24-Hour Movement Behaviors and Internalizing and Externalizing Behaviors Among Youth

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ABSTRACT

Purpose: The Canadian 24-Hour Movement Guidelines for Children and Youth (≥60 minutes of moderate-to-vigorous physical activity per day, ≤2 hours of recreational screen time per day, and 9-11 hours of sleep per night for 5-13 years old) are associated with better physical health, but less is known about how these behaviours are related to mental health. This study examined the association of meeting these guideline recommendations with internalizing and externalizing behaviours among children.

Methods: A large and broadly representative cross-sectional sample of 9- to 11-year-old U.S. children (N = 11,875) from the Adolescent Brain and Cognitive Development (ABCD) study was analyzed. Internalizing and externalizing behaviours were measured using the Child Behaviour Check List (CBCL). Associations were examined using negative binomial regression adjusted for several confounders.

Results: Compared to meeting none of the recommendations, meeting recommendations for screen time and sleep but not physical activity was associated with a lower prevalence ratio of total, internalizing, and externalizing behaviours. Meeting two or all three recommendations was more strongly associated with these outcomes than meeting one recommendation or none. The prevalence ratio (PR) of the group meeting all three recommendations was 0.77 (95% CI: 0.68-−0.86) for total problem scores, 0.78 (95% CI: 0.68−0.89) for internalizing problem scores, and 0.79 (95% CI: 0.68-0.91) for externalizing problem scores.

Conclusions: Meeting the 24-hour movement guidelines was associated with a lower risk of internalizing and externalizing behaviours in children. These associations were mainly explained by meeting the screen time and sleep duration recommendations.

Key words: physical activity; sedentary behaviour; sleep; internalizing behaviour; externalizing behaviour; epidemiology.

IMPLICATIONS AND CONTRIBUTION

This study found that children aged 9 to 11 years who met the 24-hour movement guidelines have less total problem behaviours as well as internalizing and externalizing problems. These associations were mainly driven by meeting the screen time and sleep duration recommendations.

INTRODUCTION

Mental health problems in children and youth are common. Nearly 10 to 20% of children and youth globally experience mental disorders [1]. Common symptoms of mental disorders tend to lie on two dimensions: internalizing (e.g., depression, anxiety, somatic complaints) and externalizing (e.g., aggression, delinquency). Thus, children can reveal their mental health problems on an emotional level or behaviourally [2]. Children's internalizing and externalizing behaviours have negative impacts on themselves, their family and society in the short- and long-term [3, 4]. Identifying modifiable factors associated with children's internalizing and externalizing behaviours could provide evidence that would inform intervention programs intended to enhance children's mental health.

Physical inactivity is associated with an increased likelihood of having several internalizing and externalizing behaviours [5] and the benefits of regular physical activity on children mental health are well known [6]. Physical activity enhances well-being, improves mood and can boost general self-esteem via improvements in skills and competence, body image, and physical fitness [7]. Physical activity is also associated with enhanced cognitive functioning, especially for tasks involving more complex executive functioning [8]. Importantly, physical activity is a potential therapy for internalizing and externalizing behaviours among children [9].

With rapid progress in information and communication technology, use of digital media has become ubiquitous in the everyday life of most children. Excessive screen time is associated with greater internalizing and externalizing behaviours [10]. Several possible mechanisms could explain the association between screen time and problem behaviours among children. Screen time may adversely impact mental health through the content watched on screens, disrupted interpersonal relationships, or through more direct cognitive effects, creating low emotional

stability and low self-control [11]. Moreover, the mechanisms by which excessive screen time may affect mental health may be indirect [11], via intermediate factors, such as displacing physical activity or sleep, unhealthy eating behaviour, dissatisfaction with body weight, and/or cyberbullying victimization [12-14]. Alternatively, excessive screen time may be a coping strategy for individuals who are already suffering from internalizing and externalizing behaviours [11].

Short sleep duration is increasingly widespread among children [15], and it could increase the risk of developing symptoms of internalizing and externalizing behaviours [10]. Short sleep duration affects brain activity and neurochemicals that regulate mood and cognitive function [16]. It impairs executive functions [17], such as inhibitory control and cognitive flexibility, that could result in increased irritability, impulsivity, anger and aggression [18, 19]. Short sleep duration can also make the maintenance of a healthy lifestyle (e.g., physical activity) more difficult because of subsequent daytime sleepiness, fatigue, and tiredness [20, 21]. Lastly, insufficient sleep duration could be associated with heightened stress reactivity within the hypothalamic-pituitary-adrenal axis, increasing the risk of psychopathological disorders [22].

However, previous research studies examining the associations of physical activity, screen time, and sleep duration with mental health indicators have considered these behaviours separately from each other, ignoring their codependence [23, 24]. This is concerning because these movement behaviours interact to influence health and should therefore be considered simultaneously. This has motivated the development and promotion of the *Canadian 24-Hour Movement Guidelines for Children and Youth,* which are integrated recommendations intended to provide parents, caregivers, health professionals, and policymakers guidance on the quality and quantity of physical activity, sedentary behaviour, and sleep children need in a 24-hour period to achieve health benefits. These guidelines were released in 2016 and they recommend

at least 60 minutes of moderate-to-vigorous physical activity per day, 2 hours or less of recreational screen time per day, and 9-11 hours of sleep per night for 5- to 13-year-olds and 8-10 hours per night for 14- to 17-year-olds [25]. The development of these guidelines followed a comprehensive, rigorous, and transparent process. It was informed by 4 systematic reviews and included consultation findings, compositional analysis findings, experts, different stakeholders, and end-users [25].

