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Longitudinal and cross-sectional associations of adherence to 24-hour movement guidelines with cardiometabolic risk

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ABSTRACT

This study aimed to examine 1) adherence to 24-hour movement guidelines over a 2-year follow-up in children aged 6-8 years and 2) association of this adherence with cardiometabolic risk factors. Physical activity and sleep were assessed by a monitor combining heart rate and accelerometry measurements. Screen time was reported by the parents. Body fat percentage, waist circumference, blood glucose, serum insulin, plasma lipids and blood pressure were assessed, and a cardiometabolic risk score was calculated using z-scores. Children were classified as meeting the guidelines if they had on average ≥60min/day of moderate-to-vigorous physical activity during the valid days; ≤120min/day of screen time; and 9–11h/day of sleep. In total, 485 children had valid data at baseline or at 2-year follow-up. Analyses were conducted using adjusted logistic and linear regression models. Most children adhered to the 24-hour movement guidelines at baseline, but the adherence decreased over the 2-year follow-up. Meeting physical activity guidelines individually, or in combination with screen time and/or sleep, was longitudinally associated with a lower cardiometabolic risk score, insulin and waist circumference, and cross-sectionally additionally with lower diastolic blood pressure and higher high-density lipoprotein cholesterol. However, these associations became statistically non-significant after adjustment for body fat. In conclusion, meeting 24-hour movement guidelines at baseline increases the odds of meeting them at 2-year follow-up in school-aged children. Furthermore, meeting 24-hour movement guidelines is associated with lower levels of cardiometabolic risk factors, but these associations are partly explained by lower body fat. Thus, promoting movement behaviors, especially physical activity, and healthy weight in early childhood is important in supporting cardiometabolic health in children.

Clinical Trial Registration: clinicaltrials.gov NCT01803776
Keywords: body fat, metabolic profile, movement guidelines, paediatrics, prospective

INTRODUCTION

Engaging in sufficient levels of physical activity (PA), limiting screen time (ST), and having a sufficient amount of sleep have been associated with numerous health benefits in children.[1-3] Current 24-hour movement guidelines recommend that a healthy 24-hour day in school-aged children should include 1) at least 60 minutes of moderate-to-vigorous PA (MVPA), 2) no more than two hours of ST, and 3) 9–11 hours of sleep.[4,5] However, only 2.0 to 14.9% of children aged 9-11 years from 12 countries participating in the large International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) met all these recommendations for MVPA, ST, and sleep.[6] Adherence to the 24-hour movement guidelines may track over time in preschool-aged children,[7] but not among students,[8] while such knowledge in school-aged children remains scarce.

Pathophysiological processes for cardiovascular diseases, the main cause of premature mortality worldwide,[9] start already in childhood.[10] Metabolic syndrome, referring to a cluster of cardiometabolic risk factors, including central obesity, insulin resistance, hyperglycemia, hypertriglyceridemia, low plasma high-density lipoprotein (HDL) cholesterol and hypertension, has been found to increase the risk of subclinical and clinical cardiovascular diseases in adults.[11] A large systematic review[12] estimated that the prevalence of childhood metabolic syndrome varies between 0 and 29% in different study populations, highlighting a need to clarify lifestyle-related factors that contribute to this variability.

There are few earlier studies on the combined association of movement behaviors, including PA, ST, and sleep, with cardiometabolic risk factors,[13,14] and most of them have been cross-sectional.[13,14] Studies in Canada[13] and the United States[14] have reported that children and youth who met a larger number of 24-hour movement guidelines had lower serum triglycerides (TG) and insulin,[13,14] higher serum HDL cholesterol,[13] and lower systolic blood pressure (SBP) than those meeting a smaller number of these guidelines.[13] In a longitudinal study among children in Denmark,[15] a combination of decreased MVPA and sleep duration and increased ST was associated with a 3.3 unit increase in the metabolic syndrome score over a 200-day follow-up compared with increased MVPA and sleep duration and decreased ST. Meeting the 24-hour movement guidelines has also been associated with a lower z-score for body mass index (BMI),[6] higher aerobic fitness,[13] and better health-related quality of life.[16] Thus, it is important to increase knowledge on the role of combined movement behaviors in supporting health in children and how fat mass may be related to it.

The longitudinal associations of adherence to the current 24-hour movement guidelines with cardiometabolic risk factors are unknown. We therefore examined individual and combined adherence to these guidelines at baseline, tracking of the adherence over a 2-year follow-up, and how the adherence is related to cardiometabolic risk factors cross-sectionally and longitudinally. In addition, we investigated whether differences in body fat may explain the associations of adherence to these guidelines with cardiometabolic risk factors.

