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## Oral contraceptive use in girls and alcohol consumption in boys are associated with increased blood pressure in late adolescence

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## Abstract

**Aims:** Lifestyle behaviours established during adolescence may adversely affect blood pressure (BP) and contribute to gender differences in cardiovascular risk in adulthood. We aimed to assess the association of health behaviours with BP in adolescents, using data from the Western Australian Pregnancy (Raine) Study.

**Methods:** Cross-sectional analysis on 1248 Raine Study adolescents aged 17 years, to examine associations between lifestyle factors and BP.

**Results:** Boys had 8.97 mmHg higher systolic BP, as compared with girls. The 30% of girls using oral contraceptives (OC) had 3.27 and 1.74 mmHg higher systolic and diastolic BP, respectively, compared with non-users. Alcohol consumption in boys, increasing body mass index (BMI) and the sodium-potassium ratio were associated with systolic BP. We found a continuous relationship between BMI and systolic BP in both genders; however, the gradient of this relationship was significantly steeper in boys, compared with girls not taking OC. In boys, systolic BP was 5.7 mmHg greater in alcohol consumers who were in the upper quartile of BMI and the urinary sodium-potassium ratio compared with teetotallers in the lowest quartile. In girls, systolic BP was 5.5 mmHg higher in those taking OC, in the highest BMI and urinary sodium-potassium ratio quartile as compared to those not taking the OC pill and in the lowest quartile.

**Conclusion:** In addition to gender-related differences in the effects of adiposity on BP, we found lifestyle-related health behaviours such as high salt intake for both sexes, consumption of alcohol in boys, and OC use in girls were important factors associated with BP measurements in late adolescence. This suggests that gender-specific behavioural modification in adolescence may prevent adult hypertension.

## Keywords

Oral contraceptives, alcohol consumption, blood pressure, adolescence, gender differences, hypertension, risk factors, lifestyle, salt consumption, body mass index

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## Introduction

Adolescence is accompanied by the adoption of a range of lifestyle habits that may profoundly influence blood pressure (BP) and adult cardiovascular risk.<sup>1</sup> Obesity, an emerging public health problem in childhood and adolescence worldwide, is also associated with multiple cardiovascular risk factors, including raised BP<sup>2</sup> and a higher risk of adult cardiovascular disease.<sup>3</sup> In adults, lifestyle factors such as dietary patterns, cigarette smoking, alcohol consumption, physical activity, and

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oral contraceptive (OC) use are known to influence BP; however, it is less clear what their effects are in adolescents, independent of obesity.

In addition, although gender differences in BP levels<sup>4,5</sup> and the risk of high BP<sup>4</sup> in adolescence are documented, little is known about the influence of gender on the effects of lifestyle factors on BP in this age group. It was previously suggested that OC use could raise BP in adolescent girls and thus increase the risk of hypertension in adult women.<sup>6</sup> Women taking OCs have a greater body mass index (BMI),<sup>7</sup> but to our knowledge no one has examined the relationship between OC use and BMI, and whether this affects BP in adolescent girls.

The aim of this study was to examine the relationship of lifestyle factors with BP in a population-based adolescent cohort in Western Australia, with particular reference to possible gender differences and their potential interaction with adiposity.

## Methods

### Participants

The Western Pregnancy Cohort (Raine) Study,<sup>8</sup> which had 2900 pregnant women enrolled from 1989–1992, is a longitudinal study of mothers and their children recruited from King Edward Memorial Hospital and nearby clinics in Perth, Western Australia, as described previously.<sup>9</sup> Ninety percent of the eligible women participated in the study. The 2868 live-births were evaluated and the children were followed up at 1, 2, 3, 5, 8, 10, 14 and 17 years of age.

The Human Ethics Committees of King Edward Memorial Hospital and Princess Margaret Hospital in Perth approved the study protocol. Informed parental and adolescent consent were obtained for participation in the study. The present study was a cross-sectional analysis of data from the 17-year follow-up of the cohort, which was conducted between July 2006 and June 2009.

