

Emergence of Sex Differences in Prevalence of High Systolic Blood Pressure Analysis of a Longitudinal Adolescent Cohort

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Background—High systolic blood pressure (SBP) occurs more frequently both among men and boys than among women and girls. No longitudinal study has investigated whether the impact of SBP determinants differ according to sex in youth.

Methods and Results—Between 1999 and 2005, an adolescent cohort (n=1267) completed a questionnaire survey and underwent biannual blood pressure and anthropometric assessment (grades 7, 9, and 11). Boys accounted for ≈50% of those with high SBP at grade 7 and 9 assessments but 67% of those with high SBP at the grade 11 assessment. As computed through a generalized estimating equations logistic regression model (sex, age, sex and age interaction term, overweight, physical activity, sedentary behavior, heart rate, household income, tobacco use, and 4 language categories), the likelihood of high SBP values among boys compared with girls was 1.29 (95% CI, 0.77 to 2.16) in grade 7, 1.98 (95% CI, 1.35 to 2.93) in grade 9, and 2.74 (95% CI, 1.52 to 4.94) in grade 11. Although there was a significant interaction between sex and age, interaction terms of sex with overweight, sedentary behavior, and physical activity were not statistically significant. Overweight (odds ratio [OR], 2.63; 95% CI, 1.76 to 3.92) and sedentary behavior (OR, 1.17 for increment of 5 hours weekly; 95% CI 1.04 to 1.33) demonstrated positive associations with high SBP values. Physical activity was inversely associated with the presence of high SBP (OR, 0.92 for increment of 5 activities in 7 days; 95% CI, 0.84 to 1.00).

Conclusions—Boys are more likely than girls to develop high SBP as they approach adulthood. Even among overweight adolescents, reducing sedentary behavior and increasing physical activity may lower the risk of high SBP. (*Circulation*. 2006;114:2663-2670.)

Key Words: hypertension ■ exercise ■ obesity ■ pediatrics ■ epidemiology

Among young and middle-aged adults, population surveys report hypertension to be more frequent among men than women, with sex differences of 4% in the United States, 8% in Canada, and 11% in western Europe.¹ Early sex differences in blood pressure may underlie the difference in hypertension prevalence between men and women. In the longitudinal Muscatine study, the risk for systolic blood pressure (SBP) above the 90th percentile in young adults was 2.4-fold higher among those who had ever exceeded age-specific and sex-specific SBP 90th percentile values as children or adolescents.² Boys were 10% more likely than girls to develop high SBP as adults.² High SBP has been reported to be more prevalent among boys than girls in several cross-sectional studies.³⁻⁵ For example, in the Quebec Child and Adolescent Health and Social Survey, the prevalence of high SBP among boys exceeded that among girls by 3% among 13-year-olds and by 13% among 16-year-olds.⁵

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No longitudinal study to date has investigated sex differences in the prevalence of high SBP over time. Overweight is a critical determinant of SBP in both girls and boys,^{6,7} and it is likely causally linked to recent increases in the prevalence of hypertension in this age group. However, despite accumulating evidence that childhood blood pressure levels are increasing,⁷⁻¹⁰ there are few studies that investigate a range of possible determinants of increased blood pressure in the pediatric population¹¹ or that examine the influence of sex on these determinants. Of particular interest are modifiable determinants shown to be important in adult populations, including physical inactivity¹²⁻¹⁴ and higher levels of alcohol intake.¹⁵ Using data available in a 5-year longitudinal investigation of adolescents, we studied sex differences in the early determinants of high SBP.

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Methods

Data for these analyses were drawn from the McGill University Study on the Natural History of Nicotine Dependence in Teens (NDIT), a longitudinal investigation of adolescents that examined the natural course of nicotine dependence over 5 years.¹⁶ Students were recruited from all grade 7 classes in a convenience sample of 10 Montreal-area secondary schools. Schools were selected in consultation with local school boards and school principals to ensure representation of both French and English schools (7 English schools and 3 French schools), high-income and low-income neighborhoods, and urban and suburban locations. All were public schools. Private schools were not included because it was believed that these schools would tend to include only adolescents from high socioeconomic backgrounds. In contrast, Canadian public schools tend to include children from a variety of socioeconomic backgrounds. More than half (55%) of all eligible students agreed to participate. Parents provided informed written consent, and participants provided assent. This study was approved by the Institutional Review Board of McGill University.