MATERIALS AND METHODS

Participants and Study Design

The present study is a secondary analysis utilizing baseline and 2-year follow-up data from the Physical Activity and Nutrition in Children (PANIC) study (ClinicalTrials.gov NCT01803776) that is an 8-year PA and dietary intervention study in a population sample of children from the city of Kuopio, Finland.[17] The Research Ethics Committee of the Hospital District of Northern Savo approved the study protocol in 2006 (Statement 69/2006). The parents or caregivers of the children gave their written informed consent, and the children provided their assent to participation. We invited 736 children 6-8 years of age who started the first grade in 16 primary schools of the city of Kuopio in 2007-2009. Of those children, 512 (69.6%) had data on PA, ST, or sleep. The current study population consists of 249 boys (51.3%) and 236 girls (48.7%) with complete data on PA, ST, and sleep duration at baseline or at 2-year follow-up. The included children did not differ in terms of cardiometabolic risk factors from the children who were excluded.

Assessment of movement behaviors

PA was assessed using a combined heart rate and body movement sensor Actiheart® (CamNtech Ltd., Papworth, UK) for a minimum of four consecutive days and analyzed in 60 second epochs.[18] The combined heart rate and movement sensor were attached to the child's chest with two standard electrocardiographic electrodes (Bio Protech Inc., Wonju, South Korea). The children were asked to wear the monitor continuously, including sleep and water-based activities. Heart rate data were cleaned[19] and individually calibrated using parameters obtained from the maximal cycle exercise test,[20] and were combined with movement sensor data to derive PA energy expenditure. Instantaneous PA energy expenditure was estimated using branched equation modelling[21] and expressed as time spent at intensity levels of standard metabolic equivalents (METs), one MET corresponding to 71.2 J/min/kg, in minutes per day. In the current analyses, MVPA was defined as PAs at ≥4 METs. PA data were accepted as a valid day if there was a minimum of 48 h of activity recording in weekday and weekend day hours that included at least 12 h from morning (3–9 am), noon (9 am–3 pm), afternoon (3–9 pm), and night (9 pm–3 am) to avoid potential bias from over-representing specific times and activities of the days. The children were defined reaching the PA guidelines if they had at least 60 minutes of MVPA per day as an average of the valid registered days.[4,5]

ST separately over weekdays and weekend days was assessed by the PANIC Physical Activity Questionnaire that was filled out by the parents together with their child.[22] The types of ST in our analyses included watching television and videos, using computer and playing video and console games, and using mobile phone and playing mobile games. Time spent in ST was calculated by summing up times spent in each type of activity and expressed in hours per week weighted by the number of weekdays and weekend days. The children were defined reaching the ST guidelines if they had no more than two hours of ST per day.[4,5]

Sleep duration was inferred from the combined heart rate and movement data by a trained exercise specialist and was confirmed by a physician, was subtracted from sedentary time to obtain the final sleep duration for the analyses.[23] The time of falling asleep was defined as accelerometer counts decreasing to zero and heart rate to a plateau level. The time of waking up was defined as accelerometer counts increasing and remaining above zero and heart rate increasing and remaining above the plateau level. The children were defined reaching the sleep guidelines if they had 9–11 hours of sleep per night.[4,5]

Assessment of cardiometabolic risk factors

A research nurse took blood samples in the morning after a 12-hour overnight fast. Plasma glucose was measured by a hexokinase method, serum insulin by an electrochemiluminescence immunoassay, plasma TG by a colorimetric enzymatic assay, and plasma HDL cholesterol by a homogeneous colorimetric enzymatic assay.[24] SBP and diastolic blood pressure (DBP) were measured from the right arm using the Heine Gamma G7® aneroid sphygmomanometer (Heine Optotechnik, Herrsching, Germany) to the accuracy of 2 mm Hg. The measurement protocol included a 5-minute seated resting period followed by three measurements with 2-minute intervals in between. The average of all three values was used for both SBP and DBP.

Body weight was measured using a calibrated InBody 720® bioelectrical impedance device (Biospace, Seoul, South Korea). Height was measured using a wall-mounted stadiometer without shoes. BMI was calculated by dividing body weight (kg) by height (m) squared, and BMI-SDS was obtained using Finnish reference values.[25] The prevalence of normal weight, overweight, and obesity were defined using the cut-off values provided by Cole and Lobstein.[26] Waist circumference (WC) was measured at mid-distance between the bottom of the rib cage and the top of the iliac crest, and the mean of the closest two values was used in the analyses. Body fat percentage (BF%) was measured using the Lunar® dual-energy X-ray absorptiometry device (GE Medical Systems, Madison, Wisconsin, USA).[27]

A continuous cardiometabolic risk score (CRS) was calculated as the sum of population-specific z-scores of WC, insulin, glucose, TG, HDL cholesterol, and the mean of SBP and DBP.[24] The z-score of HDL cholesterol was multiplied by -1 due to its inverse association with cardiometabolic risk. A higher CRS indicates a less favourable cardiometabolic risk profile.