### Assessments

**Clinical and biochemical.** Each study subject's resting BP and heart rate were obtained using an oscillometric sphygmomanometer (Dinamap ProCare 100, Soma Technology, USA). After 5 minutes of quiet rest, six automatic recordings were taken sequentially every 2 minutes from supine subjects provided with an appropriate cuff size. The averages of the last five readings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were calculated. Body weight was measured using a Wedderburn Chair Scale (nearest 100 g) and

height was measured with a Holtain Stadiometer (nearest 0.1 cm).

Fasting blood samples were analysed for serum lipids in the PathWest laboratory at the Royal Perth Hospital. Spot urine samples were analysed for urinary sodium and potassium excretion.

Weight status was determined based on age (17 years) and gender-specific cut-off points from the Recommendation for International Comparisons of Prevalence of Overweight and Obesity.<sup>10</sup> Being overweight was defined as BMI  $\geq 24.46$  kg/m<sup>2</sup> and  $< 29.41$  kg/m<sup>2</sup> for boys, and  $\geq 24.70$  kg/m<sup>2</sup> and  $< 29.69$  kg/m<sup>2</sup> for girls; being obese as BMI  $\geq 29.41$  kg/m<sup>2</sup> for boys and  $\geq 29.69$  kg/m<sup>2</sup> for girls. Prehypertension was defined as gender-specific BP that was  $\geq 90$ th percentile for SBP or DBP, but below the threshold for hypertension ( $\geq 95$ th percentile); while hypertension was a SBP or DBP  $\geq 95$ th percentile.<sup>11</sup> Hypertensive status was also defined employing adult JNC-7 ([www.nhlbi.nih.gov/guidelines/hypertension](http://www.nhlbi.nih.gov/guidelines/hypertension)) criteria: prehypertension as SBP 120–139 mmHg or DBP 80–89 mmHg, and hypertension as SBP  $\geq 140$  mmHg or DBP  $\geq 90$  mmHg.

**Sociobehavioural.** Socioeconomic status (SES) was assessed from annual family income (Australian dollars) and the SEIFA (Socio-Economic Indexes for Areas) score,<sup>12</sup> which is based on the adolescent's geographic postal area (a low score indicates an area of social disadvantage). Family income was used as an interpretable descriptor; however, SEIFA, a more robust measure of SES, was employed in the analysis.

Alcohol consumption information was obtained from an online questionnaire that asked about the subject's intake types (beer, wine or spirits) and amount (can, glass, stubby, nip or standard drink) of alcoholic beverages consumed daily during the past week. Alcohol consumption was defined as the average number of standard drinks consumed per day during the last 7 days, where 1 standard drink is 10 g alcohol. Alcohol drinker was defined as consumer of alcohol at any level during the last 7 days.

Adolescents were asked to report the number of cigarettes smoked each day, within the last 7 days. Physical activity was assessed from the question, 'How many hours do you usually exercise in your free time in a week, so much that you get out of breath or sweat?' We created a dichotomous variable with the cut-point at  $\geq 4$  hours per week.<sup>13</sup> Oral contraceptive use in girls was defined by a yes or no answer to the question, 'In the last 6 months, have you taken any prescription medication(s) e.g. the Pill?' (if yes, 'which medication(s), and are you still taking it?').

From a 212-item food frequency questionnaire, two dietary patterns ('Western' and 'Healthy') were identified using factor analysis.<sup>14</sup>

**Statistical analysis.** SBP and DBP were examined as continuous outcome variables. Candidate factors investigated included age, gender, SEIFA score, BMI, alcohol consumption, smoking, physical activity, dietary patterns, OC use, urinary sodium and potassium levels, and the Na/K ratio. BMI, alcohol consumption and smoking were analysed as continuous variables to avoid the loss of power and the bias behind our arbitrary choice of categorization of cut-off points. The associations between each factor and both SBP and DBP were assessed using robust linear regression, to reduce the influence of potential outliers. To examine the linearity in the relationship between BMI and BP, we used fractional polynomial regression plots. Patterns observed in these plots suggested that for alcohol consumption, a dichotomous arrangement represented the relationship with BP more closely than the continuous variable. In this instance, both the dichotomous and continuous variables were analysed in the initial models. We also investigated the interactions between gender and BMI and other covariates. Initial models were adjusted for sex, and extended models were adjusted for sex and BMI.