Over a 5-year follow-up period, participants completed self-report questionnaires at 3- to 4-month intervals, for a total of 20 survey cycles. Data on frequency of participation in physical activity were collected in each survey cycle in a 7-day recall adapted from the Weekly Activity Checklist,¹⁷ which has been validated against accelerometer-measured activity levels. In the 7-day recall, participants were asked to report on which days during the week preceding completion of the questionnaire they had participated in each of the following activities for 5 minutes or more: swimming/diving, basketball, baseball/softball, football, soccer, volleyball, racket sports, ice/hockey, jump rope, downhill skiing/snowboarding, cross-country skiing, ice skating, rollerblading/skateboarding, gymnastics, exercise/physical conditioning (eg, push-ups, weights), ball playing (eg, dodgeball), track and field, games (eg, chase, tag), jazz/classical ballet, dancing (aerobic, party), outdoor play (eg, hide and seek, climbing trees), martial arts, outdoor chores (eg, mowing, raking), indoor chores (eg, mopping, vacuum cleaning), walking, running/jogging, and other. A continuous estimate of the frequency of participation in physical activity was obtained by summing the total number of activities checked in the recall. To assess sedentary behavior, participants were asked to estimate separately for weekdays and weekends how many hours of television or videos they watched and how many hours they played computer games or used the Internet in a single day. A continuous estimate of the number of hours of sedentary behavior during a 1-week period was computed by combining hours reported for television viewing, computer games, and Internet use.

Frequency of alcohol consumption was recorded as never, a bit to try, monthly, weekly, or daily. In the present analysis, alcohol consumption was categorized as less than once per month or greater than or equal to once per month. Use of tobacco (cigarettes) was measured in each of the 3 months preceding each questionnaire. Participants reporting any tobacco use were classified as "tobacco use—ever" and those reporting no use were classified as "tobacco use—never." Sociodemographic characteristics included age, sex, language spoken at home (English, French, both English and French, other), and household income. In the province of Quebec (Canada), 80% of the population report French as their first language. Specifically in Montreal, 58% report French as their first language, 10% report English, and 31% report a language other than French or English.¹⁸ An estimate of the mean household income of families with children attending each of the 10 study schools was obtained from a report prepared for the Quebec government.¹⁹

Height, weight, and blood pressure were assessed in survey cycles 1 (at baseline when participants were in grade 7), 12 (grade 9), and 19 (grade 11) by technicians who had been trained and certified according to a standardized protocol.²⁰ Two measures of height to the nearest 0.1 cm and weight to the nearest 0.2 kg were obtained for each subject. If discrepancies >0.5 cm for height or 0.2 kg for weight were observed between the 2 measures, a third measure was obtained, and the average of the 2 closest measures was recorded. To assess interrater reliability, repeat measures of height and weight were obtained in a systematic 1-in-10 subsample of students.

Intraclass reliabilities (split-half coefficients) of 0.99 were obtained for height and for weight. Body mass index (BMI) was computed as weight divided by height squared (kg/m²). Absolute BMI was converted to a BMI percentile value based on standardized sex-specific BMI percentile curves for adolescents.^{21,22} In the present analysis, participants were classified as being overweight if their BMI was at or above the 85th percentile. Our definition of overweight includes both those considered to be "at risk" for overweight (between the 85th and 95th percentiles) and those considered to be overweight (at or above the 95th percentile) by the Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services.²³

Blood pressure and resting pulse were assessed in the right arm after a 5-minute rest period, with an oscillometric device (Dinamap XL, model CR9340, Critikon Co, Tampa, Fla).²⁴ Three consecutive measures were obtained at 1-minute intervals, and the average of the last 2 measures was used in the analyses. Oscillometric devices were calibrated against a mercury manometer before each data collection period. SBP values at or above the 90th percentile values from the National High Blood Pressure Education Program (NHBPEP) Working Group were considered to be increased in the present analysis.⁵ These 90th percentile values are specific for sex, age, and height and are based on NHANES (National Health and Nutrition Examination Survey) 1999 to 2000 data. Our definition of high SBP includes NHBPEP definitions of both high-normal (90th to 95th percentile) and elevated (at or above 95th percentile) SBP.

Statistical Analysis

With data for participants who completed all 3 blood pressure assessments, sex-specific curves were fitted to a scatterplot of SBP values using kernel smoothing.²⁵ To examine tracking of SBP, an intraclass correlation coefficient was calculated simultaneously to examine all 3 blood pressure measures among those who completed 3 assessments. Characteristics of participants with and without high SBP were examined for grade 7, 9, and 11 assessments. Characteristics of participants who completed all 3 blood pressure assessments were compared with those who completed fewer than 3 assessments.