Research has shown that children who meet the 24-hour movement guidelines have better cognitive function [26], less impulsivity [27], better quality of life [28], improved emotional and psychosocial health [29], less depressive and anxiety symptoms [30], and better dietary patterns [31]. However, little is known about the association of different combinations of movement behaviour recommendations with internalizing and externalizing behaviours (as a more global measure rather than a single mental health indicator) in children. In a sample of over 500 Canadian children aged 3 years (i.e. preschoolers), Carson et al.[32] found that children who met more recommendations had lower internalizing and externalizing behaviours as measured by the Child Behavior Checklist (CBCL). They also found that physical activity and screen time, and screen time and sleep were the specific combinations of movement recommendations associated with internalizing and externalizing behaviours [32]. However, to the best of our knowledge, no previous study has specifically examined the association between the combinations of all 3 movement behaviour recommendations and the CBCL in later childhood (i.e. schoolchildren). It is also unclear if movement behaviours are differentially associated with internalizing versus externalizing problems in this age group. Gaining such knowledge is important to inform public health interventions and policies.

The purposes of this study were to examine the association of meeting different combinations of the 24-hour movement guidelines with internalizing and externalizing behaviours among

children. We hypothesized that meeting the 24-hour movement guidelines would result in a lower risk of having high internalizing and externalizing behaviour scores. The results from these cross-sectional analyses should not be interpreted as being causal, but rather informative for future hypothesis generation.

METHODS

The cross-sectional data from 11,875 children aged 9–11 years was obtained from the Adolescent Brain Cognitive Development (ABCD) Study (release 2.0; www.abcdstudy.org), a longitudinal observational study that tracks children through adolescence across domains related to brain development and health over a 10-year period [33]. It is the largest long-term study of brain development and child health in the United States. The ABCD study uses probability sampling of public and private elementary schools within the catchment areas of 21 data collection sites across the United States resulting in a nationally diverse and geographically stratified sample [33]. Across recruitment sites, inclusion criteria included being in the desired age range (9–10 years of age) and able to provide informed consent (parents) and assent (child). Exclusions were minimal and were limited to lack of English language proficiency in the children, the presence of severe sensory, intellectual, medical or neurological issues that would impact the validity of collected data or the child's ability to comply with the protocol, and contraindications to magnetic resonance imaging scanning. The data for this analysis were collected between September 1, 2016 and November 15, 2018. Detailed information on procedures, sampling, and recruitment for the ABCD study have been described previously [33]. All parents/guardians provided written informed consent and child assent was obtained prior to participation in the study. All procedures were approved by a central institutional review board and site-level institution research ethics boards.

Dependent variables

The Child Behavior Checklist/6-18 (CBCL) was used to assess problem behaviours over the past six months [34]. The CBCL is a parent-report measure that consists of 113 questions, each scored on a three-point Likert scale (0=absent, 1=occurs sometimes, 2=occurs often), and takes 15–20 minutes to complete. Responses were summed, with higher scores representing higher levels of emotional and behavioural problems. Raw scores (vs. standardized scores) were used for our data analyses following previous recommendations [35]. The CBCL/6-18 is made up of eight syndrome scales, including anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behaviour, and aggressive behaviour. Scores on the CBCL have shown high validity and reliability (α= .78 to .94), and the eight-syndrome scale has displayed strong fit indices in 30 different societies [35]. Scores for total, internalizing, and externalizing problems were calculated. Total score includes all eight syndrome scales. Internalizing score comprises the following syndrome scales: anxious/depressed, withdrawn/depressed, and somatic complaints. The externalizing score comprises the rule-breaking and aggressive behaviour syndrome scales. In these data, internalizing and externalizing scores have shown a good reliability of 0.87 and 0.90, respectively; the total scores had an excellent reliability of 0.95.

Independent variables

Physical activity was measured using questions from the Youth Risk Behavior Survey [36]. Participants reported the number of days that they were physically active for a total of at least 60 minutes per day in the past 7 days. Recreational screen time was measured using the Youth Screen Time Survey [37], which asked participants to report the number of hours spent on a typical weekday and weekend day performing a variety of recreational screen-based activities, including: 1) TV watching, 2) video watching (e.g., YouTube™), 3) video game playing, 4)

texting on cellphone, tablet, or computer, 5) visiting social media sites, or 6) using video chat. Daily recreational screen time was calculated by taking a weighted average of weekday and weekend screen time, using the following formula: [(the sum of week day screen time in minutes x 5) + (the sum of weekend day screen time in minutes x 2)] / 7. Sleep duration was measured using one item from the Parent Sleep Disturbance Scale for Children [38], which asked parents to indicate the number of hours of sleep a child gets on most nights. The midpoint of each response option was used to provide a unique value for sleep duration in hours, as follows: 9-11 hours = 10 hours; 8-9 hours = 8.5 hours; 7-8 hours = 7.5 hours; 5-7 hours = 6 hours; < 5 hours: 2.5 hours. Children who reported being physically active 7 days per week, accumulating ≤2 hours of daily recreational screen time, and sleeping 9–11 hours per night were considered to be meeting the recommendations of the 24-hour movement guidelines [25].

