DIETARY SURVEYS AND NUTRITIONAL EPIDEMIOLOGY

BMI and cardiovascular function in children and adolescents of Mauritius Island

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Abstract
Among countries which have undergone a rapid socio-economic and nutrition transition over the past few decades, the Indian Ocean island of Mauritius is among those with the greatest surge in the prevalence of type 2 diabetes and CVD. The aim of the present study was to characterise the BMI and cardiovascular functions of children and adolescents of this at-risk population. Data were collected through measurements of anthropometry, resting heart rate and blood pressure in a nationally representative sample (n 2489) of children (5–10 years) and adolescents (11–18 years), and analysed according to sex and ethnic identity: South Asian Hindus and Muslims (both of Indian ancestry), Creole (of varying degrees of African ancestry) and Chinese (of mainland China ancestry). Based on standards of the WHO or International Obesity Task Force, one in six of these young individuals exhibit a high BMI-for-age. Analysis by ethnicity revealed that Creole males and females show higher BMI-for-age but also lower heart rate ($P < 0.001$) even after adjustment for BMI. Additionally, Chinese males and females show higher systolic blood pressure ($P < 0.01$), independently of BMI. None of these ethnic differences could be related to household income, diet type (vegetarian $v.$ non-vegetarian) or to fruit consumption. This study in children and adolescents of this multi-ethnic at-risk population for CVD reveal ethnic differences in BMI-for-age as well as consistent BMI-independent ethnic differences in heart rate and systolic blood pressure. These findings underscore the need to establish the BMI–fat % relationship across the various ethnic groups and for more detailed investigations about their differences in lifestyle and dietary habits that might explain their differential cardiovascular functions prior to adulthood.

Key words: Ethnicity: Obesity: Hypertension: Indian ancestry: Chinese ancestry: African ancestry

Since gaining independence in 1968, the island nation of Mauritius has experienced rapid economic growth, concomitant with a marked improvement in public health. Indeed, since 1960, life expectancy at birth has increased from 60 to 73 years, and the infant mortality rate has dropped from seventy to fourteen per 1000 live births[1]. However, the Mauritian population has not emerged from this rapid transition unscathed. The population now faces the health burdens of nutritional transition, with non-communicable diseases, in particular CVD and diabetes, currently the primary cause of

morbidity and mortality. With the prevalence of adult type 2 diabetes, a main contributor to CVD, almost three times the predicted global prevalence[2], the public health and subsequent economic impact is immense. A number of large population health surveys have been carried out on the island[3,4], with the 1998 National Non-communicable Diseases Survey showing a prevalence of overweight (OW) and obesity of approximately 36 and 44 % within the adult male and female population, respectively. However, despite decades of data collection and analysis concerning the adult population, the

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distribution of BMI and cardiovascular risk factors across a nationally representative sample of school-aged children and adolescents remains unreported. Furthermore, the 1·3 million Mauritians who inhabit the island are a multi-ethnic population, with the major ethnic groups being of South Asian (SA) Indian ancestry (52 % Hindu and 16 % Muslim), varying degrees of African ancestry (Creoles 27 %), and Chinese ancestry (3 %). Given a plethora of recent research that suggests that individuals of Asian descent are at increased risk of type 2 diabetes and hypertension at lower BMI[5,6], it therefore begs the question as to whether or not ethnic disparities in BMI and cardiovascular risk factors across these younger age groups exist. Therefore, the aim of the present study was (i) to characterise BMI and cardiovascular function (heart rate and blood pressure) in children and adolescents of this multi-ethnic 'at-risk' population, (ii) to determine the presence of any ethnic differences in these parameters and (iii) to investigate any potential link with general health and diet or socio-economic status.

Methods

Study design

The study design consisted of a cross-sectional, community-based survey of a qualitative and quantitative nature.

