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Intensity and Frequency of Physical Activity and High Blood Pressure in Adolescents: A Longitudinal Study

Authors: Robert J. WELLMAN[a], Marie-Pierre SYLVESTRE[b], Patrick ABI NADER[b,c], Arnaud CHIOLERO[d], Miceline MESIDOR[bf], Erika N. DUGAS[b], Gauthier TOUGRI[e], Jennifer O'LOUGHLIN[b,f]

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Affiliations: [a]Department of Population and Quantitative Health Sciences, Division of Preventive and Behavioral Medicine, University of Massachusetts Medical School, Worcester, Massachusetts; [b]Centre de recherche du Centre Hospitalier de l'Université de Montréal, Montréal, Québec, Canada; [c]Centre de formation médicale du Nouveau-Brunswick, Université de Moncton, Moncton, New Brunswick, Canada; [d]Institute of Social and Preventive Medicine, Lausanne University Hospital, Lausanne, Switzerland; [e]Centre de recherche en santé de Nouna, Nouna, Burkina Faso; [f]Department of Social and Preventive Medicine, School of Public Health, University of Montréal, Montréal, Québec, Canada

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Address correspondence to: Jennifer O'Loughlin, CRCHUM, 850 rue Saint-Denis, Bureau S03-468, Montréal, Quebec, Canada, H2X 0A9. [jennifer.oloughlin@umontreal.ca] 514-890-8000 x 15858

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ABSTRACT

Objective:

While experts recommend that adolescents engage regularly in moderate-to-vigorous activity, there is little evidence about its effect on blood pressure (BP) at that age. We explored relationships between the intensity and frequency of physical activity and the likelihood of having high blood pressure in a community-based cohort of adolescents.

Methods:

1293 adolescents from Montréal, Canada, provided data on physical activity every three months between 7th and 11th grades and had BP measured at ages 12.8, 15.2 and 17.0 years on average. We analyzed data from a 993 participants (mean (SD) age = 16.0 (1.0); 51.6% female) with BP at ages 15.2 or 17.0, using pooled ordinal logistic regressions with BP (normal/elevated/hypertensive range) as outcome and past-year physical activity intensity and frequency as predictors.

Results:

8.0% of participants had elevated BP (120-129/<80) in 8% and 3.2% BP in the hypertensive range (≥130/≥80) in 3.2%. … After adjusting for age, sex, mother's education, drinking and smoking habits, the odds of BP in the hypertensive range were lower by 3-7% for each additional session (≥5 minutes duration) per week of physical activity at medium or high intensity (ORs (95% CIs) = 0.93 (0.88, 0.97) to 0.97 (0.94, 0.99)). The relationships were not altered by adjusting for BMI.

Conclusions:

Our findings support recommendations that adolescents engage in at least moderate physical activity on a regular basis to prevent the development of high BP.

Keywords: blood pressure; hypertension; physical activity; adolescents

CONDENSED ABSTRACT

After adjusting for age, sex, mother's education, past-year drinking frequency and past-year monthly cigarette consumption, the odds of BP in the hypertensive range (≥130/≥80) were reduced by 3-7% for each additional session (≥5 minutes duration) per week of moderate, moderate-to-vigorous or vigorous physical activity in a population-based sample of adolescents followed every three months over the five years of high school. The relationships were not altered by adjusting for BMI. Our findings support recommendations that adolescents engage in at least moderate physical activity on a regular basis to prevent the development of hypertension.

INTRODUCTION

High blood pressure (BP) during childhood and adolescence tends to track over the life course [1 Chen and Wang, 2008], increasing the risk of developing hypertension [2,3] and cardiovascular diseases [4] in adulthood. [5]. Using data from the 2011-12 National Health and Nutrition Examination Survey, Kit et al. [6] found that 1.3% of 13-17-year-olds in the U.S. had systolic (SBP) or diastolic (DBP) >95th percentile (classified as hypertension), and 13.7% had SBP or DBP between the 90th and 95th percentile or ≥120/<80 mmHg but <95th percentile (classified as elevated BP [7]).