All available data on SBP and candidate correlates were collapsed across the 3 assessments (ie, those of participants who completed all 3 assessments and those of participants who completed fewer than 3 assessments), and independent correlates of SBP \geq 90th percentile (yes, no) were identified in sex-specific logistic regression models with the generalized estimating equations approach with an unstructured working correlation matrix to estimate all possible correlations between repeated measures.^{26,27} Candidate correlates investigated included overweight status, frequency of participation in physical activity, sedentary behavior, tobacco use (never/ever), frequency of alcohol consumption, resting pulse, language spoken at home and household income. For physical activity and sedentary behavior, we report associations with high SBP according to increments of 5 activities weekly on the 7-day physical activity recall and according to increments of 5 hours weekly of sedentary behavior. Models were additionally adjusted for resting heart rate. We report associations of high SBP with 5-bpm increments of resting heart rate.

To study the independent effect of sex on high SBP, we combined data across sexes in a secondary analysis and constructed a generalized estimating equations logistic regression model that included sex and the candidate correlates described above. Additionally, we tested sex interaction terms for each candidate correlate. The final model included only sex interaction terms for variables that appeared to have different effects among boys and girls in sex-specific models and for which an interaction term with sex was significant in a model that included data from both boys and girls. All analyses were performed with SAS version 9.1 statistical software (SAS Institute Inc, Cary, NC). Generalized estimating equation models were fitted by the GENMOD procedure.

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results

Blood pressure data were collected from 1267 participants in grade 7, 954 participants in grade 9, and 844 participants in

TABLE 1. Proportion With High SBP at 1, 2, or 3 Assessments Among Boys and Girls Who Were Ever Recorded as Having a High SBP Value

| | High SBP, n (%) | | |
|-------------------|-----------------|--------------|-------------|
| | Boys (n=67) | Girls (n=50) | All (n=117) |
| All 3 assessments | 12 (18) | 15 (30) | 27 (23) |
| Two assessments | 26 (39) | 16 (32) | 42 (36) |
| First and second | 2 | 6 | 8 |
| First and third | 12 | 8 | 20 |
| Second and third | 12 | 2 | 14 |
| One assessment | 29 (43) | 19 (38) | 48 (41) |
| First | 11 | 7 | 18 |
| Second | 8 | 9 | 17 |
| Third | 10 | 3 | 13 |

grade 11. The mean (SD) age of participants in grades 7, 9, and 11 was 12.8 (0.6), 15.2 (0.4), and 17.0 (0.4) years, respectively. Among individuals who completed 3 blood pressure assessments, the intraclass correlation coefficient examining all 3 SBP measures simultaneously indicated a moderate level of tracking over time in both boys and girls (intraclass correlation coefficient $r=0.33$ among boys, $r=0.44$ among girls, $P<0.0001$ for both boys and girls). For both boys and girls, among those who had at least 1 high SBP value during the follow-up period, $\approx 60\%$ had a high SBP at 2 or more assessments, and $\approx 40\%$ had high SBP at only 1 assessment (Table 1). Mean SBP values (SD) among girls were relatively stable over time; values were 104.1 (9.8), 103.9 (10.2), and 106.2 (10.0) mm Hg over the 3 assessments. In boys, the mean SBP values increased over time from 105.4 (10.6) to 108.5 (10.6) and 114.9 (11.3) mm Hg (Figure 1). At both grade 7 and grade 9 assessments, prevalence of high

SBP (ie, SBP above sex-, age-, and height-specific 90th percentile thresholds based on NHANES 1999 to 2000 data) was 5% among girls and 6% among boys. At the grade 11 assessment, the prevalence was 4% among girls and 8% among boys. High diastolic blood pressure (ie, above sex-, age-, and height-specific 90th percentile thresholds based on NHANES 1999 to 2000 data) was infrequent, occurring among 4 participants at the grade 7 assessment (3 girls, 1 boy) and in 1 participant at the grade 11 assessment (1 girl).

Table 2 describes selected characteristics of participants who completed 3 blood pressure assessments, stratified by presence or absence of high SBP. The proportion of girls was $\approx 50\%$ among both those with and those without high SBP at grade 7 and grade 9 assessments. However, in grade 11, 33% of those with high SBP were girls, compared with 53% of those without high SBP. Compared with those without high SBP, a greater proportion of those with high SBP across the 3 assessments were overweight and reported speaking French only or both English and French at home. A greater proportion with high SBP reported alcohol consumption once or more per month in grade 7, but a lower proportion reported such consumption at grade 9 and grade 11 assessments. Those with high SBP reported a lower frequency of physical activity and had a somewhat lower household income across assessments. There were no substantive differences with the inclusion of data for those who did not present for all 3 blood pressure assessments. Although Table 2 provides values only for those who presented for 3 blood pressure assessments, all data, including those from individuals who did not present for all 3 assessments, were included in the multivariate analyses (generalized estimating equation logistic regression models) described below.