Multiple imputation was performed using Royston's Ice program<sup>15</sup> to estimate the urinary Na/K ratio, missing in approximately one-third of the sample. The imputation process, based on iterative multivariable regression, generated 20 new datasets, each containing an estimated value for the missing ratio. These datasets were then analysed separately and estimates combined to obtain a final single solution. Our analysis of complete cases and imputed data did produce the same estimates of the association between Na/K and SBP. Independently of Na/K itself, the reduced sample of complete cases did create bias in the estimated effects of other covariates; hence, imputation maintained the whole sample in the analysis to reduce sample bias.

A 3-level gender variable incorporating oral contraceptive use (girls not using OC, girls using OC, and boys) was created to assess the effect of OC in the final multivariable models. Variables significantly associated with BP in the initial models, as well as the relevant interaction terms, were included in the multivariable regression models. Non-significant variables were removed in a backward process that included examination of the effect on coefficients and *p* values of all remaining variables, at each step.

Stata MP version 11 (Stata Corp, College Station, TX) was used for statistical analysis, and significance was set at  $p < 0.05$ .

## Results

At 17 year of age, 1771 adolescents from the original 2868 live-born children participated in our follow-up study. There were 13.2% who deferred from participation, 16.6% had withdrawn from the study, 1.2% were deceased and 7.2% were lost to follow-up. Of the 1771 participants, 1257 submitted to anthropometric, cardiovascular, biochemical assessments and detailed health questionnaires. We excluded nine cases with major congenital malformations, resulting in a study sample size of 1248. Apart from having a higher percentage of subjects with a higher family income, these participants were comparable to non-participants of the 17-year survey (see supplementary material Table S1). Our study sample was comprised of 88% Caucasians, which is representative of the Western Australian population.

Demographic, anthropometric and socio-behavioural characteristics of these adolescents are shown in Table 1. At around 17 years, boys were heavier and had a larger waist size than girls ( $p < 0.001$ ). Within the previous week, 51% of the adolescents had consumed alcohol at any level. More boys than girls exercised  $\geq 4$  hours in their free time per week (42.6% versus 21.3%,  $p < 0.001$ ), while 30% of the girls used OC.

Mean SBP was higher in boys, as compared with girls (117.9 versus 108.6 mmHg,  $p < 0.0001$ ) (Table 2), whereas mean DBP was lower in boys, as compared with girls (58.2 versus 59.5 mmHg,  $p = 0.0007$ ). Employing gender-specific criteria, we found that 8% of all adolescents were prehypertensive and 7.8% were hypertensive, with similar proportions for boys and girls; but by using hypertensive status defined according to adult (JNC-7) criteria, we found a significantly higher prevalence of prehypertension and hypertension in boys, compared with girls (36% versus 8.9%, and 2.2% versus 0.3%, respectively;  $p < 0.001$ ). Overall, 34% of overweight and 38% of obese adolescents had a BP defined as prehypertensive or hypertensive (Table 3).

