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The longitudinal association between temperament and physical activity in young children

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Short title: NA predicts PA in young children

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Abbreviations: NA=Negative Affectivity; PA=Physical activity; CVD=Cardiovascular disease; MDD=Major depressive disorder; CBQ=Children’s behaviour questionnaire; SES=Socioeconomic status; BMI=Body mass index; ADHD=Attention deficit hyperactivity disorder
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ABSTRACT

Objective: To examine the longitudinal association of negative affect and physical activity in a population of preschool children.

Study Design: Participants included 763 children (53% male) attending scheduled health supervision visits in their primary care physicians’ offices. Data were collected at two time points at mean ages 27 (SD = 5.4) and 47 (SD = 6.2) months. Negative affect (NA) was measured using the Negative Affectivity (frustration/anger, decreased soothability) domain of the Children’s Behaviour Questionnaire. Physical Activity (PA) was assessed using a parent-report questionnaire. Multiple regression analyses tested the association between NA and PA, adjusting for child age, sex, z-BMI, PA at Time 1, maternal education, household income, and season, and examined for sex differences in the relationship between NA and PA.

Results: The longitudinal association between NA at Time 1 and PA at Time 2 was moderated by sex (p<.001). After adjusting for covariates, females with greater NA at Time 1 had decreased PA at Time 2 (p=.01), whereas males with greater NA at Time 1 had increased PA at Time 2 (p=.01). Specifically, among females, every 1 unit increase in NA at Time 1 was associated with a 9.9 minute/day decrease in PA at Time 2 (95% CI: -17.1,-2.8).

Conclusions: NA and PA were associated early in childhood and the effects of NA on PA were gender specific. These findings underscore the importance of longitudinal and gender-specific analyses in mood-obesity research.
INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death for individuals with Major Depressive Disorder (MDD)\(^1\), with a standardized mortality ratio of 1.5-1.9\(^1,2\) and surpassing all other causes of death, including suicide. A primary route by which the increased risk of CVD among depressed individuals may be conferred is through obesity. Moreover, emerging evidence suggests that the pathways leading from MDD to CVD among adults may be gender-specific, such that the relationship may be mediated in part by obesity for women but not for men\(^2,3\).

Uncovering mechanisms of the association between MDD and obesity are critical for providing insight into effective targets of preventive intervention programs. It has been suggested, for example, that the association between MDD and obesity may be the result of overlapping illness consequences: depressive amotivation, fatigue and low energy lead to increased sedentary behaviour, overeating, decreased physical activity, and in turn, weight gain. Indeed, depression has been associated with low levels of physical activity\(^4\). However, researchers have also noted that depression in childhood and adolescence predicts increased overweight in adulthood, even after controlling for the persistence of depressive symptoms into adulthood\(^5\). Moreover, evidence suggests that many healthy lifestyle factors, such as engaging in regular physical activity, are established prior to the onset of MDD and may be circumscribed early in childhood\(^6,7\).

An alternate explanation for the MDD and obesity co-morbidity observed in adult samples is that common factors, present prior to the onset of either condition, may underlie the association and predispose a child to the development of both MDD and obesity. Data from the International Children’s Accelerometry Database (n=20,871)\(^8\) and the International Study of
Childhood Obesity, Lifestyle and the Environment (n=6,539) confirm that time spent in 
physical activity is more strongly associated with obesity than time spent in sedentary behavior, 
indicating that decreased physical activity is a key driver of obesity. A growing body of research 
now suggests that the processes leading to obesity, including low physical activity, begin in 
childhood. Also, compelling research confirms that childhood temperamental factors (i.e. a high 
degree of early negative emotionality) predicts future childhood and adult MDD and is 
significantly associated with parental depression, the most established risk factor for future 
MDD. Moreover, a recent systematic review and meta-analysis has found that increased 
physical activity among older children and adolescents is associated with decreased 
contemporaneous, and to a lesser extent future, depressive symptoms. Thus, we aimed to 
investigate whether child temperament and physical activity are associated in the preschool 
period. Understanding the temporal association of these risk factors in this very early 
developmental period is critical to the development of interventions that have the potential for 
sustained effects. For example, by determining early antecedents to low physical activity, 
targeted intervention strategies may prevent the development of a pattern of inactivity before it 
becomes entrenched. To our knowledge, this is the first study to examine the longitudinal 
relationship of temperament and physical activity in very young children.