The sex-specific multivariate analyses (Figure 2) suggested that overweight and resting pulse were positively associated with the presence of high SBP among girls, whereas increased frequency of physical activity was protective. Among

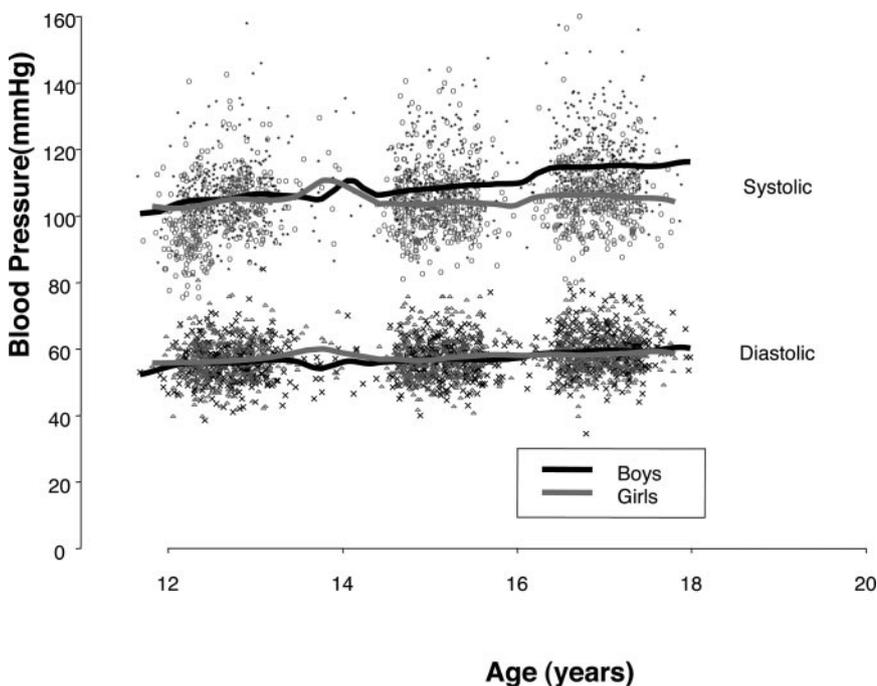
**Figure 1.** Sex-specific curves fitted to scatterplots of SBP and diastolic blood pressure values with kernel smoothing.

TABLE 2. Characteristics of Study Participants Who Completed All 3 Blood Pressure Assessments, Stratified by Presence or Absence of High SBP

| | Assessment 1 | | Assessment 2 | | Assessment 3 | |
|---|-----------------------|--------------------|-----------------------|--------------------|-----------------------|--------------------|
| | Normal SBP (n=662) | High SBP (n=41) | Normal SBP (n=666) | High SBP (n=37) | Normal SBP (n=664) | High SBP (n=39) |
| Boys, n (%) | 319 (48) | 22 (54) | 322 (48) | 19 (51) | 315 (47) | 26 (67) |
| Age, y, mean±SD | 12.7±0.4 | 12.8±0.5 | 15.1±0.4 | 15.2±0.4 | 17.0±0.4 | 17.1±0.4 |
| Resting heart rate, bpm, mean±SD | 85.0±11.8 | 94.2±13.0 | 78.9±11.4 | 80.5±12.6 | 77.4±11.8 | 85.7±16.2 |
| Overweight, n (%) | 152 (23) | 20 (49) | 137 (21) | 12 (32) | 105 (16) | 18 (46) |
| BMI, kg/m ² , mean±SD | 19.5±3.4 | 23.1±6.4 | 21.4±3.6 | 22.7±3.5 | 22.2±3.6 | 27.1±7.7 |
| Physical activity, median n/wk (IQR) | 9 (5, 16) | 6 (4, 10) | 9 (5, 17) | 7 (5, 17) | 6 (2, 10) | 5 (2, 8) |
| Sedentary behavior, median h/wk (IQR) | 8 (5, 12) | 8 (5, 15) | 8 (5, 12) | 8 (6, 15) | 7 (4, 11) | 8 (5, 12) |
| Drank alcohol once or more per month, n (%) | 61 (9) | 7 (17) | 243 (36) | 12 (32) | 429 (65) | 15 (38) |
| Ever used tobacco, n (%) | 75 (11) | 4 (10) | 127 (19) | 2 (5) | 155 (23) | 8 (21) |
| Language, n (%) | | | | | | |
| English | 363 (55) | 15 (37) | 368 (55) | 10 (27) | 363 (55) | 15 (38) |
| French | 172 (26) | 21 (51) | 175 (26) | 18 (49) | 176 (27) | 17 (44) |
| Both English and French | 71 (11) | 5 (12) | 69 (10) | 7 (19) | 70 (11) | 6 (15) |
| Other | 56 (8) | 0 | 54 (8) | 2 (5) | 55 (8) | 1 (3) |
| Household income, Canadian dollars, mean±SD | 70 000±23 000 | 62 000±21 000 | 70 000±23 000 | 60 000±21 000 | 70 000±23 000 | 63 000±20 000 |