Covariates

Covariates included age (years), gender (girls/boys), ethnoracial background (African-American/Asian/Caucasian/Hispanic/multiracial), household income (combined income in past 12 months from all sources before taxes and deductions), parental education (measured in years), and body mass index (BMI) z-scores. BMI was calculated from measured height and weight, and age- and sex-specific BMI z-scores were calculated using reference data from the WHO [39].

Statistical analyses

Analyses were adjusted for the cluster effect of sites using STATA 14.1 (Stata Corp., College Station, Texas, USA) using svyset command. Descriptive statistics including means, standard deviations, and proportions were used to characterize the sample. The outcome variables of total, internalizing, and externalizing problems were treated as count variables and exhibited an over-dispersion (i.e., greater variances than means). Therefore, negative binomial regression

analyses were used to examine the associations of meeting different combinations of movement behaviour recommendations with the three outcomes. Prevalence ratios (PR), their 95% confidence intervals, and p-values are presented. PR is a measure of association that quantify the strength of association between a given outcome and a suspected risk factor [40]. It indicates how large is the prevalence of the outcome in a group of exposed subjects (i.e. with suspected risk factor) relative to the group of unexposed subjects (i.e. without the suspected risk factor). Covariates included age, gender, ethnicity, family income, parental education, and BMI z-scores. Given that gender×meeting movement behaviour recommendations interaction was not significant for any of the outcomes, data for both genders were pooled to maximize statistical power. Missing data were handled using complete case analyses by outcome. Information regarding missing data is described in Table 1. Statistical inferences were based on *p* values <0.05 and confidence intervals.

RESULTS

The descriptive characteristics of the sample are shown in Table 1. The mean age of the 11,875 participants was 9.9 ± 0.6 years. Just over half (52.1%) were boys, 52.5% were Caucasian and 17.4% were of Hispanic ethnic background. Overall, the prevalence of meeting the physical activity, screen time, and sleep duration recommendations were 16.4%, 35.1%, and 47.4%, respectively (Figure 1). Different combinations of meeting the physical activity, screen time, and sleep duration recommendations are displayed in Figure 1. Overall, only 3.9% of the participants met all three movement behaviour recommendations, while 32.2% did not meet any of the recommendations. Boys were more likely than girls to meet the physical activity recommendation alone (6.7% vs. 4.8%), sleep duration recommendation alone (24.8% vs. 20.4%), or both (5.1% vs. 3.3%).

Results from negative binomial regression analyses examining the associations of meeting different combinations of movement behaviour recommendations with total, internalizing, and externalizing problems are summarized in Tables 2 to 4. Compared to children who met none of the recommendations, meeting any single movement behaviour recommendation or any combination of movement behaviour recommendations was associated with a lower risk of total problems, except for physical activity alone (PR: 1.06; 95% CI: 0.99 – 1.15). Meeting the sleep duration recommendation alone or any combination of movement behaviour recommendations was also associated with a lower risk of internalizing problems relative to children who met none of the recommendations. Meeting the screen time recommendation (PR: 0.85; 95% CI: 0.77 − 0.94), the sleep duration recommendation (PR: 0.86; 95% CI: 0.80 − 0.93), the screen time + sleep duration recommendation (PR: 0.74; 95% CI: 0.67 − 0.81), and all 3 recommendations (PR: 0.79; 95% CI: 0.68 − 0.91) were associated with a lower risk of externalizing problems. In contrast, children who met the physical activity recommendation had a greater risk of externalizing problems than those who met none of the recommendations (PR: 1.18; 95% CI: 1.08 – 1.30). Meeting the physical activity + screen time (PR: 0.90; 95% CI: 0.78 − 1.04) or screen time + sleep duration (PR: 0.91; 95% CI: 0.78 – 1.07) recommendations were not significantly associated with externalizing behaviours. The multivariable associations between meeting different combinations of movement behaviour recommendations and each syndrome scales are outlined in Supplemental Table 1.

The associations of number of movement behaviour recommendations met with total, internalizing, and externalizing problems are summarized in Supplemental Table 2. There was a dose-response gradient from meeting none of the recommendations up to two recommendations, but not from two to three recommendations. Meeting all three

recommendations had comparable strength of associations to meeting two recommendations for all three outcomes.

Given that 8.6% were dropped due to missing data on family income, a sensitivity analysis (where family income was removed from the multivariable models) was conducted and showed similar results (data not shown). Similarly, sensitivity analyses using multiple imputations provided similar results (data not shown).

