second, the endurance run test, as an indicator of cardiovascular endurance, is measured differently worldwide, and this discrepancy may affect the comparability of these results with those from other countries. Third, the population of this study is limited to the Han ethnicity, which comprises 90% of the population in China. The situation of other ethnic groups, which may be different from Han ethnicity, still calls for further exploration.

## CONCLUSION

In summary, overweight children aged 7–12 years had a significantly higher risk of HBP and low CRE levels increased this risk independently of BMI. Given the distinct effects of CRE in different age groups and weight status groups, specific health promotions and therapeutic interventions aimed at improving fitness and controlling pediatric obesity in a diverse population may contribute to the maximization of public health benefits.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Supplementary Information accompanies the paper on Hypertension Research website (<http://www.nature.com/hr>)