The objective of this study was to prospectively investigate the longitudinal association 
between child temperament and physical activity in a primary-care based sample of preschool 
children. Further, we aimed to determine the temporal association of these factors. Consistent 
with the literature regarding MDD and physical activity in older adults, we hypothesized that 
greater negative affect (NA) would be associated with decreased physical activity (PA), and that 
this relationship would be stronger for girls than for boys.
METHOD

Sample

TARGet Kids! is a primary care-based research network in Toronto, Ontario, Canada comprised of 10 pediatric or family practice primary care clinics, with 3 to 9 physicians in each practice\textsuperscript{23}. The practice sites were selected to represent geographical and socioeconomically diverse areas in Toronto. A complete description of the TARGet Kids! cohort has been published\textsuperscript{23}. Trained research assistants embedded in the practices obtained data at the time of children’s scheduled health supervision visits. The cohort is comprised of children followed prospectively from birth to 5 years of age, with a retention rate of 71\% over the first five years of life\textsuperscript{23}. Temperament and physical activity data were collected at two time points, at least 12 months apart, corresponding to the 3-year and 5-year health supervision visit. Data used in this analysis were collected from 763 children with non-missing data on childhood temperament at Time 1 (T1) and physical activity at Time 2 (T2). Exclusion criteria included birth weight < 2500g, presence of a chronic illness that might affect feeding or growth (e.g. cystic fibrosis), or severe developmental delay. Data were collected between December 2008 and August 2015. Written informed consent was obtained. The study protocol was approved by the Institutional Research Ethics Boards.

Measures

Child Temperament

Parent-reported measures of child temperament were collected using the Early Childhood Behavior Questionnaire\textsuperscript{24} (ECBQ; T1) and Children’s Behavior Questionnaire – very short form\textsuperscript{25} (CBQ; T1 and 2), depending on the age of the child (ECBQ for children less than 3 years
at T1, CBQ for children 3 years of age and older at T1). The ECBQ and the CBQ are developmentally equivalent measures that have been shown to have satisfactory inter-rater reliability and longitudinal stability, both within and across measures\(^{26}\), and internal consistency (0.68 to 0.93)\(^{27}\). Parents are asked to rate their children on a 7-point scale ranging from 1 (never/extremely untrue) to 7 (always/extremely true). Higher scores indicate that the child exhibits more of the temperamental trait. Factor analyses of the ECBQ and CBQ scales yield a similar three-factor resolution indicating three broad domains of temperament: Effortful Control, Surgency/Extraversion, and Negative Affectivity\(^{24,26-28}\). Effortful control is characterized by increased attentional capacities, inhibitory control, and enjoyment of low-intensity activities. Surgency/Extraversion is characterized by impulsivity, positive anticipation, smiling and laughter, enjoyment of intense experiences, and a lack of shyness. Negative affectivity (NA) is characterized by proneness to sadness, anger, discomfort, fear and a reduced ability to soothe oneself\(^{27}\). These measures are the most widely used measures of temperament of young children and validated in samples of children from diverse cultural backgrounds\(^{29-32}\).

Physical Activity

Physical activity in children was measured by parent report. Parents were asked “Aside from time in daycare and preschool, on a typical weekday, how much time does your child spend outside in unstructured free play?” Parents were instructed to provide their response in minutes per day. This question has been used to assess regular physical activity of children in the Canadian Community Health Survey\(^{33}\), a national survey of population health, and has been shown to correlate with accelerometry in the current sample\(^{34}\).
Variables hypothesized to be associated with NA and PA were included as covariates, including household income, maternal education, child age and sex, child body mass index (BMI), and season at the time of physical activity measure. Covariates were determined a priori and are presented as is, without model selection based on the p-value, in order maintain the interpretation of the p-values in our hypothesis testing. Weight and height were measured at the time of primary clinic visit. BMI was calculated as weight in kilograms divided by height in meters squared to allow for computation of BMI z-scores, which indicate relative weight adjusted for child age and sex, according to reference standards.