In univariate models examining lifestyle and socio-demographic factors (supplementary material Table S2), we found that SBP was significantly associated with male gender, BMI, urinary sodium, the urinary Na/K ratio, and being an alcohol drinker, plus OC use in girls. When adjusted for BMI (supplementary material Table S3), a significant association with SBP remained for male gender, being an alcohol drinker, OC use in girls, urinary sodium and the Na/K ratio. Dietary patterns were not related to SBP nor DBP. In girls, DBP was positively associated with OC use and negatively associated with BMI (Table S2). This BMI-DBP negative association in girls became non-significant when

**Table 1.** Demographic, anthropometric and socio-behavioural characteristics of the study population

	Girls n = 620 (49.7%)	Boys n = 628 (50.3%)	Whole sample n = 1248
	mean (95%CI)	mean (95%CI)	mean (95%CI)
Age, y	17.05 (17.03, 17.07)	17.02 (17, 17.04)	17.04 (17.02, 17.05)
Height, m	1.659 (1.653, 1.664)	1.783 (1.777, 1.789)	
Weight, kg	62.5 (61.5, 63.4)	71.0 (69.9, 72)	
Waist circumference, mm	768 (759, 776)	799 (790, 807)	
BMI, kg/m <sup>2</sup>	22.7 (22.4, 23)	22.3 (22.0, 22.6)	
<i>Socio-behavioural</i>			
SEIFA score*	1041.4 (1035.8, 1046.9)	1045.1 (1039.6, 1050.5)	1043.2 (1039.4, 1047.1)
Alcohol consumption <sup>†</sup>	0.97 (0.88, 1.08) % (95% CI)	1.29 (1.15, 1.46) % (95% CI)	1.12 (1.04, 1.22) n (%)
Alcohol drinker <sup>‡</sup>	50.2 (46.3, 54.2)	51 (47.1, 55)	628 (50.7)
Smoker <sup>§</sup>	18.2 (15.2, 21.3)	15.1 (12.3, 17.9)	208 (16.7)
Oral contraceptive user	30 (26.3, 33.6)		
Physically active <sup>  </sup>	21.3 (17.9, 24.8)	42.6 (38.3, 46.9)	334 (31.5)
User of at least one recreational drug type <sup>¶</sup>	13.2 (10.6, 15.9)	15.4 (12.6, 18.3)	179 (14.3)
Annual family income			
≤ A\$ 35,000	13.8 (10.9, 16.8)	12.8 (10.1, 15.6)	145 (13.3)
A\$ 35,001 – ≤ 78,000	33.3 (29.3, 37.4)	33 (29.1, 36.9)	361 (33.2)
> A\$ 78,000	52.8 (48.6, 57.1)	54.2 (50.1, 58.3)	583 (53.5)

Data are presented as mean (95%CI), or for categorical variable as percentage (95%CI) or n (%) as indicated; BMI: Body Mass Index; SEIFA: Socio-Economic Indexes for Areas; \*Index of advantage/disadvantage, Australian Bureau of Statistics SEIFA; †Average number of standard drinks consumed during the last 7 days; ‡Consumer of alcohol at any level over the last 7 days; §Smoking ≥ 1 cigarettes in a week; || Having ≥ 4 hours of exercise in free time per week; ¶Drug types included amphetamines, marijuana, and party drugs.

four subjects with BMI ≥ 40 were excluded ( $\beta = -0.08$ ;  $p = 0.221$ ).

In multivariable models, male gender, alcohol drinking in boys, OC use in girls, BMI, and urinary Na/K ratio were positively associated with SBP (Table 4). SBP in boys was 8.97 mmHg higher, as compared with girls. Girls using OC measured 3.27 mmHg higher in SBP, as compared with the non-OC users. There was a significant interaction between BMI, gender and OC use in girls. The relationship between BMI and SBP for boys differed when compared to girls not on OC (Figure 1). For an increase in BMI of 1 kg/m<sup>2</sup>, SBP increased by 0.65 mmHg in boys compared to 0.38 mmHg in the non-OC using girls ( $p = 0.028$ ). However, the interaction term indicated there was no difference between boys and girls on OC ( $p = 0.522$ ) or OC using and non-OC using girls ( $p = 0.482$ ). We found DBP was negatively associated with physical activity and positively associated with OC use.