IQR indicates interquartile range.

boys, in addition to overweight and resting pulse, age and sedentary behavior were positively associated with the presence of high SBP. An inverse association between physical activity and high SBP was not statistically significant in the boys-only model. Among both girls and boys, participants whose first language was French were more likely to have high SBP than those whose first language was English. The sex-specific models presented in Figure 2 are based on 67 high-SBP outcomes in boys and 50 high-SBP outcomes in girls. Given that it is generally recommended that for every additional variable tested in a multivariate model, there should be ≈10 outcomes of interest, we repeated the sex-specific analyses including only age, heart rate, overweight, physical activity, sedentary behavior, and language (dichotomous classification: English-only language at home, yes/no). The ORs obtained and corresponding CIs were similar to those calculated through the 11-variable sex-specific models.

In models that combined data across sexes, there were significant interactions between sex and age and between sex and tobacco use with respect to impact on the presence of high SBP (Figure 2). Other interaction terms with sex were not statistically significant (Figure 2). The significant interaction between sex and age was consistent with the results of the sex-specific models (positive association of age with likelihood of high SBP in boys but not in girls); however, the significant interaction between sex and tobacco use was not consistent with sex-specific models, which identified no significant association of tobacco use with high SBP among either girls or boys. To better understand any possible association between tobacco use and SBP values among either girls or boys, curves were fitted to scatterplots of SBP values (kernel smoothing) separately for girls and boys with and without any history of tobacco use (Figure 3). Among girls, in early and late adolescence, SBP values appeared

similar for those with and those without a history of tobacco use. In mid adolescence, however, SBP levels appeared to be somewhat lower among girls with a history of tobacco use. Among boys, history of tobacco use appeared to be associated with higher SBP values throughout adolescence.

The final model that combined data across sexes included heart rate, overweight, physical activity, sedentary behavior, language spoken at home, household income, sex, age, and a sex-by-age interaction term. As computed from this model, the likelihood of high SBP values among boys compared with girls was 1.29 (95% CI, 0.77 to 2.16) in grade 7, 1.98 (95% CI, 1.35 to 2.93) in grade 9, and 2.74 (95% CI, 1.52 to 4.94) in grade 11. Overweight (odds ratio [OR], 2.63; 95% CI, 1.76 to 3.92) and sedentary behavior (OR, 1.17; 95% CI, 1.04 to 1.33) demonstrated positive associations with high SBP values. Physical activity was inversely associated with the presence of high SBP (OR, 0.92; 95% CI, 0.84 to 1.00). Tobacco use (OR, 0.82; 95% CI, 0.53 to 1.26), alcohol consumption (OR, 0.91; 95% CI, 0.59 to 1.42), and household income (increment of \$10 000 Canadian; OR, 1.02; 95% CI, 0.9 to 1.16) were not significantly associated with high SBP. Language spoken at home demonstrated a significant association with high SBP (English, reference; French, OR, 3.44 [95% CI, 1.74 to 6.81]; both French and English, OR, 2.12 [95% CI, 1.10 to 4.06]; other, OR, 0.83 [95% CI, 0.28 to 2.42]).

Discussion

Over a 5-year follow-up period, absolute SBP values changed little among girls but rose progressively among boys, with a moderate degree of intraindividual tracking in both girls and boys. The major finding of the present study was the identification of a sex difference in the evolution of risk for high SBP during adolescence. This risk remained unchanged among girls but increased 19% annually among boys. Such a