Statistical analyses

Baseline (T1) assessments of the relationships between covariates, temperament domains and PA were performed using t-tests, ANOVA, or chi-squared tests, as appropriate. Pearson product-moment, point-biserial, and phi correlations were computed to assess the relationship between continuous-continuous, dichotomous-continuous, and dichotomous-dichotomous variables, respectively (see Table 3). After checking for collinearity, multiple linear regression analyses were conducted to examine the relationship between each temperament domain (e.g. NA) and PA. For each temperament domain examined, the T1 measure of PA was included as a covariate in order to control for degree of PA at the earlier time point. Covariates included child age, sex, z-BMI, maternal education, household income, and season (fall/winter or spring/summer). As previous research suggests that the association between depression and cardiovascular risk factors may be gender-specific, the a priori decision was made to further examine the interaction of temperament domain and child sex on PA. Determination of the interaction variable was conducted after computing centered variables for inclusion in the regression analysis. Centering, or subtracting the mean from a variable and leaving deviation scores, was performed under these circumstances to improve the
interpretability of the regression coefficients and reduce multicollinearity among predictor variables. Covariate data was missing for 78 (9%) participants. Comparison of T1 demographic factors, temperament domain score and PA level between participants with missing and with complete data revealed that participants with missing data were younger than those with complete data (p < .05). Participants with missing and complete data did not differ on other factors examined. Data was analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows Version 23.0.

RESULTS

Demographic factors, physical activity, and temperament characteristics of the 763 participants (404 boys, 358 girls) are presented in Table 1. Participants were a mean age 27 months (SD = 5.4) at Time 1, and 47 months (SD = 6.2) at Time 2. At T1, participants’ mean z-BMI was equal to 0.3 (SD=1). The amount of time that children spent participating in physical activity decreased over the study period from 64 minutes/day (T1) to 53 minutes/day (T2) \[ t(762)=4.96, \ p<.001 \]. Significant changes in child temperament were reported over the course of the study, with older children demonstrating greater scores on NA \[ t(762)=-18.4, \ p<.001 \] and Effortful Control \[ t(762)=-9.0, \ p<.001 \], and lower scores on Surgency/Extraversion \[ t(762)=10.1, \ p<.001 \] at T2 compared with reports at younger ages (T1).

Multiple linear regression was conducted to examine the association of temperament at T1 with Physical Activity (PA) at T2, controlling for age, sex, maternal education, household income, season, z-BMI, and PA at T1. As the interaction of NA and sex was significant (\( p<.001; R^2= 0.112 \)) in predicting PA (see Figure 1), further analyses were stratified by sex.
Among girls, NA was significantly associated with PA at T2 ($p=.011$) and explained 10.9% of the variance in PA (see Table 2). Similarly among boys, NA was significantly associated with PA at T2 ($p=.01$) and explained 15.3% of the variance in PA (Table 2). However, the direction of the association was different for girls and for boys. Among girls, for every unit increase in NA score, PA decreased by 9.9 minutes per day (95% CI = -17.1, -2.8), whereas among boys, for every unit increase in NA score, PA increased by 9.0 minutes per day (95% CI = 2.0, 14.3). Sensitivity analyses conducted for temperament measure subgroups (ie. CBQ at T1 and T2; n=482) yielded similar results (data available upon request). Examination of the relationship between variables found that covariates in the model were not highly correlated (Table 3). Factors of moderate strength that were significantly correlated were decreased physical activity and winter season ($r = -.27$, $p<.01$), level of PA at baseline and at follow-up ($r = .27$, $p<.01$), and degree of NA at T1 and T2 ($r = .45$, $p<.01$). Neither surgency/extraversion ($p = .43$) nor effortful control ($p = .76$) temperament domains predicted PA. Controlling for potential effects of concurrent temperament in the model, by including the T2 measure of the temperament domain (for example, NA at T2), had no appreciable change on these results (data not shown).