Assessment of covariates

The education of the more educated parent was used as parental education (categorized as low [vocational school or less], middle [polytechnic], or high [university degree]). The children were allocated to the intervention group (N=293, 60.4%) and the control group (N=192, 39.6%) after the baseline measurements.[28] The combined PA and dietary intervention consisted of six intervention visits during the 2-year follow-up. The children and their parents received individualized advice regarding PA and diet from a specialist in exercise medicine and a clinical nutritionist. The intervention and control groups were merged in the present analyses. Food consumption as well as energy and nutrient intake were assessed by food records administered by the parents on four predefined consecutive days, including two weekdays and two weekend days (99%) or three weekdays and one weekend day (1%). The Finnish Children Healthy Eating Index was used as an indicator of diet quality. The index was calculated by summing the reported consumption of the following foods based on their quantiles in the present study population: vegetables, fruit and berries (scored 1–10); high-fat (≥60%) vegetable oil-based spreads and vegetable oils (0–10); low-fat (<1%) milk (0–9); fish (0–6); and foods with high sugar content (10–1). The index ranged between 2 and 45, a higher score indicating higher diet quality.[29]

Statistical Analysis

The characteristics of the children are provided as arithmetic means (standard deviations, SDs) or frequencies (percentages, %). The children were categorized as meeting or not meeting 1) individual movement guidelines, 2) combinations of any two movement guidelines, or 3) all three movement guidelines at baseline. Logistic regression analyses were used to assess whether adherence to guidelines at baseline tracked over the 2-year follow-up. All models were adjusted for age, sex, parental education, and study group at baseline. Furthermore, linear regression analyses were used to examine the associations of CRS and each cardiometabolic risk factor with 1) individual movement guidelines, 2) combinations of any two movement guidelines, 3) all three movement guidelines, and 4) the number of movement guidelines met. The models were conducted both cross-sectionally at baseline and prospectively over the 2-year follow up (i.e., association of adherence to movement guidelines with CRS at baseline and with individual cardiometabolic risk factors at 2-year follow-up). The Model 1 was unadjusted, and in Model 2, the data were adjusted for sex, age, parental education, and study group at baseline. In additional analyses, the Model 2 was adjusted for BF%. In the sensitivity analyses, we included also energy intake and the Finnish Children Healthy Eating Index in the model as possible confounding factors. However, further adjustment for these dietary factors had no influence on the associations studied (Data not shown), and thus, we decided not to include them in the final models. All statistical analyses were performed using the SPSS Statistics software, Version 25 (IBM, Armonk, NY, USA). Associations with 2-sided p-values of <0.05 were considered statistically significant.

RESULTS

The characteristics of the children at baseline and at 2-year follow-up are described in Table 1. Out of 448 children with complete data on PA, ST, and sleep duration at baseline, 235 (52.5%) complied with all three 24-hour movement guidelines (Figure 1), 173 (38.6%) two guidelines, 37 (8.3%) one guideline, and 3 (0.7%) none of the guidelines. Out of 365 children with complete data on PA, ST, and sleep duration at 2-year follow-up, 91 (24.9%) complied with all three guidelines (Figure 2), 167 (45.8%) two guidelines, 91 (24.9%) one guideline, and 16 (4.4%) none of the guidelines.

Adherence to the 24-hour movement guidelines

Children who met all three 24-hour movement guidelines at baseline had 3.4 (95% confidence interval [CI] 1.97 to 6.02) times higher odds of meeting the guidelines also at 2-year follow-up compared with children who did not meet the guidelines at baseline after adjustments (P<0.001). Similarly, children who met the PA guidelines at baseline had 2.5 (95% CI 1.41 to 4.56) times higher odds of meeting the PA guidelines also at 2-year follow-up compared with children who did not meet the PA guidelines at baseline (P=0.002). Children who met the ST guidelines at baseline had 5.0 (95% CI 2.88 to 8.74) times higher odds of meeting the ST guidelines at 2-year follow-up compared with children who did not meet the ST guidelines at baseline (P<0.001). Meeting the sleep guidelines at baseline was significantly not associated with odds of meeting the sleep guidelines at 2-year follow-up (OR 1.9, 95% CI 0.87 to 4.32, P=0.11).