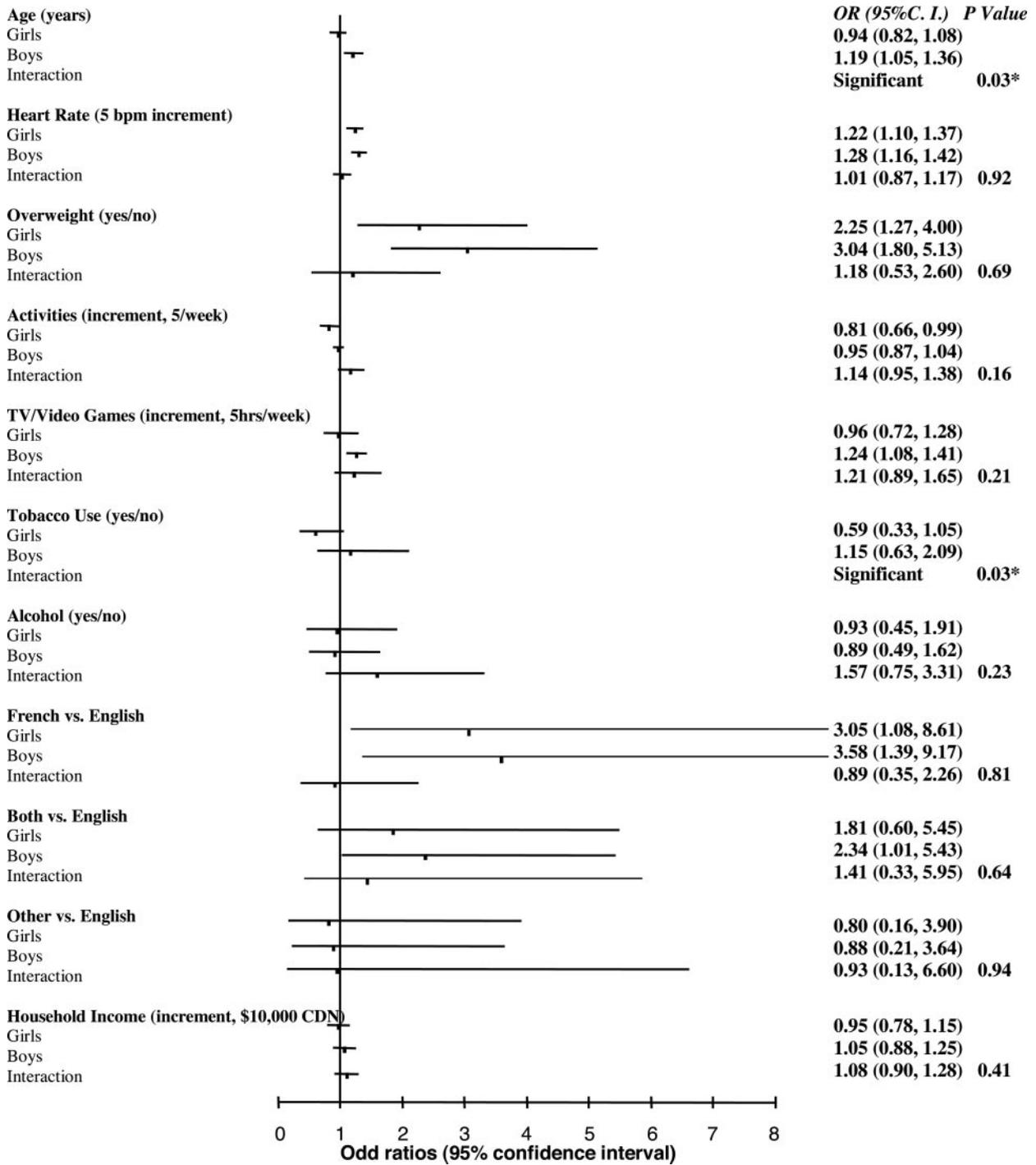


Figure 2. Determinants of high SBP: generalized estimating equations logistic regression models. For each variable of interest, the likelihood of having an SBP value at or above the age-, sex-, and height-specific 90th percentile value is provided as computed through a model that included only girls (girls) and a model that included only boys (boys). In addition, under the heading “interaction,” the statistical significance (*P* value) is provided for the interaction between sex and the variable of interest, as calculated through a model that included both girls and boys and all other variables listed in the figure. The OR and CI associated with the interaction term in each of these models are provided when no significant interaction was detected. No OR is provided when the interaction is significant, because accurate interpretation would require, for continuous variables, presentation of ORs for a range of variable values. Please refer to Results section for likelihood of high SBP among boys compared with girls at 12.8, 15.2, and 17.0 years, as computed through the model that included both boys and girls, all variables listed in Figure 2, and a sex-age interaction term. Overweight was defined as being at or above 85th percentile of standardized percentile curves; physical activity, increment of 5 activities on 7-day recall; sedentary behavior, increment of 5 hours per week; Language, language spoken at home (English, French, both English and French, other); Tobacco use, never (reference) or ever; Alcohol consumption, less than once per month (reference) or once or more per month; and Household income, increment of \$10 000 Canadian.