Prospective studies consistently demonstrate that physical activity (PA) protects adults against developing high BP [8]. Based on this evidence in adults, experts in the U.S. and Canada recommend that children and adolescents reduce their cardiovascular risk by limiting sedentary activities and engaging in moderate-to-vigorous physical activity (MVPA). Youth aged 12-17 are advised to engage in ≥60 minutes of MVPA daily; perform vigorous activities on ≥3 days per week; and perform some PA on ≥3 days each week to strengthen bones and muscles [9,10]. Yet adherence to the guidelines among Canadian children (ages 5-11) and youth (ages 12-17) is poor, with fewer youth than children and fewer girls than boys at each age meeting the guidelines [11]. Indeed, variations in PA over adolescence appear to be quite common [12,13], and engagement in PA generally declines with age [12].

One large cross-sectional study demonstrated an inverse relationship between daily engagement in PA and the odds of being hypertensive in youth aged 8-17 [14], and although several longitudinal studies in youth have investigated the relationship between PA and the full range of BP, findings are mixed [15-19]. To our knowledge, no previous longitudinal study has directly examined the relationship between PA and the likelihood of having high BP in adolescents. The current study extends previous cross-sectional and longitudinal findings on PA and BP by exploring relationships between the intensity and frequency of PA and the likelihood of having high BP, in a community-based cohort of adolescents.

METHODS

We drew data from the longitudinal Nicotine Dependence in Teens (NDIT) Study of 1293 adolescents from a convenience sample of ten public secondary schools in or near Montréal, Canada who were followed every three months between 7th (1999-2000) and 11th (2004-05) grades (total 20 cycles) [20]. The NDIT sample is 82% Caucasian. Baseline characteristics of the NDIT sample were similar to those of a 1999 provincially representative sample of 12-year-olds in Québec [21], except that NDIT participants were more likely to have university-educated mothers, less likely to speak French at home, and less likely to have ever smoked; SBP, DBP, BMI and number of PA sessions per week were comparable between the two groups [20]. Self-report questionnaires were administered in-class in each cycle; height, weight and BP were measured in cycle 1 (7th grade), cycle 12 (9th grade) and cycle 19 (11th grade), when the mean (*SD*) age was 12.8 (0.5), 15.2 (0.4) and 17.0 (0.4) years, respectively. Parents/guardians provided informed consent and participants provided assent at baseline. The study was approved by the Montréal Department of Public Health Ethics Review Committee, the McGill University Faculty of Medicine IRB, and the Ethics Research Committee of the Centre de Recherche du Centre Hospitalier de l'Université de Montréal.

The current analyses used a pooled sample of participants with data on BP from either cycle 12 or 19 (or both), and data on PA drawn from cycles 9-12 and 16-19, representing the year preceding BP measurement in cycle 12 or 19.

Study Variables

Blood pressure

SBP and DBP were assessed by trained technicians using standardized methods [22]. Participants voided and rested for 5 minutes before BP was assessed while sitting, with an oscillometric device (Dinamap XL, model CR9340, Critikon Co, Tampa, FL) on the right arm, which rested at heart height on a table. Arm circumference determined cuff size (Brassard Baumanomètre): 16.0-22.5 cm, size 9 (adolescent), 22.6-30.0 cm, size 12 (adult), 30.1-37.5 cm, size 15 (large adult), 37.6-43.7 cm, size 17.5 (thigh). Oscillometric devices were calibrated against a mercury sphygmomanometer before each data collection. Up to five consecutive measures were obtained at 1-minute intervals, with the first reading discarded to account for BP reactivity [23]. The mean of the two last readings was calculated.

Because of intra-individual variability in BP [24,25], clinical guidelines require repeated BP assessments over multiple visits to diagnose hypertension [7]. Because we measured BP on a single occasion only, we classified BP as normal, elevated or "hypertensive range" using standardized categories: normal BP = <120/<80; elevated BP = 120/<80 to 129/<80; hypertensive range = ≥130/≥80 [7]. For analyses, BP was treated as an ordinal variable.