Using the final multivariable model, we compared boys and girls in the upper and lower quartiles for

those factors that were significantly associated with SBP. In boys who were drinkers and were in the 75th percentiles for BMI and urinary Na/K ratio, their average was 119.9 mmHg SBP, compared to 114.1 mmHg for those who were not drinkers and in the 25th percentile for both BMI and urinary Na/K ratio. In girls using OC and who were in the 75th percentile for both BMI and the urinary Na/K ratio, average SBP was 114.5 mmHg SBP compared to 105.9 mmHg for those not using OC and in the 25th percentile for both BMI and urinary Na/K ratio.

## Discussion

In this adolescent population, we have shown that there was a significant association of a range of lifestyle factors with BP, including some that were gender specific. Higher SBP was significantly associated with use of OC in girls and alcohol consumption in boys. In general, boys had significantly higher SBP than girls. Furthermore, OC use in girls was associated with

**Table 2.** Clinical and biochemical characteristics, and comorbidities of the study population

	Girls n = 620 (49.7%)	Boys n = 628 (50.3%)	Whole sample n = 1248
	mean (95%CI)	mean (95%CI)	mean (95%CI)
SBP, mmHg	108.6 (107.9, 109.4)	117.9 (117.1, 118.6)	113.3 (112.7, 113.9)
DBP, mmHg	59.5 (59, 60)	58.2 (57.7, 58.7)	58.8 (58.5, 59.2)
HR, bpm	67.2 (66.5, 67.9)	62.9 (62.2, 63.6)	65.0 (64.5, 65.5)
<i>Fasting</i>			
Glucose, mmol/L	4.63 (4.59, 4.66)	4.82 (4.78, 4.87)	4.73 (4.70, 4.76)
Insulin, mU/L	7.64 (7.21, 8.1)	6.86 (6.49, 7.25)	7.22 (6.94, 7.52)
Total cholesterol, mmol/L	4.30 (4.24, 4.37)	3.93 (3.87, 3.99)	4.11 (4.06, 4.15)
Triglycerides, mmol/L	0.95 (0.91, 0.98)	0.95 (0.92, 0.99)	0.95 (0.93, 0.97)
HDL-C, mmol/L	1.39 (1.36, 1.42)	1.20 (1.18, 1.22)	1.29 (1.28, 1.31)
LDL-C, mmol/L	2.43 (2.38, 2.49)	2.24 (2.19, 2.29)	2.33 (2.29, 2.37)
<i>Urine</i>			
Sodium, mmol/L	132.84 (127.2, 138.47)	122.93 (118.07, 127.78)	127.59 (123.89, 131.29)
Potassium, mmol/L	41.45 (39.23, 43.8)	41.24 (39.37, 43.2)	41.34 (39.89, 42.84)
Sodium/potassium ratio	2.85 (2.67, 3.04)	2.69 (2.54, 2.84)	2.76 (2.65, 2.88)
<i>Hypertensive status</i>			
	% (95% CI)	% (95% CI)	n (%)
<i>Adolescent gender-defined*</i>			
Prehypertension	7.8 (5.7, 9.9)	8.3 (6.1, 10.5)	100 (8)
Hypertension	7.8 (5.7, 9.9)	7.8 (5.7, 10)	97 (7.8)
<i>Adult criteria<sup>†</sup></i>			
Prehypertension	8.9 (6.7, 11.4)	36 (32.2, 39.9)	280 (22.5)
Hypertension	0.3 (0.03, 1)	2.2 (1.2, 3.7)	16 (1.3)

Data are presented as mean (95% confidence interval), or for categorical variable as percentage (95% confidence interval) or n (%) as indicated; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; \*Gender-specific SBP or DBP  $\geq$  90th percentile but  $<$  95th percentile (prehypertension);  $\geq$  95th percentile (hypertension); <sup>†</sup>SBP 120–139 mmHg or DBP 80–89 mmHg (prehypertension);  $\geq$  140 mmHg or DBP  $\geq$  90 mmHg (hypertension).

higher DBP, as compared to non-OC using girls. There were also significant gender differences in the relationship between obesity and BP, as boys showed a steeper gradient for the effect of BMI on SBP than girls not taking OC.