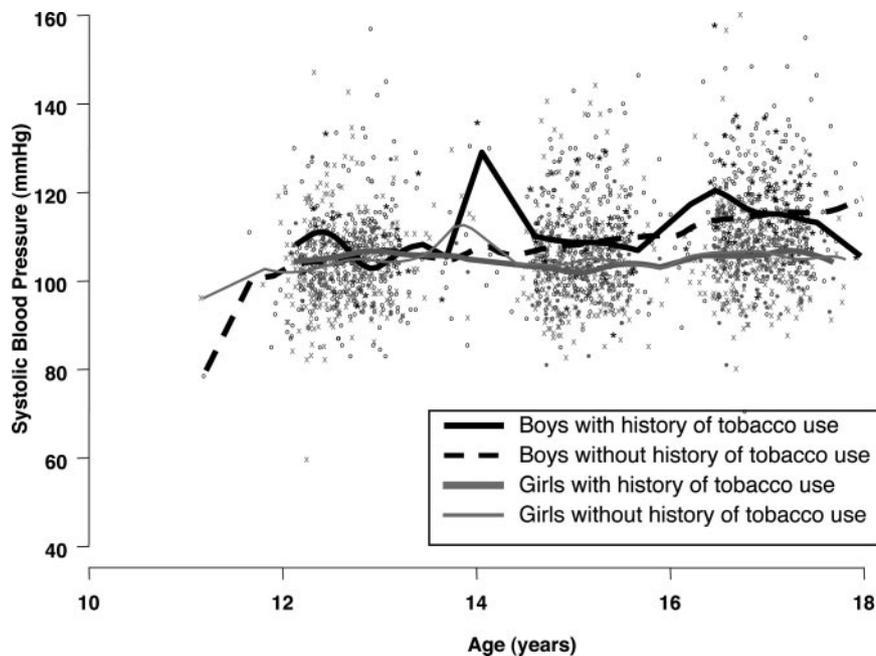


Figure 3. Sex- and tobacco use-specific curves fitted to scatterplots of SBP values with kernel smoothing.

sex difference has not been described previously in a longitudinal adolescent cohort study.

The emergence of a sex difference in the risk of high SBP during adolescence that we have detected, the higher prevalence of hypertension reported among men compared with women in young and middle-aged adults,^{1,28} and the higher prevalence of hypertension among women compared with men in older adults²⁸ suggest that sex steroids may have an important impact on blood pressure levels. In support of this possibility, in a genetic association study by the Victorian Family Heart Study investigators, men inheriting the “a” allele of the estrogen receptor- α single-nucleotide polymorphism had significantly higher SBP levels than men with other genotypes.²⁹ No significant associations between estrogen receptor genes and blood pressure were detected among women.²⁹ Recent long-term follow-up results from the Medical Research Council National Survey of Health and Development cohort³⁰ suggest that in men, later onset of puberty may be associated with lower SBP at 53 years of age. An association between age of onset of puberty and later SBP levels was not demonstrated in women. Unfortunately, NDIT did not include measures of puberty. However, we believe that the genetic association study by the Victorian Family Heart Study investigators and the follow-up results of the Medical Research Council cohort study complement our detection of the emergence of a sex difference in likelihood of high SBP during adolescence: All support the possibility that sex differences in risk of high SBP may be somehow linked to the impact of sex steroids on blood pressure.

The prevalence of high SBP detected among both boys and girls (high SBP defined as SBP above sex-, age-, and height-specific 90th percentile thresholds based on NHANES 1999 to 2000 data) was lower across assessments than the 10% prevalence that would be expected given the 90th percentile threshold used. This is at least partly attributable to a lower prevalence of overweight among NDIT participants compared with the reference standard for pediatric blood pressure values (NHANES

1999 to 2000 cohort). Percentile thresholds for definitions of overweight are based on cohort data from National Health Examination Survey data and NHANES data collected before 1988.³¹ Among NHANES 1999 to 2000 cohort participants, prevalence of BMI above the 85th percentile in adolescents was $\approx 30\%$ among both girls and boys. In the NDIT cohort, among 12- to 13-year-olds, prevalence of BMI above the 85th percentile was 29% among boys but 23% among girls.

The present analyses identified overweight as an important determinant of high SBP among both girls and boys, as indicated in several previous studies.^{32–34} We additionally identified low frequency of participation in physically active behaviors and greater number of hours involved in sedentary behaviors as independent determinants of high SBP. A 5-activity increment in number of physically active behaviors during a 7-day period (physical activity) was significantly associated with a 20% reduced likelihood of high SBP in the girls-only model. The inverse association between physical activity and high SBP was in the same direction and approached statistical significance in the boys-only model (5% reduced likelihood) and the model that included both boys and girls (8% reduced likelihood). A 5-hour increment per week in hours of sedentary behavior (television/video games/Internet) was associated with a 24% increased likelihood of high SBP in the boys-only model and a 17% increased likelihood in the model that included both boys and girls. In constructing a model that included data from both girls and boys, interaction terms tested between sex and physical activity and between sex and sedentary behavior were not statistically significant. Lower amounts of television viewing were correlated with lower mean arterial pressure in previous studies among children and youth (Quebec Family Study, 342 boys and 268 girls 9 to 18 years of age from the Quebec City area)³⁵ and older adults,³⁶ but no significant association was identified in the CARDIA (Coronary Artery Risk Development In young Adults) study among young adults.³⁷

Although the sex-specific models did not indicate any significant association between tobacco use and likelihood of high

SBP, the interaction term between sex and tobacco use was significant when tested in a multivariate model that included all the variables indicated in Figure 2 and all available data from boys and girls. Given the absence of significant associations between tobacco use and high SBP in sex-specific models, we suspect that the significance of the sex-tobacco use interaction term may be attributable either to chance or to a 3-way interaction among sex, tobacco use, and overweight. For example, girls may smoke to lose weight, and lower body weight is associated with lower blood pressure levels. In the present study, however, the sample size was not sufficiently large for the examination of 3-way interaction terms.