The sampling method employed ensured a nationally representative sample, with sufficient numbers of subjects in each of the two target populations: 5–10 years of age (primary school-aged children) and 11–18 years of age (referred to as adolescents), and with the distribution of ethnicity being close to that of the whole Mauritian population. Subjects were selected from the fourteen Primary Enumeration Areas which were identified and chosen, under the guidance of the WHO Regional Office for Africa, for a non-communicable disease and risk factor survey that was being carried out simultaneously. This standardised non-communicable disease survey procedure has been described in detail elsewhere[7]. A random multi-stage cluster sampling procedure was applied to identify these fourteen clusters out of the 379 Primary Enumeration Areas defined by the Central Statistics Office and used in the island's 2000 population census. Between 161 and 207 individuals from each cluster were included in the final data analysis. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committee of the Mauritius Ministry of Health and Quality of Life. Written informed consent was obtained from all subjects or their parents.

Data collection

The field work was carried out between September and October 2004, with an overall response rate of 89·8 and 86·0 % for the 5–10 years and 11–18 years groups, respectively. Data were collected by trained staff through interviews, anthropometric measurements and blood analysis. Ethnicity was determined by self-report to the interviewer. Monthly family income (used as a marker of socio-economic status)

was classified as 'Rs. 8000 or less', or 'over Rs. 8000'. Diet type was defined as either 'vegetarian' (no animal flesh eaten) or 'non-vegetarian', and daily fruit consumption grouped into 'less than 2 per d' or '2 or more per d'. For all anthropometric measures, subjects wore light clothing and no shoes.

Body weight was measured to the nearest 0·1 kg without shoes and in light clothing, using a standard lever balance (Detecto). Two initial measurements were obtained, and if these varied by more than 0·5 kg, a third measurement was taken. The mean of the two closest measurements was used for analysis. Scales used were calibrated daily.

Standing height was measured to the nearest 0·5 cm using a wall-mounted stadiometer (Seca 206). If the two initial measurements varied by more than 0·5 cm, a third measurement was taken. The mean of the two closest measurements was used for analysis.

Heart rate and blood pressure measurements were performed in a seated position after a period of rest of at least 5 min, using a suitable cuff size and standard automated sphygmomanometer (Microlife). Two measurements were taken, with a 1 min interval between them, and the mean of the two measurements calculated. If the difference between the first and second measurement was greater than 10 mmHg, for either systolic or diastolic blood pressure, a third measurement was taken, and the mean was calculated from the two closest readings.

Blood was collected by venepuncture in the non-fasting, random state. The subject was in the seated position and the sample was taken by the standard technique from the cubital fossa of the opposite arm to that used for the blood pressure measurement. A total of 10 ml of whole blood was taken for anaemia profiling and for detecting infection, specifically through the measurements of blood Hb, haematocrit, erythrocyte count and leucocyte count, in order to determine the overall health status and to take into account individuals displaying overt pathogenesis in the interpretation of data on BMI and cardiovascular function.

Statistical analyses

BMI-for-age was classified according to two different international standards: the WHO[8–10] and the International Obesity Task Force[11,12]. Height-for-age was calculated using WHO growth references[13]. Differences in the tested variables (e.g. blood pressure) between categorical groups (e.g. ethnic, BMI-for-age classification, dietary and income groups) were assessed by ANOVA and subsequent Fisher's protected least-significant difference *post hoc* analysis. The effects of sex and age on these variables were tested by ANCOVA. Relationships between continuous variables (e.g. blood pressure, BMI-for-age z-score, height-for-age z-score and blood measurements) were assessed by regression analysis. Individuals aged 5–10 years were referred to as children and those aged 11–18 years as adolescents. All statistical tests were performed using Statview software (SAS Institute), with $P < 0.05$ considered statistically significant. Unless otherwise stated, all data are presented as means with their standard errors.

Results

Characteristics of study population

The present study consisted of 2489 individuals, with 48·5 % male and 51·5 % female. These individuals were further divided into subgroups based on age and ethnicity. The number of subjects in each subgroup is given in Table 1.

BMI

BMI-for-age z-scores of the Mauritian study population showed a marked left shift when compared with the WHO reference standards (Fig. 1). This shift, of 1 SD, occurs in both sexes and is independent of ethnicity.