DISCUSSION

This study examined the association between meeting different combinations of the 24-hour movement guideline recommendations and problem behaviours among children, and tested if gender was a moderator of the associations. Our results showed that, compared to meeting no recommendations, meeting all 3 recommendations was associated with a lower risk of total, internalizing, and externalizing problems in a large and broadly representative sample of U.S. children, and these associations were mainly explained by meeting the screen time and sleep duration recommendations. Although boys were more likely than girls to meet the physical activity and sleep duration recommendations, the gender×movement behaviour recommendation interactions were not significant, suggesting that the association of meeting the movement behaviour combinations with internalizing and externalizing behaviours in children did not differ by gender.

Our results are consistent with previous studies that found that meeting all 3 movement behaviour recommendations is associated with lower emotional problems in children and adolescents, such as depressive and anxiety symptoms [30]. Similarly, in a large nationally representative sample of over 17 000 Canadians aged 10–17 years from the 2013/2014 cycle of

the Health Behaviour in School-aged Children study (HBSC), Janssen et al. [29] found that meeting all 3 recommendations was associated with lower odds of emotional problems. However, children can manifest their mental health problems on an emotional level or in a more behavioural manner [2]. To our knowledge, we are the first to show that meeting all three movement behaviour recommendations is associated with a lower risk of behavioural problems, including rule-breaking behaviour and aggressive behaviour, before and after adjusting for multiple confounders in a large and representative sample of children.

Contrary to Janssen et al. [29] who found a monotonic dose–response pattern between the number of recommendations achieved and emotional problems, indicating that the health outcome improved as more recommendations were achieved, our study identify a dose-response gradient from meeting none of the recommendation up to meeting two recommendations, but not from two to three recommendations. It is possible that differences in sample characteristics and outcome measures explain, at least in part, the discrepant findings. Indeed, our sample was comprised of children aged 9 to 10 years, whereas the HBSC data used by Janssen et al. [29] encompassed students aged 10 to 17 years. There are important variations between emotional/behavioural problems by age groups [41]. For example, the prevalence of depression is very low among prepubescent children (less than 1%), and then increases significantly throughout adolescence [42]. It is also possible that differences in the measures of movement behaviour explain these discrepancies. For example, Janssen et al. [29] added together the amount of MVPA participants did in their class time at school, in their free time (including organized sports and programs and active play), and time spent in active transportation. However, the ABCD has a particularly weak measure of physical activity using a single item measure. Moreover, emotional health in our study was measured using the CBCL [34], a well validated parent-reported measure. However, in the HBSC study, emotional health

was measured using a 9-item self-report measure, which was constructed based on underlying theory and on factor and reliability analyses [2].

Our results further indicated that the significant associations between meeting all three recommendations and a lower risk of internalizing and externalizing behaviours were mainly driven by meeting the screen time and sleep duration recommendations. These findings are somewhat consistent with those from previous studies suggesting that meeting the physical activity recommendation is not as important as meeting the screen time and the sleep duration recommendations regarding mental health outcomes in the ABCD dataset. Indeed, Walsh et al. [26] found that meeting the screen + sleep or screen-only recommendations were the strongest predictors of superior cognition compared to not meeting any recommendations. Similarly, Guerrero et al. [27] found that children who met the sleep and screen time recommendations scored more favourably on all 8 dimensions of impulsivity than children who did not meet any recommendation. They also found that meeting the sleep duration + screen time recommendations had the strongest association with the impulsivity dimensions [27]. It is possible that the poor measure of physical activity (i.e. single item measure) in the ABCD explains, at least in part, the lack of association between physical activity and emotional and behavioural problems. However, in a sample of Canadian adolescents, Patte et al. [43] found no prospective association between meeting the physical activity recommendation and depressive symptoms. Future studies using objective measures of physical activity are needed to replicate these findings. Although meeting the physical activity recommendation was not associated with a lower risk of emotional and behavioural problems, active living should not be neglected due to its proven multiple health benefits in children and youth [6]. Research has further indicated that physical activity is a good treatment option for emotional problems, such as depression and anxiety [9].

We found a somewhat counterintuitive finding of the association between meeting the physical activity recommendation and higher externalizing behaviour. It is possible that reverse causation explains these results. We cannot rule out this alternative given the cross-sectional nature of our study. These findings could also be partly due to measurement issue (i.e. single item measure of physical activity), but also children with behavioural disorders are more likely to be hyperactive (ADHD) and tend to act out more [41]. Children with behavioural disorders may be more attracted to physical activity, or their parents encourage physical activity as a means to dealing with behavioural issues. Indeed, physical activity has been identified as an effective means to manage ADHD symptoms and behavioural disorders [44, 45]. So in this context, the findings are not completely unexpected. As such, physical activity could constitute a result of people with externalizing symptoms. Longitudinal studies are therefore needed to confirm temporality between meeting the physical activity recommendation and higher externalizing behaviour among children.

Strengths and limitations

Strengths of this study include the use of a large and broadly representative sample of U.S. children, and the use of generalized linear models (negative binomial models) which are more appropriate for overdispersed response variables than general linear models. The present study is the first to examine the association between the combination of movement guidelines and internalizing and externalizing behaviour measured by CBCL in school aged children. Whereas, a previous study has examined these associations in preschoolers [32]. Other studies have focused on specific aspects of internalizing problems in adolescents, such as emotional health, anxiety and depressive symptoms, and suicidality among adolescents [29, 30, 46-48].