As noted above, NDI cohort assessments did not specifically incorporate questions concerning breast/genitalia development, age of menarche, or physical examination other than blood pressure, heart rate, and anthropometrics. Therefore, Tanner stage could not be estimated. Given recently reported results from the Medical Research Council National Survey of Health and Development cohort,³⁰ it is possible that early onset of puberty may be a determinant of high SBP among boys but not among girls. This indicates a need for future studies designed to determine whether the sex-specific impact of age on likelihood of high SBP that we have identified is actually attributable to sex differences in the effect of time of puberty onset.

We did not have data on family history of hypertension or ethnic background, both of which have been demonstrated to be important determinants of increased blood pressure in previous studies. We did, however, have information on linguistic background. Univariate analyses indicated that among those with high SBP, a greater proportion were French-speaking than among those without high SBP. All multivariate models indicated that among both girls and boys, French-speaking Canadians were more than twice as likely as English-speaking Canadians to have a high SBP. Interestingly, in the cross-sectional Quebec Child and Adolescent Health and Social Survey, the prevalence of high SBP was 2- to 3-fold greater⁷ than in the present study, and the proportion of French-speaking students was also higher, at >80% compared with <35% in the present study. In contrast, the prevalence of hypertension and obesity in adult populations is lower in Quebec than in other parts of Canada, which largely include English-speaking populations.^{38,39} These findings indicate a need for future studies to examine differences in high SBP, as well as the origins of these differences, between French- and English-speaking adolescents and adults in Canada.

Male youth are progressively less likely to visit a healthcare professional during adolescence and young adulthood, in contrast to female youth, who seek medical attention more frequently as they become older.⁴⁰ Given the progressive increase in likelihood of high SBP among adolescent boys that we have identified, targeted efforts may be necessary to encourage male youths and young adults to undergo blood pressure assessment for the detection of increased blood pressure levels. The results of the present study support the importance of weight control and an active lifestyle for the maintenance of optimal blood pressure levels during adolescence. Previous pediatric studies have identified a positive association between television viewing and overweight,^{41,42} and 1 randomized controlled trial demonstrated that an educational intervention that discouraged televi-

sion, videotape, and video game use achieved a significant reduction in BMI.⁴³ Given our identification of sedentary behavior as a determinant of high SBP, interventions that reduce television viewing, Internet use, and video game time may also have a favorable impact on blood pressure levels, even in the absence of weight change.

In conclusion, the results of the present study demonstrate that not only are boys more likely than girls to have high SBP in youth but that this risk difference increases in magnitude during the adolescent period, likely accounting for higher prevalence of hypertension among men compared with women in young and middle-aged adults. Greater understanding of sex differences in cardiovascular risk factors may ultimately lead to improved strategies for the prevention of cardiovascular disease in both women and men.

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Disclosures

None.

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CLINICAL PERSPECTIVE

Our analysis of a longitudinal cohort in a North American urban center demonstrates that as boys move from early to late adolescence, they become progressively more likely to develop high systolic blood pressure levels, which places them at increased risk for adult hypertension. In contrast, the risk for high systolic blood pressure levels among girls remains low throughout adolescence. Previous studies indicate that older adolescent boys and young men are less likely than girls and young women to seek medical attention. The former group must be encouraged to undergo periodic blood pressure screening for the early detection of adult hypertension. Some experts have questioned the utility of blood pressure surveillance during adolescence, because there is no long-term study demonstrating that blood pressure control during adolescence is associated with a reduction in cardiovascular events later in life. Although there may be understandable reluctance to initiate antihypertensive medication in youth, the promotion of healthy lifestyle choices, including prudent dietary intake, exercise and sports, and limited sedentary periods, is perhaps an underused alternative approach. Our analysis also underscores the importance of weight control and physical activity in preventing and treating high systolic blood pressure during adolescence. With respect to physical activity, we have demonstrated that not only is frequent participation in sports and exercise beneficial in this regard, but also that lengthy sedentary periods, including television viewing, computer games, and Internet use, may be detrimental.