Physical Activity

PA in the week preceding each data collection cycle was assessed with "Think about the physical activity you did during the last week, outside of your regular physical education classes at school. For each activity that you performed *for 5 minutes or more at one time*, mark an "X" to show the day(s) on which you did that activity." Twenty-nine activities were listed including sports (e.g., basketball, ice hockey, volleyball, gymnastics), general fitness and recreational activities (e.g., bicycling, dance, general exercise, skiing, rollerblading, jumping rope, dodge ball, kick ball, catch), martial arts, and outdoor or indoor chores (e.g., raking leaves, mowing, mopping, vacuuming, sweeping). Each activity was classified according to intensity as light, moderate or vigorous based on its MET equivalent, a measure of energy expenditure during an activity relative to the body at rest [26], using the age-graded Youth Compendium [27]. Activities generating 1.5-3.9 METs were classified as light (LPA), those generating 4.0-5.9 METs as moderate (MPA), those generating ≥4 METs as moderate-to-vigorous (MVPA) and those generating ≥6.0 METs as vigorous (VPA) [28].

Four past-year intensity variables were created representing the mean number of sessions/week of at least five minutes duration at each intensity level in the year prior to BP measurement (i.e., cycles 9-12 for BP measured in cycle 12 and cycles 16-19 for BP measured in cycle 19). Past-year frequency of PA was calculated as the mean number of days/week (0-7) during the preceding year on which participants engaged in at least one PA activity (excluding walking) for ≥5 minutes duration.

Covariates were chosen based on their empirical relationship with physical activity and/or BP in adolescents and availability in the NDIT dataset. Demographic variables included sex, age and mother's education (no university vs. some university) as a measure of socioeconomic status [29]. Lifestyle variables included cigarette consumption and alcohol consumption [30]. Since excess body weight is likely causally related to high BP in adolescents [24,31], we included body mass index (BMI percentile) in some models. Finally, we included SBP at baseline in a sensitivity analysis.

Cigarette consumption

In each cycle, participants provided data on cigarette consumption for each of the three preceding months including number of days (0-31) on which the participant had smoked each month, and usual number of cigarettes smoked per day on the days on which the participant had smoked [32]. These two measures were multiplied and averaged over each month interval to represent the average monthly cigarette consumption in each cycle. Test-retest reliability (intraclass correlation coefficient) of the average monthly cigarette consumption measure based on 3-month recall was 0.64 [33]. Past-year (i.e., mean for cycles 9-12 and mean for cycles 16-19) cigarette consumption variables were created for each participant.

Alcohol consumption

Drinking frequency was assessed in each cycle by "During the past three months, how often did you drink alcohol (beer, wine, hard liquor)?", with response options (*never* (1), *a bit to try*, *once or a couple of times a month*, *once or a couple of times a week*, *usually every day* (5)). Past-year (i.e., mean for cycles 9-12 and mean for cycles 16-19) alcohol consumption variables were created for each participant.

Body mass index

Height (to the nearest 0.1 cm) and weight (to the nearest 0.2 kg) were measured twice by trained technicians using a stadiometer (model 214 Road Rod; Seca Corp., Hanover, Maryland, USA) and scale (floor model 761; Seca Corp.), with participants in light clothing without shoes. A third measurement was taken if the difference between the first two exceeded 0.5 cm (height) or 0.2 kg (weight). Measurements were repeated systematically on every 10^{th} participant; interrater reliability for both height and weight was 0.99. BMI was computed, using the mean of the two measurements with the least difference, as weight/height^2 (kg/m^2) and was converted to a *z*-score based on national sex- and age-specific growth curves [34].

Statistical analyses

Data analyses were undertaken in 2019 using Stata (version 14.2, revision 19, 2018; Stata Corp., College Station, Texas) and IBM SPSS Statistics for Windows (version 24, 2016; IBM Corp. Armonk, NY).

To examine the relationship between BP and average PA in the past year, the analytic sample was restricted to participants with BP measurements in either cycle 12 or 19, or both. We compared baseline characteristics of participants retained for analyses to those not retained with *t*-tests, chi-square, Mann-Whitney U-tests or *z*-tests of proportions, as appropriate.