In our study, SBP was 8.97 mmHg higher in boys compared with girls, consistent with previous reports on adolescent SBP.<sup>2</sup> Using gender-specific percentiles to define hypertensive status, not surprisingly there was no difference between the sexes. However, in 17-years-olds it is perhaps more logical to employ adult criteria cut-offs; using the JNC-7 criteria, we found that approximately 24% of the adolescents were prehypertensive or hypertensive. In addition, we found marked gender differences in the prevalence of prehypertension (36% in the boys versus 9% in the girls) and even hypertension (2% in boys versus 0.3%

in girls). Gender differences in prehypertension prevalence were previously reported in an adolescent population aged 16–19 years.<sup>16</sup>

The proportion of obese girls and boys that were prehypertensive in our study was 15% and 51%, respectively. As a measure of adiposity, BMI is a strong predictor of SBP in children and adolescents<sup>17</sup> and was previously shown to have a similar relationship to BP compared with other anthropometric measurements when this same population was studied at age 14.<sup>18</sup>

The 30% of our female adolescents who reported taking OC had significantly increased SBP and DBP, as compared with non-OC users. These data agree with results from a study of 17-year-old girls that shows a 4.6 mmHg higher SBP in low-dose OC users,<sup>19</sup> which suggests a marked pressor effect of OC in adolescence.

**Table 3.** Hypertensive status by weight categories

	Adult criteria categories of blood pressure		
	Normotensive	Prehypertensive	Hypertensive
<b>Whole sample (n = 1243)</b>			
Normal weight	79.6 (76.8, 82.1)	19.8 (17.3, 22.5)	0.63 (0.23, 1.36)
Overweight	66.1 (58.7, 73)	31.1 (24.4, 38.4)	2.8 (0.9, 6.4)
Obese	62.5 (52.5, 71.8)	32.7 (23.8, 42.6)	4.8 (1.6, 10.9)
<b>Girls (n = 618)</b>			
Normal weight	92.6 (89.8, 94.8)	7.2 (5, 9.9)	0.2 (0.005, 1.2)
Overweight	86 (77.3, 92.3)	14 (7.7, 22.7)	0
Obese	83 (70.2, 91.9)	15.1 (6.7, 27.6)	1.9 (0.05, 10.1)
<b>Boys (n = 625)</b>			
Normal weight	66.9 (62.6, 71.1)	32 (27.9, 36.4)	1 (0.3, 2.4)
Overweight	44.8 (34.1, 55.9)	49.4 (38.5, 60.4)	5.7 (1.9, 12.9)
Obese	41.2 (27.6, 55.8)	51 (36.6, 65.2)	7.8 (2.2, 18.9)

Data are presented as percentage (95%CI); Overweight as BMI  $\geq 24.46$  kg/m<sup>2</sup> and  $< 29.41$  kg/m<sup>2</sup> (boys) and  $\geq 24.70$  kg/m<sup>2</sup> and  $< 29.69$  kg/m<sup>2</sup> (girls); obese as BMI  $\geq 29.41$  kg/m<sup>2</sup> (boys) and  $\geq 29.69$  kg/m<sup>2</sup> (girls); Prehypertension as SBP 120–139 mmHg or DBP 80–89 mmHg; hypertension as  $\geq 140$  mmHg or DBP  $\geq 90$  mmHg (hypertension); BMI: Body Mass Index; SBP: systolic blood pressure; DBP: diastolic blood pressure.