Our analyses adjusted for important covariates, which strengthen the validity of our findings. Nevertheless, this study had several limitations worth mentioning. First, the cross-sectional nature of the analyses precludes confirmation of causality between meeting the 24-hour movement guidelines and problem behaviours. Second, the data were self- (or parent-) reported and may be subject to recall and social desirability biases. However, the CBCL is a well validated tool [34] and single-item measures of sleep duration have been indicated to provide a reliable and valid assessment of sleep duration among children and adolescents [49]. Self-reported questions of physical activity and screen time tend to be modestly reliable and valid in children [50], suggesting that a fair amount of misclassification could still occur. Thus, the measure of effects reported in this study are likely underestimated (and to different extents for different movement behaviours). Third, the present study did not examine other characteristics of movement behaviour, such as type, intensity, and context of physical activity, type of screen use, and quality of sleep. The study did also not assess intermittent patterns of activity, multitasking or overlap in movement behaviours. Future research could account for these factors in the context of meeting the 24-hour movement guidelines and internalizing and externalizing behaviours. Finally, although our analyses adjusted for potential confounders, there is possibility of residual confounding by unmeasured variables.

Conclusions

This study shows that meeting the 24-hour movement guidelines was associated with a lower risk of total problem behaviours as well as internalizing and externalizing problems. These associations were mainly explained by meeting the screen time and sleep duration recommendations. These findings can help to inform the development of early intervention efforts directed towards the improvement of the emotional and behavioural health of children. Increased awareness is needed among all stakeholders, including parents, caregivers, health professionals, policymakers, and children themselves on the benefits of meeting the 24-hour

movement guidelines. Future research using experimental and longitudinal designs are needed to verify the relationships among 24-hour movement behaviours and internalizing and externalizing behaviours among children.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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Table 1. Descriptive characteristics of the sample.

Characteristics	Sample N=11,875	Missing data (% of overall sample)
	Mean (SD)[1]	n (%)
Socio-demographics and body weight		
Age (years)	9.9 (0.6)	0
[Min: 9.0, Max: 10.9]		
Gender, n (%)		6 (<1)
Girls	5,681 (47.9)	
Boys	6,188 (52.1)	
Ethnicity, n (%)		120 (1.0)
Caucasian	1,779 (52.5)	
African American	255 (15.1)	
Asian	6,176 (2.2)	
Hispanic	2,047 (17.4)	
Multiracial	1,498 (12.7)	
Parental education, years	16.6 (2.8)	20 (<1)
[Min: 1, Max: 21]		
Family income[2]	7.2 (2.4)	1,018 (8.6)
[Min: 1, Max: 10]		
BMI z-scores	0.7 (1.5)	46 (<1)
[Min: -14.1, Max: 7.5]		
Outcomes (CBCL)		
Total problems	18.2 (18.0)	0
[Min: 0, Max: 139]		
Internalizing problems	5.0 (5.5)	0
[Min: 0, Max: 51]		
Externalizing problems	4.2 (5.5)	0
[Min: 0, Max: 47]		
Exposures (movement behaviours)		
Meet the physical activity recommendation, n (%)		31 (<1)
No	9,896 (83.6)	
Yes	1,948 (16.4)	
Meet the screen time recommendation, n (%)		29 (<1)
No	7,684 (64.9)	
Yes	4,162 (35.1)	
Meet the sleep duration recommendation, n (%)		6 (<1)
No	6,241 (52.6)	
Yes	5,628 (47.4)	

SD = standard deviation. Data are shown as Mean (SD) unless otherwise specified.

[2]Combined income in past 12 months from all sources before taxes and deductions on a scale of 1=<US$5000; 2=$5000−11 199; 3=$12 000−15 999; 4=$16 000−24 999; 5=$25 000−34 999; 6=$35 000−49 999; 7=$50 000−74 999; 8=$75 000−99 999; 9=$100 000−199 999; and 10=≥$200 000.

Table 2. Association between meeting different combinations of movement behaviour recommendations and total problems.

	Univariable			Multivariable		
	PR	**95% CI**	***p***	**PR**	**95% CI**	***p***
24-hour movement guideline combinations (reference = meeting none)						
Only physical activity	1.04	0.96 − 1.12	0.334	1.06	0.99 − 1.15	0.108
Only screen time	0.81	0.74 − 0.89	<0.001	0.89	0.82 − 0.97	0.011
Only sleep duration	0.81	0.75 − 0.87	<0.001	0.86	0.81 − 0.92	<0.001
Physical activity + screen time	0.80	0.71 − 0.90	0.001	0.86	0.77 − 0.96	0.009
Physical activity + sleep duration	0.83	0.72 − 0.95	0.009	0.85	0.76 − 0.96	0.012
Screen time + sleep duration	0.68	0.63 − 0.72	<0.001	0.76	0.71 − 0.82	<0.001
Physical activity + screen time + sleep duration	0.70	0.61 − 0.80	<0.001	0.77	0.68 − 0.86	<0.001
Covariates						
Age	0.97	0.93 − 1.02	0.275	0.95	0.91 − 1.00[a]	0.034
Gender (reference = girls)	1.24	1.19 − 1.29	<0.001	1.21	1.16 − 1.27	<0.001
Ethnicity (reference = Caucasian)						
African American	1.09	0.96 − 1.24	0.179	0.83	0.74 − 0.92	0.002
Asian	0.67	0.54 − 0.83	0.001	0.69	0.58 − 0.84	0.001
Hispanic	1.03	0.91 − 1.17	0.595	0.86	0.77 − 0.96	0.011
Multiracial	1.18	1.08 − 1.29	0.001	1.03	0.96 − 1.11	0.394
Family income	0.94	0.92 − 0.95	<0.001	0.94	0.92 − 0.95	<0.001
Parental education	0.96	0.95 − 0.98	0.001	1.00	0.99 − 1.01	0.817
BMI Z-scores	1.04	1.02 − 1.06	<0.001	1.02	1.00[a] − 1.03	0.041