After comparison using the WHO reference range (Table 2), the prevalence of low BMI-for-age (underweight; UW) was 13·6 %. However, UW or 'thinness', as defined by the International Obesity Task Force, was found in 31·5 % of the study population; 19 % 'thinness grade 1', 8·4 % 'thinness grade 2', and 4·1 % 'thinness grade 3'. Conversely, a high BMI-for-age (OW and obese) was observed in 18·5 % (WHO) and 15·6 % (International Obesity Task Force) of the study population.

BMI-for-age, classified by the WHO reference ranges, for each ethnic group is summarised in Table 3. Although the prevalence of high BMI-for-age (OW and obese) in the Creole population was not higher than in the other ethnic groups, the BMI-for-age distribution of the Creoles was found to be shifted to the right in the range of z-score corresponding to UW and normal weight (z-score <1, Fig. 1) when compared with both the SA Hindu ($P < 0·001$) and SA Muslim ($P < 0·05$) groups, this difference being observed independently of age group and sex.

In those who responded to income/diet questioning, BMI-for-age showed no relationship to monthly family income (n 1318; ANOVA $P = 0·96$), diet type (n 2482; ANOVA $P = 0·81$), or daily fruit consumption (n 2368; ANOVA $P = 0·65$).

Cardiovascular haemodynamics

Heart rate showed a U-shaped relationship with the WHO BMI-for-age classification (Table 4), with higher heart rates

observed in the UW and obese groups ($P < 0·01$) than in the normal-weight and OW groups.

Positive relationships were observed between WHO BMI-for-age classification and systolic ($P < 0·001$), diastolic ($P < 0·001$), and subsequently pulse pressure ($P < 0·001$) (Table 4).

No relationships were found between any of the measured cardiovascular parameters and monthly family income, daily fruit consumption or diet type – with the exception of a slightly lower pulse pressure observed in the vegetarian $v.$ the non-vegetarian group (vegetarian: 42 (SE 1·0) mmHg; non-vegetarian 44 (SE 0·2) mmHg; ANOVA $P = 0·046$).

Creoles exhibited a significantly lower heart rate than both SA Hindus ($P < 0·001$) and SA Muslims ($P < 0·001$), irrespective of BMI-for-age (Table 5). This difference (approximately 3–4 beats per min) persists across age groups and sex.

The Chinese ethnic group showed a significantly elevated systolic blood pressure in comparison with all other ethnic groups (approximately 5·5 mmHg, $P < 0·01$; Table 5). This difference persists across sex and age groups, and is independent of BMI-for-age; no such difference was observed in diastolic blood pressure (Table 5).

Although height-for-age was positively correlated with both systolic and diastolic blood pressure across the population sample (r 0·29; $P < 0·001$), there was, however, no significant difference in height-for-age between ethnic groups (ANOVA $P = 0·7$), and furthermore, the elevated blood pressure observed in the Chinese group persisted when height-for-age was included as a covariate.

Similarly, the Chinese had significantly elevated pulse pressure in comparison with all other ethnicities (Creole, $P < 0·05$; SA Hindu, $P < 0·001$; SA Muslim, $P < 0·01$; Table 5). However, despite being an independent cardiovascular risk factor, this difference in pulse pressure was solely due to the increased systolic blood pressure observed in this group.

Blood markers

Blood markers of anaemia and infections (blood Hb, haematocrit, erythrocyte count and leucocyte count) were measured during the present study in order to assess overall health status and ensure that observed changes in BMI and cardiovascular function were not related to overt pathogenesis. All these blood markers were within the internationally acceptable range.

From the blood sample analysis, the prevalence of anaemia (as defined by the WHO using blood Hb levels[15]) was found to be 7·1 % overall (4·3 % in males; 9·7 % in females). Of those anaemic individuals, twenty/120 females, and four/forty-seven males presented with moderate anaemia, comprising just 1 % of the overall study population, while the remainder were classified as mildly anaemic. This prevalence constitutes 'mild' public health significance by WHO standards. The overall prevalence of anaemia by Centers for Disease Control classification was 4·6 % (4·9 % in females; 4·2 % in males).