We pooled PA and BP measures over cycles 12 and 19 and examined bivariate relationships between intensity and frequency of past-year PA and BP. To further investigate the relationship between past-year PA and BP, we conducted a series of ordinal logistic regressions using pooled data. Ordinal logistic regressions sequentially estimate the cumulative probabilities that a response on the outcome falls in or below each consecutive category. Because our outcome (BP) has three categories (i.e., normal, elevated, or hypertensive ("hyper") range), the model simultaneously describes two relationships: the association between the exposure (PA) and the odds that BP > normal (i.e., is either elevated or hyper vs. normal) and BP > elevated (i.e., is hyper vs. either normal or elevated). A key assumption of ordinal regression is that the effect of the exposure is the same for each cumulative probability (a proportional odds model) [35]. In practice, the proportional odds (ppo) assumption is often violated because an exposure might exert greater or lesser effects at different levels of the outcome. When the ppo assumption is violated the estimates of the associations are distorted. Consequently, partial ppo models have been developed that allow for strategic relaxation of the ppo assumption [36].

We employed used the gologit2 module for Stata [37] with ppo or partial ppo assumptions as appropriate. The initial model was unadjusted (i.e., contained only the PA exposure of interest), model adjusted-1 added sex, age, mother's education, average past-year drinking frequency and average past-year monthly cigarette consumption as covariates, model adjusted-2 added BMI percentile and model adjusted-3 added baseline SBP. Each of the five PA exposures (i.e., LPA, MPA, MVPA, VPA, and frequency of PA) was tested in a separate ordinal regression analysis. The models were then tested with a sex-by-PA interaction term and an age (median split) by PA interaction term to explore potential sex and age differences in the association between PA and BP. All analyses included clustered standard errors to account for the intra-individual correlation of repeated measures [38].

RESULTS

Table 1 compares baseline characteristics of participants retained and not retained for the analyses. Compared to the 300 participants excluded from analyses because of missing data on BP in both cycles 12 and 19, the 993 participants (76.8% of 1293 cohort participants) retained were younger, less likely to be Francophone, more likely to have been born in Canada and more likely to have a university-educated mother. They engaged less often in MPA but engaged in any PA on more days/week, were less likely to drink monthly and smoked fewer cigarettes. Retained and non-retained participants did not differ by sex, baseline SBP or DBP, BMI percentile, or frequency of engagement in LPA, MVPA or VPA.

Elevated (8%, n=79) and hypertensive range (3.2%, n=32) BP were relatively rare; 84.8% of participants (n=842) had normal BP. As expected, baseline SBP was associated strongly and consistently with the odds of having elevated or hypertensive range BP at later measurement occasions. Each 1 mmHG increase in baseline SBP increased the odds of high BP by 11% (adjusted OR (95% CI) = 1.11 (1.09, 1.13), $p < 0.001$).

Table 2 presents relationships between PA indicators categorized using quartile cut-offs, and BP. With the possible exception that the proportion of participants in the hypertensive range tended to decline as PA quartile increased for light, moderate, moderate-to-vigorous PA, there did not appear to be any trends in the data suggestive of a strong linear relationship between PA and BP. Rather, the proportion of participants with normal BP was lowest in the lowest PA quartile for light, moderate and moderate-to-vigorous PA. For PA frequency, the proportion of participants with normal BP was lowest in the highest PA frequency quartile, and the proportion of participants in the hypertensive range was highest in the lowest PA frequency quartile. Although some patterns of association with PA were identifiable in the normal and hypertensive range categories of BP, this was less apparent in the elevated BP category – there were no strong consistent patterns in the association between PA quartile and elevated BP.

In unadjusted analyses, past-year engagement in PA at any intensity other than light was protective against having BP in the hypertensive rather than the normal or elevated range (Table 3). After adjusting for age, sex, mother's education, past-year drinking frequency and past-year monthly cigarette consumption, the odds of hypertensive range BP were reduced by 3-7% for each additional session (≥5 minutes duration) per week of PA. Frequency of PA (i.e., engaging in any PA except walking for more days/week) was not related to BP. The relationship for all intensities was robust after adjusting for BMI, and for MPA and MVPA after adjusting for baseline SBP. None of the age-by-PA or sex-by-PA interaction terms were statistically significant.