PR: prevalence ratio; CI: confidence interval; BMI: body mass index.

[a]This is a rounding error.

Table 3. Association between meeting different combinations of movement behaviour recommendations and internalizing problems.

	Univariable			Multivariable		
	PR	**95% CI**	***p***	**PR**	**95% CI**	***p***
24-hour movement guideline combinations (reference = meeting none)						
Only physical activity	0.97	0.90 − 1.06	0.499	1.00	0.91 − 1.09	0.956
Only screen time	0.93	0.86 − 1.02	0.105	0.96	0.88 − 1.06	0.414
Only sleep duration	0.85	0.79 − 0.91	<0.001	0.87	0.81 − 0.93	<0.001
Physical activity + screen time	0.83	0.72 − 0.96	0.013	0.82	0.71 − 0.96	0.013
Physical activity + sleep duration	0.82	0.70 − 0.95	0.012	0.82	0.72 − 0.94	0.007
Screen time + sleep duration	0.80	0.75 − 0.85	<0.001	0.83	0.77 − 0.89	<0.001
Physical activity + screen time + sleep duration	0.76	0.67 − 0.87	<0.001	0.78	0.68 − 0.89	0.001
Covariates						
Age	1.02	0.97 − 1.07	0.433	1.01	0.96 − 1.05	0.728
Gender (reference = girls)	1.01	0.98 − 1.05	0.423	1.00	0.96 − 1.04	0.902
Ethnicity (reference = Caucasian)						
African American	0.88	0.78 − 1.00[a]	0.044	0.69	0.62 − 0.77	<0.001
Asian	0.75	0.58 − 0.96	0.024	0.70	0.56 − 0.87	0.002
Hispanic	1.04	0.93 − 1.17	0.469	0.88	0.79 − 0.99	0.029
Multiracial	1.11	1.03 − 1.21	0.012	1.00	0.94 − 1.07	0.987
Family income	0.96	0.94 − 0.97	<0.001	0.94	0.93 − 0.95	<0.001
Parental education	0.98	0.97 − 0.99	0.002	1.01	1.00[a] − 1.02	0.033
BMI Z-scores	1.03	1.01 − 1.05	0.011	1.02	0.99 − 1.04	0.151

PR: prevalence ratio; CI: confidence interval; BMI: body mass index.

[a]This is a rounding error.