Despite a prevalence of 10·5 % in the UW female sub-group, anaemia showed no statistical relationship with BMI-for-age classification ($P = 0·93$). The prevalence of anaemia in the UW group (7·9 %) was similar to that in the normal-weight

Table 1. Distribution of subjects (n 2489) by sex, age and ethnicity*

	Male		Female		Male:female ratio	Total
	Children	ADO	Children	ADO		
South Asian Hindu	282	323	256	369	0·97	1230
South Asian Muslim	147	195	164	172	1·02	678
Creole	105	124	131	155	0·80	515
Chinese	8	24	12	22	0·94	66
Total	542	666	563	718	0·94	2489
		1208		1281		

ADO, adolescents.
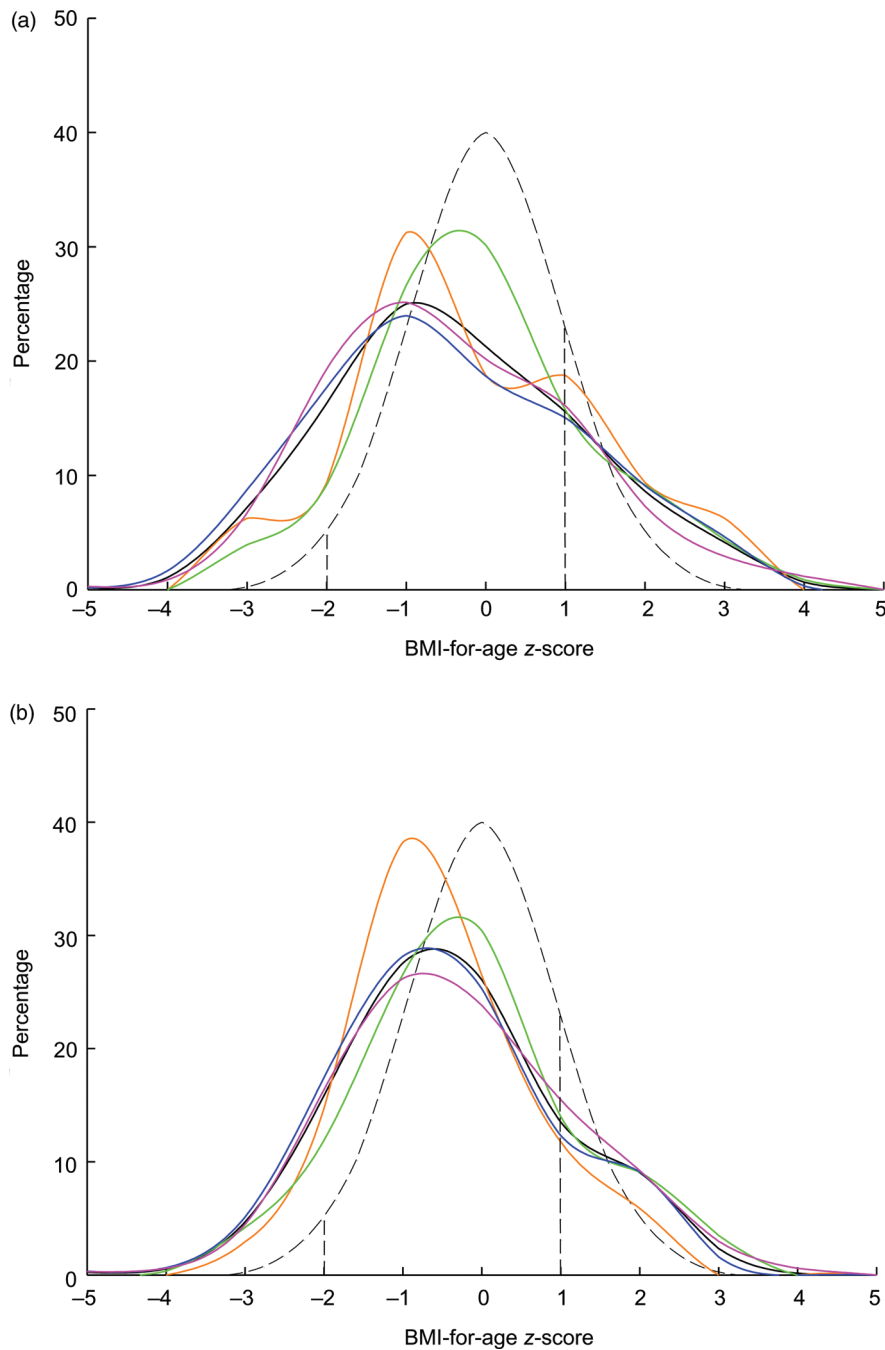* Children, age 5–10 years; ADO, age 11–18 years.