**DISCUSSION**

This study examined the longitudinal relationship of early childhood temperament and later physical activity among preschool aged children, and found significant associations between NA and physical activity which were moderated by child sex. Among girls, greater early NA predicted decreased future physical activity, whereas among boys, greater NA was associated with later increased physical activity. These findings remained after controlling for child age, BMI, family income, season, or previous physical activity level. Neither child surgency nor effortful control domains were associated with future PA.
Our findings with respect to girls are consistent with those reported on the relationship between depression and physical activity in adolescent and adult populations, though few studies have examined the relationship in children, and to our knowledge, no previous study has examined this association in preschoolers. A systematic review of adult studies found that depression was associated with decreased future physical activity levels, though sex effects were not examined. Similarly, in a follow-up study of adolescents who had been depressed in childhood, adolescents with child-onset (mean age 9 years) depression had lower PA levels compared with their never-depressed siblings and controls, even though the majority of the sample (85%) was not depressed at follow-up. However, as in the systematic review above, sex differences in the relationship between depression and low physical activity were not examined. Our findings are, however, consistent with emerging literature reporting sex differences in the association of youth-onset depression with future CVD, in which the potentially mediating role of obesity may be of greater importance for women than for men.

Biological maturation during puberty, social, racial/ethnic, and socioeconomic influences have all been reported to contribute to a general decrease in level of physical activity among girls relative to boys in the adolescent age group.

In the preschool age group, the mechanism by which increased NA might differentially influence physical activity among boys and girls is less clear. One possible explanation may be that girls demonstrate greater homotypic continuity of NA with depressive symptoms over time. That is, that NA is a developmental precursor of depression, with similar phenotypic expression over time. Decreased experience of enjoyment, difficulty overcoming fear associated with novel physical activities, persistence in the discomfort that may accompany outdoor play, or belief in one’s ability to compare favorably with one’s peers may be present earlier and with greater
stability for girls. In contrast, boys have been reported to demonstrate heterotypic continuity of psychopathological symptoms\textsuperscript{45}. That is, the earliest manifestations of adolescent or adult depressive risk among boys are more likely to be disruptive and hyperactive behaviours at younger ages\textsuperscript{45}. Thus, boys with greater temperamental NA may also demonstrate increased behavioural hyperactivity, with resultant increased physical activity at younger ages when compared with girls. Further support for this explanation comes from population-based studies of Attention Deficit Hyperactivity Disorder (ADHD), a disorder that affects twice as many boys as girls\textsuperscript{46}, which confirm that boys with ADHD in early childhood are at increased risk of depression at adolescent and older ages\textsuperscript{46} (an example of heterotypic continuity). Other plausible explanations for the discordant gender findings in our study include potential differential parenting responses to girls and boys who are distressed or difficult to soothe\textsuperscript{47}, different parenting approaches for boys and girls regarding physical activity\textsuperscript{48,49}, or more direct effects of a common underlying etiological basis for both depression and obesity-related cardiometabolic risk that are detectable early in the lifecourse. Several studies, for example, have implicated common pathophysiological pathways in the etiology of both conditions, including disturbances in the HPA axis and norepinephrine systems\textsuperscript{50}, potentially shared genetic vulnerabilities\textsuperscript{51}, and increased immuno-inflammatory activity\textsuperscript{52,53}.

This study found that while many of the variables considered in our model were weakly or not at all correlated, stronger associations in the weak to moderate range were found for PA at T1 and T2, and for PA with season of measurement. These findings are consistent with previous studies and with the experience of life in Canada, in which young children receive less outdoor physical activity during the colder and shorter winter days compared with the warmer seasons. The strongest association was observed between NA at both time points, indicating the relative
stability of temperament over time. That parents of children in our sample reported relatively greater effortful control, and decreased surgency/extraversion, at T2 as compared with T1 is also consistent with current developmental knowledge regarding children’s increased ability to regulate their reactions and responses in different contexts as they mature.