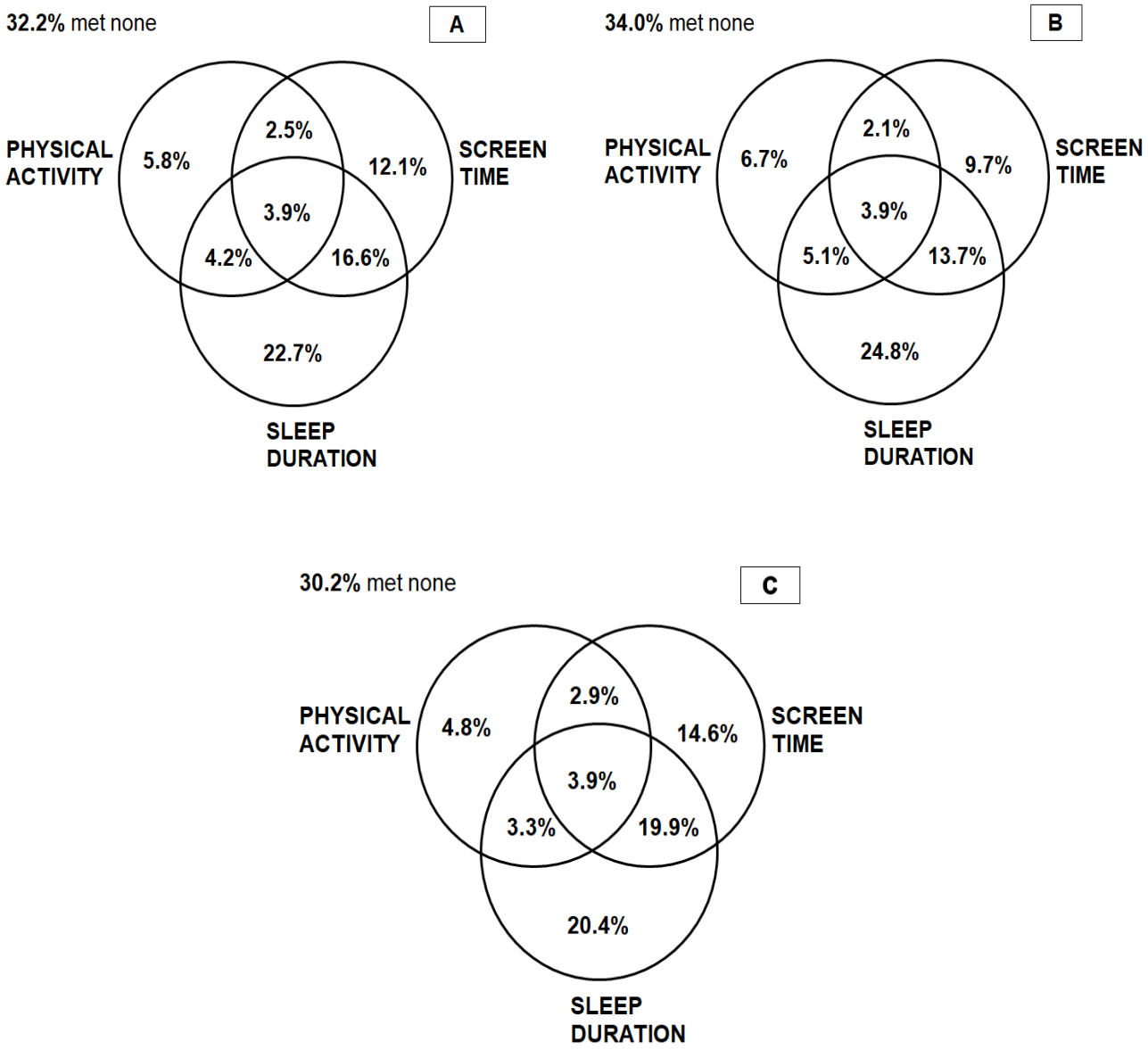
Table 4. Association between meeting different combinations of movement behaviour recommendations and externalizing problems.

	Univariable			Multivariable		
	PR	**95% CI**	***p***	**PR**	**95% CI**	***p***
24-hour movement guideline combinations (reference = meeting none)						
Only physical activity	1.13	1.03 − 1.24	0.010	1.18	1.08 − 1.30	0.001
Only screen time	0.73	0.65 − 0.82	<0.001	0.85	0.77 − 0.94	0.002
Only sleep duration	0.76	0.69 − 0.85	<0.001	0.86	0.80 − 0.93	0.001
Physical activity + screen time	0.78	0.67 − 0.91	0.004	0.90	0.78 − 1.04	0.153
Physical activity + sleep duration	0.84	0.70 − 1.01	0.056	0.91	0.78 − 1.07	0.233
Screen time + sleep duration	0.60	0.54 − 0.67	<0.001	0.74	0.67 − 0.81	<0.001
Physical activity + screen time + sleep duration	0.67	0.56 − 0.80	<0.001	0.79	0.68 − 0.91	0.002
Covariates						
Age	0.96	0.91 − 1.02	0.214	0.93	0.88 − 0.99	0.015
Gender (reference = girls)	1.36	1.31 − 1.42	<0.001	1.32	1.26 − 1.39	<0.001
Ethnicity (reference = Caucasian)						
African American	1.29	1.09 − 1.53	0.005	0.91	0.79 − 1.03	0.138
Asian	0.54	0.42 − 0.71	<0.001	0.64	0.49 − 0.85	0.003
Hispanic	1.04	0.90 − 1.19	0.592	0.82	0.71 − 0.93	0.004
Multiracial	1.23	1.10 − 1.38	0.001	1.03	0.94 − 1.14	0.482
Family income	0.91	0.88 − 0.94	<0.001	0.92	0.90 − 0.94	<0.001
Parental education	0.94	0.92 − 0.97	0.001	0.99	0.98 − 1.01	0.486
BMI Z-scores	1.05	1.03 − 1.08	<0.001	1.02	1.00[a] − 1.04	0.036

PR: prevalence ratio; CI: confidence interval; BMI: body mass index.

[a]This is a rounding error.

Figure 1. Venn diagram showing the number of children meeting no guidelines, the physical activity, screen time, and sleep duration recommendations, and various combinations of the recommendations in the total sample (Panel A, N=11,875), boys (Panel B, N=6,188), and girls (Panel C, N=5,681).



Note: p-value of difference between boys and girls was <0.001. Boys were more likely than girls to meet the physical activity and sleep duration recommendations.

Supplemental Table 1. Multivariable associations between meeting different combinations of movement behaviour recommendations and each syndrome scales.