Fig. 1. BMI-for-age for (a) males and (b) females of each ethnic group in comparison with WHO standards[8,10,14]. ——, All ethnicities (1208 males, 1281 females); ---, WHO reference; ——, Chinese (thirty-two males, thirty-four females); ——, Creole (229 males, 286 females); ——, South Asian Hindu (605 males, 625 females); ——, South Asian Muslim (342 males, 336 females).

group (7·2 %). However, positive correlations were observed between BMI (unadjusted for age) and blood Hb levels (r 0·21; $P < 0.001$), haematocrit levels (r 0·23; $P < 0.001$), and erythrocyte count (r 0·16; $P < 0.001$). Blood haematocrit and erythrocyte counts were higher in both the obese and OW groups compared with the normal-weight and UW groups, but all group averages were within the established reference ranges[16,17].

Leucocyte count (1000 cells/µl) was significantly affected by ethnicity ($P < 0.0001$), with all four ethnic groups differing from one another – in increasing order: Chinese (6·18), Creole (6·87), SA Hindu (7·27), and SA Muslim (7·62). These differences persisted across age group and sex.

Conversely, the Chinese group presented higher blood Hb and haematocrit levels than all other ethnic groups. However, average values of these blood markers for each ethnicity were still within the Third National Health and Nutrition Examination Survey (NHANES III) reference ranges[16].

Discussion

In the past four decades, the island of Mauritius has undergone rapid socio-economic development. However, despite vast improvements in public health, the Mauritian population has been experiencing a parallel increase in lifestyle-related

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Table 2. Comparison of the prevalence of underweight (UW), normal weight (NW), overweight (OW), and obese (OB) in the Mauritian population as defined by the WHO[8,10,14] and International Obesity Task Force (IOTF)[11,12] standards, and stratified by age and sex*

| | Male | | | | Female | | | | | |
| | Children | | ADO | | Children | | ADO | | Total | |
	n	%	n	%	n	%	n	%	n	%
WHO										
UW	100	18·5	76	13·7	91	13·5	72	10·0	339	13·6
NW	349	64·4	425	63·8	389	69·1	527	73·4	1690	67·9
OW	45	8·3	89	13·4	55	9·8	78	10·9	267	10·7
OB	48	8·9	61	9·2	43	7·6	41	5·7	193	7·8
IOTF										
UW	211	38·9	171	25·7	199	35·3	203	28·3	784	31·5
NW	265	48·9	364	54·7	279	49·6	409	57·0	1317	52·9
OW	42	7·7	93	14·0	63	11·2	73	10·2	271	10·9
OB	24	4·4	38	5·7	22	3·9	33	4·6	117	4·7
Total	542		666		563		542		2489	

ADO, adolescents.
* Children, age 5–10 years; ADO, age 11–18 years.

diseases, such as hypertension and type 2 diabetes. Although the prevalence of such conditions in the adult population is recognised and widely reported[3,4,18], the cardiovascular health of the child and adolescent populations has thus far remained unknown.

The present study is the first to report the prevalence of OW/obesity and UW in both Mauritian school-aged children and adolescents. Interestingly, with approximately 17 % of these individuals exhibiting a high BMI-for-age according to internationally recognised standards, and 32 % having a low BMI-for-age, the results of this study highlight the 'double burden' commonly observed in newly developed and developing countries[19]. Indeed, these values are almost identical to those reported in Iranian children[20] and exhibit a similar pattern those of the Seychelles[21]. These data are also in agreement with a recently published report of BMI among 9- to 10-year-old Mauritius children[22], and a small-scale study investigating secondary school children in Mauritius in 2008[23], perhaps indicating a relative stability in BMI

distribution which merits large-scale follow-up investigation. Nonetheless, there was no indication that the relatively high prevalence of UW was associated with anaemia, as the prevalence of anaemia within the population was not noticeably elevated, and there was no observed relationship with BMI-for-age classification. Furthermore, in contrast to a recent small-scale study by Fokeena and Jeewon[24], no relationship between BMI and socio-economic status (as measured by monthly family income) was observed, or any relation to diet type or daily fruit consumption.