**Table 4.** Multivariable models for adolescent systolic and diastolic blood pressure

	Regression coefficient	95% CI	p
<b>SBP</b>			
Male gender*	8.97	7.43, 10.5	<0.001
OC use	3.27	1, 5.54	0.005
Urinary Na/K ratio <sup>‡</sup>	0.27	0.02, 0.51	0.031
<b>BMI<sup>§</sup></b>			
Boys	0.65	0.48, 0.81	<0.001
Girls using OC <sup>¶</sup>	0.52	0.17, 0.87	0.004
Girls not using OC	0.38	0.21, 0.55	<0.001
<b>Alcohol drinker<sup>#</sup></b>			
Boys	2.48	1.09, 3.87	<0.001
Girls using OC	-0.12	-1.8, 1.56	0.89
Girls not using OC	0.28	-2.29, 2.85	0.83
Constant	107.46	106.3, 108.6	<0.001
<b>DBP</b>			
Male gender*	-0.26	-1.15, 0.63	0.571
OC use	1.74	0.55, 2.93	0.004
Physical activity <sup>†</sup>	-1.22	-2.1, -0.34	0.007
Constant	60.22	58.95, 61.49	<0.001

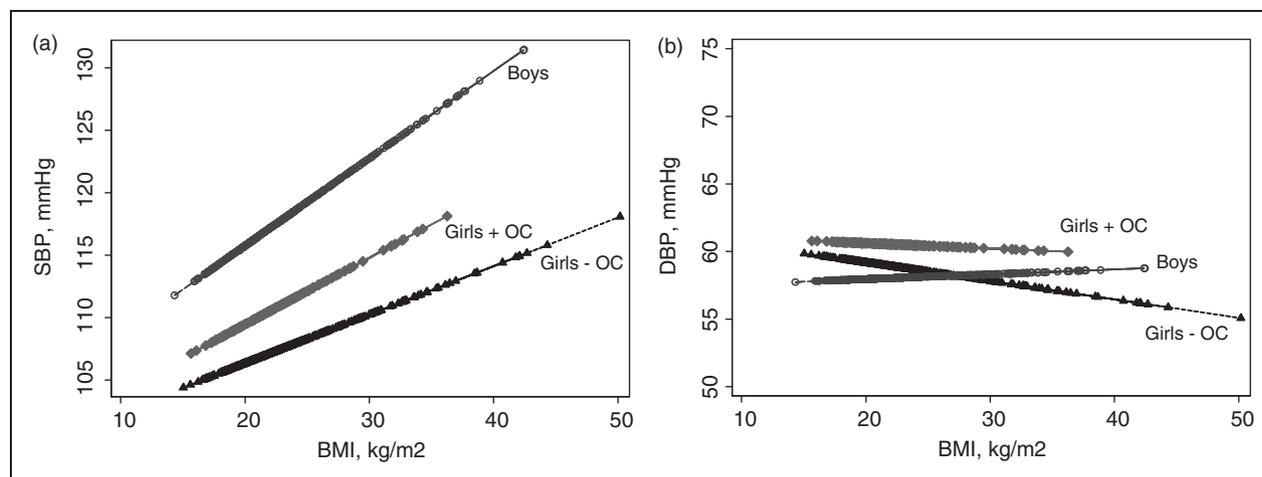
SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: Body Mass Index; OC: oral contraceptives; Na/K ratio: sodium to potassium ratio; \*Reference group was girls not using OC; <sup>‡</sup>Na/K - mean Na/K; <sup>§</sup>BMI - mean BMI; <sup>¶</sup>p = 0.028, boys versus non-OC girls; <sup>†</sup>p = 0.482, OC using girls versus non-OC girls; <sup>#</sup>Consumer of alcohol at any level over the last 7 days; <sup>†</sup> $\geq 4$  hours versus  $< 4$  hours of exercise outside of study or work, per week.

Even at low dose, OC use was previously shown to raise BP and the prevalence of hypertension in adult women.<sup>6</sup>

We observed a significant and positive association between SBP and drinking alcohol at any consumption level within the last 7 days in boys, but not in girls. Previously, in a cohort of 365 students aged 13–18 years, a weak, albeit significant relationship was found between frequency and quantity of alcohol consumption and DBP, with a greater prevalence of hypertension in male heavy drinkers.<sup>20</sup> Similarly, others observed higher BP in 18-year-old Australians with alcohol binge-drinking behaviours.<sup>21</sup> Also, a stronger alcohol-SBP association was reported in older, compared with younger men, but not in women.<sup>22</sup>