DISCUSSION

The novel finding in this study, that engagement in any level of PA more intense than light over the course of a year is associated with a lower odds of having BP in the hypertensive range, suggests that PA may protect against high BP in adolescents. This is important because youth could alter their odds of developing hypertension by making small changes to daily patterns of activity. British 15-year-olds spent approximately half their time in LPA, compared to only 4% of their time in MPA and <1% of their time in VPA [39 Collings], and the proportion of U.S. adolescents who engaged in ≥60 minutes/day of MVPA remained around 9% from age 16-18 [40 Li]. Considering our finding that one additional session of at least five minutes of MPA per week reduces the odds of having BP in the hypertensive range by 7%, it seems feasible to encourage adolescents to add one more session of MPA to their usual practice. Although this might not provide additional protection to individual adolescents, on a population basis it should achieve a 7% reduction.

In our study, PA apparently had a stronger association with BP at the higher levels of BP (i.e., PA was more protective in the transition from normal or elevated BP to the hypertensive range than in the transition from normal to elevated or the hypertensive range BP). This parallels findings from a large cross-sectional study of youth ages 8-17 that, although there was only a modest inverse correlation between PA (measured over seven days) and BP, increasing frequency of both total PA and MVPA was associated with a curvilinear decrease in the odds of being hypertensive (defined as BP≥ 90^{th} percentile for age, height and sex). Relative to no PA, increasing total PA by 30, 60, 90 or 120 minutes per week reduced the likelihood of hypertension by 20%, 39%, 46% and 60%, respectively, and increasing MVPA by 30 or 60 minutes per week reduced the odds of hypertension by 50% and 62%, respectively [14]. Also in accord with our findings, a narrative review of nine prospective trials of PA in normotensive and six in hypertensive adolescents found no relationship between PA and BP in the normotensive population, but evidence that endurance and resistance training reduced SBP significantly in the hypertensive population [41]. Moreover, we found a strong and consistent relationship between baseline BP and the odds of having BP in the hypertensive range, in contrast to Kelley et al. [18], whose meta-analysis of prospective studies of short-term trials of PA found no relationship between initial resting BP and changes in BP.

Mechanisms underlying the PA - BP association remain unclear [42], although reductions in vascular resistance produced by the sympathetic nervous system and the renin-angiotensin systems may play a role [43]. Studies in overweight or obese youth report that PA participation normalized endothelial-dependent dilatation, contributing to reductions in SBP [44,45]. The durability of the reduction in vascular resistance is unknown, ranging from under eight weeks in one study [46] to more than two years in another; the longer duration was observed in obese youth who sustained their PA participation [47].

In our study, regardless of BMI status, individuals who self-reported engaging in at least moderate PA were less likely to be have BP in the hypertensive range. Our results parallel those of Maggio et al. [47] in highlighting the importance of sustaining PA behavior, since abnormal vascular function was detected in at-risk individuals when PA was discontinued. Moreover, findings from the prospective Young Finns study and its follow-ups demonstrate that elevated BP observed at age 9 years or later in childhood predicts subclinical atherosclerosis in adulthood and that childhood BP levels had a more permanent influence on later cardiovascular risk factors than did childhood obesity [48].

Among study limitations, our measure of PA was imprecise regarding the duration of each session, precluding recommendations about how much PA in a single session might be effective. Self-report PA measures may contribute to misclassification bias. While BP was measured up to five times in each of cycles 1, 12 and 19, measurements were taken at one sitting only, precluding investigation of fluctuating BP over the short-term and making a definitive diagnosis of hypertension. Additionally, the device used has not been clinically validated for use with adolescents, which may have resulted in BP readings different from what would have been attained by auscultation [49]. We did not assess pubertal growth, which is related to increases in SBP [50], but the BP classifications we used were adjusted for age and sex, which should have mitigated any bias. Selection bias related to loss-to-follow-up and residual confounding could also have biased the findings. Finally, use of a purposive sample could limit generalizability of the findings, although the similarity of the NDIT sample to a provincially representative sample [21] suggests that such limitation may be minimal.