It is important to remember, however, that BMI-for-age may not necessarily be reflective of body fat mass[25,26]. This is particularly pertinent when comparing between different ethnic groups. A number of studies have now demonstrated that the relationship between BMI and body fat mass differs across ethnic groups, with individuals of Asian descent, particularly those from the Indian sub-continent, shown to have a higher body fat mass, irrespective of BMI[27–29]. This observation has recently been confirmed in Australian children of

Table 3. Comparison of the prevalence of underweight (UW), normal weight (NW), overweight (OW) and obese (OB) in the Mauritian population as defined by WHO[8,10,14] standards, and stratified by sex and ethnicity*

| | WHO classification | | | | | | | | Total |
| | UW | | NW | | OW | | OB | | |
	n	%	n	%	n	%	n	%	n
Male									
South Asian Hindu	113	18·7	370	61·2	66	10·9	56	9·3	605
South Asian Muslim	54	15·8	222	64·9	35	10·2	31	9·1	342
Creole	20	8·7	164	71·6	25	10·9	20	8·7	229
Chinese	4	12·5	18	56·3	8	25·0	2	6·3	32
Female									
South Asian Hindu	84	13·4	444	71·0	63	10·1	34	5·4	625
South Asian Muslim	40	11·9	233	69·3	35	10·4	28	8·3	286
Creole	21	7·3	211	73·8	32	11·2	22	7·7	336
Chinese	3	8·8	28	82·4	3	8·8	0	0·0	34
Total	339	13·6	1690	67·9	267	10·7	193	7·8	2489

ADO, adolescents.
* Children, age 5–10 years; ADO, age 11–18 years.

Table 4. Comparison of cardiovascular function measured at rest for underweight (UW), normal weight (NW), overweight (OW) and obese (OB) as defined by the WHO[8,10,14]
(Mean values with their standard errors)

	Heart rate (beats/min)		Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)		Pulse pressure (ΔmmHg)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
UW	86·8[a]	0·8	103·5[a]	0·6	61·1[a]	0·5	42·4[a]	0·5
NW	84·6[b]	0·3	107·2[b]	0·3	63·5[b]	0·2	43·6[b]	0·2
OW	84·1[b]	0·9	111·3[c]	0·7	67·6[c]	0·5	43·7[a,b]	0·6
OB	87·0[a]	1·0	115·7[d]	1·0	69·2[d]	0·7	46·4[c]	0·9
ANOVA P	<0·01		<0·001		<0·001		<0·001	

[a,b,c,d] Mean values within a column with unlike superscript letters were significantly different ($P < 0.05$; pair-wise statistical comparison by Fisher's protected least-significant difference test after significant difference across ethnic groups indicated by ANOVA).

Sri Lankan origin[30] and also in Asian Indian adolescents from Guadeloupe[31]. Conversely, individuals of African descent have been shown to have a lower body fat mass and higher lean body mass for a given BMI[32]. Therefore, the elevated BMI-for-age observed in the Creoles of the present study should be interpreted with caution. If their higher BMI were to represent an elevated lean body mass, coupled with the persistently lower heart rate also seen independently of BMI in this group, it may indicate enhanced fitness, and therefore decreased cardiovascular risk in comparison with individuals of other ethnicity. This hypothesis remains to be tested with measurements of body composition and fitness.