This study found that a one unit increase in NA is associated with a 10 minute decrease in PA among girls. In our sample of preschool-aged children, a one unit rise in NA corresponds to an increase of just over one standard deviation, or approximately 35%. As temperament measures do not yield clinical diagnoses, it cannot be determined whether such an increase would result in a clinical diagnosis of depression. However, research has reported that higher temperamental negative emotionality is associated with a concurrent and future diagnosis of depression among very young children and increased risk of future depression. Similarly, our results suggest that the magnitude of the decrease in physical activity for children with high NA is also of clinical relevance. In keeping with our finding of decreased PA at T2, recent research has reported that among children 3 to 5 years of age, younger children are more likely to meet physical activity guidelines. Moreover, these data report that 5 year old girls in Canada are less physically active than 5 year old boys (68 vs 81 minutes/day of moderate-vigorous physical activity, p<.05). A decrease in PA of 10 minutes/day represents a potential further 15% decline among girls with higher temperamental NA. Thus, the results of this study may have clinical implications when defining a population of preschool aged girls at risk for both negative mental and physical health outcomes.

As the first study to report on the longitudinal association of early childhood temperament with physical activity, this study has several strengths including recruitment from population based primary care settings, inclusion of measured height and weight, and an analytical approach
that accounted for previous PA level. However, our findings must also be interpreted within the context of the limitations of this study. Children and families that participated in the study were primarily of middle to higher socioeconomic status (SES), which may limit the ability to generalize our findings. However, previous research has found that the proportion of children meeting current PA guidelines in the TARGet Kids! Cohort is similar to other Canadian studies of this age group\(^59\), and self-reported income levels of our cohort are consistent with population-based measures of Canadian family incomes\(^60\). Research regarding the association of SES with child physical activity has yielded inconsistent findings\(^61 \text{--} 63\), thus whether or not the present study’s findings would be altered in a sample with greater heterogeneity is unclear. Similarly, although we found the demographic characteristics and physical activity levels in our sample to be comparable with those of other Canadian studies, we cannot eliminate the possibility of selection bias in our analyses. We were also unable to account for the potential role of siblings in This study used the most widely studied, validated and reliable measure of childhood temperament, however, the measure was completed by a single informant. Use of multiple informants or independent observer rated temperament may decrease the potential for rater bias, though parent report of temperament has been reported to correlate with that of a familiar, unrelated adult (teacher) in this age group\(^64\). Future studies would benefit from employing multiple raters of child temperament in this age group, to minimize the potential for rater bias. Also, this study investigated the level of children’s PA outside of daycare and as such, cannot address the potential moderating role of childcare settings on PA. However, an underestimation of PA level in the current study based on daycare attendance is unlikely as a growing body of literature shows that children are not physically active in many child care settings\(^65 \text{--} 67\) and we have found that parent-report of unstructured free play demonstrated the strongest correlation
with accelerometry data, irrespective of daycare attendance\textsuperscript{34}. Finally, this study employed report-based measurement of PA for young children. Accelerometry may provide more precise information regarding PA, although is also subject to inaccuracy if removed for activities (e.g. swimming) or if adhered to inconsistently. Accuracy may also vary with the specific device employed\textsuperscript{68}. The use of accelerometry in the TARGet Kids! sample may similarly underestimate child PA in this age group\textsuperscript{34}. This would not be expected to alter the findings of the present study, however, as patient-related factors did not predict differences in PA-accelerometry correlation, such that we would not expect variation in correlation across subgroups.

**Conclusions**

This study suggests that early NA is associated with future PA and that the relationship is moderated by sex. Moreover, this study suggests that the putative psychological risk factors for depression are observable prior to those that may ultimately lead to increased cardiometabolic risk. These findings underscore the importance of including longitudinal and gender-specific analyses in mood-obesity research, to detect changes in symptom emergence throughout key developmental periods and ensure interventions are aimed at the right targets, in the right population, during the right period of development.
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Figure 1. NA and child sex interact to predict physical activity

Legend: Child sex moderates the association between NA and physical activity.