Conclusion

This study adds longitudinal evidence that past-year PA during adolescence is inversely associated with having BP in the hypertensive range. While additional investigations are needed, perhaps focused on youth with high BP [18], our findings support recommendations that adolescents engage in at least moderate physical activity on a regular basis to prevent the development of hypertension.

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Table 1. Baseline characteristics of participants retained and not retained, Nicotine Dependence in Teens study (Canada), 1999-2005 (*n*=1293)

		Retained (*n*=993)	Not retained (*n*=300)	p[a]
Age (years), *M* (SD)		12.7 (0.44)	13.0 (0.78)	< 0.001
Female, %		51.6	52.7	0.773
Francophone, %		28.4	35.7	0.016
Born in Canada, %		93.7	87.0	< 0.001
Mother university-educated, %[b]		45.8	31.9	0.011
Systolic blood pressure, *M* (SD) mmHg		105.0 (10.1)	106.1 (10.4)	0.111
Diastolic blood pressure, *M* (SD) mmHg		56.5 (6.3)	57.2 (6.10	0.086
BMI percentile[c], *M* (SD)		57.5 (29.8)	59.4 (28.8)	0.366
Intensity of physical activity[de], *Mdn* (IQR)	Light	6.0 (2.0, 9.0)	6.0 (1.0, 8.5)	0.630
	Moderate	3.0 (1.0, 7.0)	5.0 (1.0, 8.0)	0.001
	Moderate-vigorous	9.0 (4.0, 17.0)	10.0 (5.0, 19.0)	0.066
	Vigorous	5.0 (2.0, 11.0)	6.0 (2.0, 12.0)	0.730
Days of physical activity[f], *Mdn* (IQR)		5.0 (4.0, 6.0)	3.0 (1.0, 4.0)	< 0.001
Drank at least monthly, %		10.3	18.7	< 0.001
Mean number of cigarettes consumed in past month, *Mdn* (IQR)		0.0 (0.0, 0.0)	0.0 (0.0, 0.5)	< 0.001

[a] .

[b] Of participants with complete data on mother’s education; 10.7% of retained vs. 69.7% of non-retained were missing data.

[c] Based on age and sex [NCHS].

[d] Mean number of sessions of at least five minutes duration at each intensity level in the past week.

[e] Intensity measured in units of metabolic equivalent of task (MET): Light = 1.5-3.9 METs, Moderate = 4-5.9 METs, Moderate-to-vigorous = ≥4 METs, Vigorous = ≥6 METs [28].

[f] Number of days in the past week engaged in any physical activity except walking.

Table 2. Proportion of participants at each level of past-year physical activity (PA) per blood pressure category, Nicotine Dependence in Teens study (Canada), (n=993; n_{obs}=1753)[a].

Intensity of physical activity[cd]		n_{obs}	Blood pressure category[b] Normal (n_{obs}=1509)	Elevated (n_{obs}=165)	Hypertensive range (n_{obs}=79)
Light	0. 0-0.3	401	83.3	11.5	5.2
	0.5-1.8	445	87.9	7.0	5.2
	2.0-4.5	459	85.8	9.8	4.4
	4.7-14.0	448	87.1	9.6	3.4
Moderate	0.0-4.5	453	82.8	10.4	6.8
	4.7-7.0	454	86.8	9.3	4.0
	7.0-9.5	434	87.8	6.9	5.3
	9.7-38.5	412	87.1	11.2	1.7
Moderate-to-vigorous	0.0-7.5	432	84.3	9.5	6.3
	7.8-12.0	450	88.0	7.6	4.4
	12.3-18.8	433	85.7	10.6	3.7
	19.0-95.8	438	86.3	10.1	3.7
Vigorous	0.0-2.0	439	87.5	8.0	4.6
	2.3-5.3	425	88.0	6.6	5.4
	5.5-10.5	447	83.0	12.8	4.3
	10.8-62.0	442	86.0	10.2	3.9

Frequency[e]	0.0-3.5	395	87.6	6.8	5.6
	3.8-5.3	525	86.3	10.1	3.6
	5.5-6.0	322	86.7	8.7	4.7
	6.3-7.0	511	84.3	11.2	4.5

[a] Data were pooled over cycles 12 and 19.