Despite a relatively small group size, the Chinese displayed a number of concerning cardiovascular risk factors. The higher systolic blood pressure is of particular interest as, although n is small and the statistical results should be interpreted with caution, this increase was found across both age groups and sexes, and independent of BMI. Furthermore, in spite of the majority (90 %) of the Chinese group inhabiting urban areas, sub-group analysis of these urban clusters found the systolic blood pressure to be persistently higher in the Chinese group in comparison with all other urban ethnic groups. Similarly, higher blood pressure was unrelated to anaemia and/or infection as by judged Hb, haematocrit and leucocyte counts. It is unusual to observe such a large (5 mmHg) and consistent difference in such a tightly regulated physiological parameter. The higher systolic blood pressure in children and adolescents of Chinese ethnicity has particular clinical relevance given that the adult Chinese population in Mauritius[33], and indeed in China itself[34], has already been reported to be at an increased risk of hypertension and CVD. Furthermore, elevated blood pressure in childhood and adolescence, even within the normal blood pressure range, is a recognised predictor of hypertension in adulthood[35–37], and hence the observation that risk factors present early during growth in this ethnic group warrants further investigation. Whether the young Chinese have a higher salt consumption than the other ethnic groups would be one interesting avenue for future research. Indeed, our findings that their higher blood pressure resides primarily in a higher systolic blood pressure are consistent with well-controlled longitudinal studies of experimental hypertension[38] indicating that the slow development of salt-induced hypertension arises primarily from an increase in systolic, rather than diastolic, blood pressure.

There are three limitations in the present study which should be discussed. Firstly, the blood samples obtained during the present study were collected in the non-fasting state, and as such the interpretable measurement of blood glucose and lipids was not possible. Furthermore, complementary measures of waist and hip circumferences were not made. Given the high prevalence of type 2 diabetes in the Mauritian adult population such measurements in the younger population are of particular interest and should be incorporated in future surveys. Secondly, the sample size of the Chinese group is much smaller than each of the other ethnicities. However, the ethnic distribution of our sample was close to that of Mauritius as a whole; with the Chinese population on the Island and our Chinese sample size both comprising 3 % of the total. Thirdly, the large-scale nature of this epidemiological study and the cultural sensitivities of this multi-ethnic population precluded the assessment of pubertal stage. It is therefore possible

Table 5. Ethnic differences in cardiovascular function measured at rest
(Mean values with their standard errors)

	Heart rate (beats/min)		Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)		Pulse pressure (ΔmmHg)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
South Asian Hindu	85·4[a]	0·4	107·5[a]	0·4	64·4	0·3	43·1[a]	0·3
South Asian Muslim	86·5[a]	0·5	107·4[a]	0·5	63·4	0·3	44·0[a,b]	0·4
Creole	82·3[b]	0·6	108·3[a]	0·5	63·9	0·4	44·4[b]	0·4
Chinese	84·7[a,b]	1·6	113·2[b]	1·5	65·7	1·0	47·5[c]	1·2
ANOVA P	<0·001		<0·01		NS		<0·001	

[a,b,c] Mean values within a column with unlike superscript letters were significantly different ($P < 0.05$; pair-wise statistical comparison by Fisher's protected least-significant difference test after significant difference across ethnic groups indicated by ANOVA).

that some individuals within the younger age group (5–10 years) had already entered puberty, and conversely that some individuals in the older age group (11–18 years) were in the pre-pubertal stage. It could be argued that this may have confounded the results, particularly with respect to the Chinese sample, where the ratio of children to adolescents was different from that of the other ethnic groups. However, our conclusions of BMI-independent ethnic differences in cardiovascular function in the investigated population remain valid since the higher blood pressure in those of Chinese ethnicity as well as the lower heart rate and higher BMI in the Creoles were all observed across both age groups and across sex.

Childhood and adolescence are important phases of development, and represent significant targets for intervention and the prevention of adulthood diseases. Globally, industrialised and developing countries alike are experiencing rapidly increasing levels of adult obesity and associated CVD, with such pathophysiologies appearing in younger individuals with each passing generation. Indeed, the present study reveals ethnic differences in BMI-for-age as well as consistent, BMI-independent, ethnic differences in heart rate and systolic blood pressure. These findings highlight the early emergence of risk factors in a recognized at-risk population for CVD, and underscore the need to establish the BMI–fat percentage relationship across the various ethnic groups. Coupled with more detailed analyses of lifestyle and dietary habits which might explain this differential cardiovascular risk prior to adulthood, such research will enable us to accurately assess the current state of cardiovascular health across all age groups, sexes and ethnicities, and target research, education, and expenditure accordingly, to stem this burgeoning health crisis.

Acknowledgements

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