The association between sodium consumption and BP is extensively documented in adults, children and adolescents.<sup>23</sup> We observed a significant relationship between the urinary Na/K ratio and SBP, in both boys and girls. The urinary Na/K ratio is shown to correlate strongly with age-related BP increases in adults.<sup>24</sup> Our data reinforce the evidence in favor of a diet balanced for lower intake of salt-containing foods and higher intake of potassium-rich foods and vegetables.<sup>25</sup>

With regard to the gender difference in the continuous relationship between BMI and SBP, a novel finding in our study was that in boys, there was a significantly greater increase in SBP with increasing BMI, as compared with girls that were not taking OC. Gender differences in BP most likely relate to the different effects



**Figure 1.** Relationship of BMI and (a) systolic BP (with  $p = 0.028$ , boys versus girls not using OC (Girls - OC);  $p = 0.482$ , girls using OC (Girls + OC) versus girls not using OC), or (b) diastolic BP in boys versus girls using or not using OC. BMI: body mass index; BP: blood pressure; OC: oral contraceptives; SBP: systolic blood pressure; DBP: diastolic blood pressure.

of testosterone and oestrogens on BP regulation,<sup>26</sup> as well as to some other lifestyle factors demonstrated here.

We confirmed that a continuous BP-weight status is associated with hypertension risk, rather than there being a threshold effect. In adults, the existence of linearity or a threshold in the BMI-BP relationship has been equivocal,<sup>27</sup> with some suggesting a threshold at 21 kg/m<sup>2</sup> for BMI.<sup>28</sup> Others have adopted this arbitrary figure for the interpretation of BP data in children.<sup>29</sup> Our observation of there being a continuous positive linear relationship between BMI and SBP across the entire range of BMI in both boys and girls is important in this context, as it suggested that a BMI threshold in adolescence is not appropriate.

In adolescents of both sexes, moderate to vigorous physical activity was reported to be inversely related to higher SBP levels.<sup>30</sup> Our data showed that twice as many boys engaged in more regular physical activity, as compared with girls, a finding that is consistent with other studies.<sup>31</sup> We found that self-reported habitual exercise was negatively associated with DBP, in both boys and girls. These results are in agreement with other reports<sup>32,33</sup> about children and adolescents.

Applying our model that best describe the association between SBP and lifestyle factors, our findings showed that the boys who drank alcohol and were in the 75th percentile for both BMI and urinary Na/K ratio had 5.7 mmHg higher SBP, as compared to non-drinkers who were in the 25th percentile for both BMI and Na/K ratio. Similarly, girls taking OC who were in the 75th percentile for both BMI and Na/K had 5.5 mmHg higher SBP, as compared to those not using OC and in the 25th percentile for both BMI and urinary Na/K ratio.

Interpretation of our findings with regard to causality requires caution, in view of the cross-sectional design of the study. However, the strengths of the study include: having a population-based sample; a study large enough to detect gender effects and to analyse for the multiplicative effects of several lifestyle factors; and the collection of comprehensive and standardised phenotypic, lifestyle and socio-behavioural data by trained personnel.

In conclusion, in our study of 17-year-old adolescents, increased BP was associated with OC use in girls and alcohol consumption in boys, as well as with increasing BMI, increasing Na/K ratio, and a lower level of physical activity. There were marked gender differences in SBP and its relation to increasing BMI. When applying adult criteria, we found that boys had four times the prevalence of prehypertension compared with girls. These substantial differences in SBP in boys and girls, between those with a healthier versus a less favourable lifestyle pattern, are likely to significantly affect their risk of both ischemic heart disease and stroke in adulthood. Adolescence is a time of life when unhealthy lifestyle behaviours that impact BP and related metabolic disorders tend to become entrenched. Our findings suggest that significant public health benefits may be achieved from implementation of a range of gender-appropriate lifestyle modifications within this age group of adolescents.

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## Conflict of interest

None declared.

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