[b] Blood pressure categories: Normal (<120/<80 mmHg); Elevated (120-129/<80 mmHg); Hypertensive range (≥130/≥80 mmHg) [7].

[c] Mean number of sessions/week of at least five minutes duration at each intensity level in the past year, in quartiles.

[d] PA intensity levels in Metabolic Equivalent of Task (MET) units: Light (1.5-3.9 METs); Moderate (4-5.9 METs); Moderate-to-vigorous (≥4 METs); Vigorous (≥6 METs) [28].

[e] Mean number of days/week in the past year on which the participant engaged in at least one session of PA at any level of intensity (except walking), in quartiles.

Note: Row proportions may not sum to 100% because of rounding.

Table 3. ORs and 95% CIs for blood pressure as a function of intensity and frequency of physical activity, Nicotine Dependence in Teens study (Canada), 1999-2005 (*n*=993)

Physical activity[b]			Model[a] Unadjusted (n_{obs}=1,753)	Adjusted-1 (n_{obs}=1,746)	Adjusted-2 (n_{obs}=1,744)	Adjusted-3 (n_{obs}=1,639)
Intensity[cd]	Light (LPA)		0.99 (0.94, 1.04)	1.01 (0.96, 1.06)	1.00 (0.95, 1.06)	1.03 (0.98, 1.09)
	Moderate (MPA)	BP > normal	0.97 (0.94, 1.01)	0.99 (0.96, 1.02)	0.99 (0.96, 1.02)	1.00 (096, 1.03)
		BP > elevated	0.91 (0.87, 0.96)***	0.93 (0.88, 0.97)**	0.93 (0.88, 0.98)**	0.94 (0.90, 0.99)*
	Moderate-vigorous (MVPA)	BP > normal	1.00 (0.99, 1.02)	1.00 (0.98, 1.01)	1.00 (0.98, 1.01)	1.00 (0.99, 1.02)
		BP > elevated	0.97 (0.95, 0.99)*	0.97 (0.94, 0.99)**	0.97 (0.94, 0.99)**	0.98 (0.96, 0.999)*
	Vigorous (VPA)	BP > normal	1.02 (1.00, 1.04)	1.00 (0.98, 1.02)	1.00 (0.98, 1.02)	1.01 (0.98, 1.03)
		BP > elevated	0.98 (0.95, 1.01)	0.96 (0.93, 0.99)*	0.96 (0.93, 0.99)*	0.98 (0.95, 1.01)
Frequency[e]			1.04 (0.94, 1.14)	0.95 (0.86, 1.05)	0.94 (0.85, 1.05)	0.98 (0.88, 1.09)

[a] Adjusted-1 includes age, sex, mother's education, past-year monthly cigarette consumption and past-year drinking frequency; Adjusted-2 adds BMI (percentile by age and sex) measured concurrently with BP; Adjusted-3 adds SBP at baseline. Data were pooled over cycles 12 and 19.

[b] The proportional odds assumption was met only for LPA and frequency of PA. Analyses of MPA, MVPA and VPA incorporated non-proportional odds. Because the outcome (BP) had three categories (i.e., normal, elevated, or hypertensive ("hyper") range), the

model simultaneously describes two relationships: the association between the exposure (PA) and the odds that BP > normal (i.e., is either elevated or hyper vs. normal) and that BP > elevated (i.e., is hyper vs. normal or elevated), and two estimates are generated for each PA intensity.

[c] PA intensity levels in Metabolic Equivalent of Task (MET) units: Light (1.5-3.9 METs); Moderate (4-5.9 METs); Moderate-to-vigorous (≥4 METs); Vigorous (≥6 METs) [28].

[d] Estimates for PA intensity represent the effect of one session/week of PA ≥5 minutes in duration over the past year.

[e] Estimates for PA frequency represent the effect of engaging in PA of any intensity (except walking) for ≥5 minutes on one additional day per week over the past year.

[*] $p < 0.05$; [**] $p \leq 0.01$; [***] $p \leq 0.001$