	Univariable		
	PR	**95% CI**	***p***
INTERNALIZING PROBLEMS			
Anxious/depressed			
24-hour movement guideline combinations (reference = meeting none)			
Only physical activity	1.01	0.93 − 1.09	0.779
Only screen time	0.99	0.90 – 1.10	0.910
Only sleep duration	0.87	0.81 − 0.94	0.001
Physical activity + screen time	0.86	0.72 – 1.02	0.087
Physical activity + sleep duration	0.84	0.72 − 0.99	0.037
Screen time + sleep duration	0.87	0.79− 0.94	0.003
Physical activity + screen time + sleep duration	0.79	0.66 − 0.94	0.011
Withdrawn/depressed			
24-hour movement guideline combinations (reference = meeting none)			
Only physical activity	0.87	0.76 − 1.00*	0.045
Only screen time	0.98	0.86 – 1.11	0.703
Only sleep duration	0.83	0.76 − 0.90	<0.001
Physical activity + screen time	0.73	0.56 − 0.97	0.031
Physical activity + sleep duration	0.62	0.50 − 0.78	<0.001
Screen time + sleep duration	0.76	0.71 − 0.83	<0.001
Physical activity + screen time + sleep duration	0.62	0.53 − 0.74	<0.001
Somatic complaints			
24-hour movement guideline combinations (reference = meeting none)			
Only physical activity	1.07	0.95 − 1.20	0.259
Only screen time	0.90	0.83 − 0.98	0.021
Only sleep duration	0.88	0.80 − 0.98	0.016
Physical activity + screen time	0.82	0.69 − 0.99	0.035
Physical activity + sleep duration	0.93	0.84 – 1.03	0.161
Screen time + sleep duration	0.80	0.74 − 0.87	<0.001
Physical activity + screen time + sleep duration	0.86	0.75 − 0.98	0.026

EXTERNALIZING PROBLEMS			
Rule-breaking			
24-hour movement guideline combinations (reference = meeting none)			
Only physical activity	1.19	1.06 − 1.34	0.005
Only screen time	0.77	0.71 − 0.84	<0.001
Only sleep duration	0.84	0.77 − 0.91	<0.001
Physical activity + screen time	0.86	0.68 – 1.08	0.172
Physical activity + sleep duration	0.91	0.75 – 1.11	0.342
Screen time + sleep duration	0.67	0.60 − 0.75	<0.001
Physical activity + screen time + sleep duration	0.74	0.62 − 0.88	0.002
Aggressive behaviour			
24-hour movement guideline combinations (reference = meeting none)			
Only physical activity	1.18	1.08 − 1.29	0.001
Only screen time	0.88	0.79 − 0.97	0.016
Only sleep duration	0.87	0.80 − 0.94	0.001
Physical activity + screen time	0.92	0.80 – 1.04	0.168
Physical activity + sleep duration	0.91	0.78 – 1.06	0.219
Screen time + sleep duration	0.76	0.69 − 0.84	<0.001
Physical activity + screen time + sleep duration	0.81	0.70 − 0.93	0.004

PR: prevalence ratio; CI: confidence interval

Models are adjusted for age, gender, ethnicity, family income, parental education, and BMI z-scores.

[a]This is a rounding error.

Supplemental Table 2. Multivariable associations of number of movement behaviour recommendations met with emotional and behavioural problems.

	Total problem behaviours			Internalizing behaviours			Externalizing behaviours		
	PR	**95% CI**	***p***	**PR**	**95% CI**	***p***	**PR**	**95% CI**	***p***
Number of recommendations met (reference = zero)									
One	0.90	0.85 − 0.95	0.001	0.92	0.86 − 0.97	0.007	0.91	0.85 − 0.97	0.007
Two	0.79	0.75 − 0.84	<0.001	0.83	0.78 − 0.87	<0.001	0.80	0.73 − 0.87	<0.001
Three	0.77	0.69 − 0.87	<0.001	0.78	0.68 − 0.89	0.001	0.80	0.69 − 0.92	0.003
Age	0.96	0.92 − 1.00	0.052	1.01	0.97 − 1.05	0.643	0.94	0.89 − 0.99	0.032
Gender (reference = girls)	1.22	1.16 − 1.28	<0.001	1.00	0.96 − 1.04	0.959	1.34	1.27 − 1.41	<0.001
Ethnicity (reference = Caucasian)									
African American	0.84	0.75 − 0.93	0.003	0.69	0.63 − 0.77	<0.001	0.92	0.81 − 1.05	0.224
Asian	0.69	0.57 − 0.83	<0.001	0.70	0.57 − 0.87	0.003	0.63	0.47 − 0.83	0.003
Hispanic	0.86	0.76 − 0.96	0.013	0.89	0.79 − 0.99	0.038	0.81	0.71 − 0.93	0.004
Multiracial	1.03	0.96 − 1.11	0.353	1.00	0.94 − 1.07	0.924	0.05	0.95 − 1.14	0.421
Family income	0.94	0.92 − 0.95	<0.001	0.94	0.93 − 0.95	<0.001	0.92	0.90 − 0.94	<0.001
Parental education	1.00	0.99 − 1.01	0.914	1.01	1.00[a] − 1.02	0.038	0.99	0.97 − 1.01	0.408
BMI Z-scores	1.02	1.00[a] − 1.03	0.030	1.01	0.99 − 1.04	0.150	1.02	1.00[a] − 1.04	0.026

PR: prevalence ratio; CI: confidence interval; BMI: body mass index.

[a]This is a rounding error.