Cross-sectional associations between adherence to the 24-hour movement guidelines and cardiometabolic risk factors at baseline

Meeting all three guidelines, the guidelines for PA and ST, the guidelines for PA and sleep, or the guidelines for PA alone were inversely associated with CRS, WC, and insulin after adjustments for sex, age, parental education, and study group (Table 2). Similarly, meeting all three guidelines or the guidelines for PA alone were inversely associated with DBP and directly with HDL cholesterol. After further adjustment for BF%, the associations were no longer significant (P>0.05). Meeting the guidelines for ST and sleep or for ST alone were inversely associated with insulin after adjustment for sex, age, parental education, and study group. After further adjustment for BF%, the associations remained significant (ST+sleep: B -0.54, 95% CI -0.98 to -0.09; ST: B -0.51, 95% CI -0.99 to -0.03), respectively. Meeting three guidelines compared to two, one or zero guidelines was inversely associated with CRS, WC, and insulin after adjustment for sex, age, parental education, and study group (Table 3).

Longitudinal associations between adherence to the 24-hour movement guidelines and cardiometabolic risk factors

Meeting all three guidelines, the guidelines for PA and ST, or the guidelines for PA alone at baseline was inversely associated with CRS, WC, and insulin at 2-year follow-up after adjusting for sex and age, parental education, and study group (Table 4). After further adjustment for BF%, the associations were no longer significant (P>0.05). Meeting three guidelines compared to two, one, or zero at baseline was inversely associated with CRS and WC at 2-year follow-up after adjusting for sex and age, parental education, and study group (Table 3). In addition, meeting three guidelines compared to one or zero at baseline was inversely associated with insulin. All associations became non-significant after further adjustment for BF%.

DISCUSSION

Our study shows that over half of the school-aged children who participated in the PANIC study met all three 24-hour movement guidelines at baseline, while the proportion was one-fourth two years later. Meeting the guidelines, for all except sleep, at baseline increased the odds of meeting the guidelines at 2-year follow-up compared to not meeting the guidelines at baseline. Furthermore, meeting the guidelines, except for sleep, was cross-sectionally and longitudinally associated with reduced cardiometabolic risk. However, the associations with cardiometabolic risk were largely explained by differences in BF%.

The proportion of children meeting all three guidelines was higher than the proportions reported in other studies.[6,13,14,30] The majority of children met the guidelines for sleep, while the rates were lowest for ST, being still above the rates reported in other studies.[6,13,30] The decrease in the adherence over the 2-year follow-up was highest regarding sleep, whereas adherence to ST was moderate and PA did not change remarkably. Varying proportions of children adhering to the guidelines between the studies may be due to differences in the age of the participating children, cultural-related practices regarding movement behaviors as well as different methodologies in assessing movement behaviors. Having a sufficient amount of sleep has been associated with numerous health benefits in children,[3] and therefore, our finding highlight the need to promote healthy sleep habits in early childhood. Moreover, the time period from 8 to 10 years may be critical in terms of increasing ST due to entertaining and/or educational reasons. Since we also found that adherence to guidelines tracked over the 2-year follow-up, the findings highlight the need to establish good practices already at an early age. Tracking of adherence to 24-hour movement guidelines has previously been reported in preschool-aged children,[7] but not among students.[8] Our study shows that the tracking is apparent also in school-aged children, except what comes to sleep. Therefore, achieving the guidelines already in early childhood may help to adhere to the guidelines and maintain cardiometabolic health when children get older.

To the best of our knowledge, this is the first study investigating longitudinal associations of adherence to 24-hour movement guidelines with cardiometabolic risk factors.

Meeting all the guidelines in which PA was included at baseline were associated with reduced overall cardiometabolic risk (i.e., CRS) and several individual risk factors (i.e., mainly insulin and WC) at 2-year follow-up. The findings indicate that PA may be the driver in supporting cardiometabolic health in midchildhood above and beyond ST and sleep. Using different levels of each movement behaviors, Hjorth et al.[15] found that lower levels of MVPA and shorter sleep were associated with an increased cardiometabolic risk profile over 200-day follow-up. Yet, our findings provide more knowledge on the associations over a longer follow-up period, and indicate that paying attention to more than one movement behaviour at the same time may optimize the health benefits in the long-term. However, due to the different methodologies applied between studies, including differences in follow-up periods, and in the assessment of movement behaviors and cardiometabolic risk factors, the findings should be confirmed in future studies. Furthermore, our results showed that body fat influences the associations, which has been found also in Danish children.[15] In future studies it is also important to investigate more deeply the interactive associations of body fat and movement behaviors with cardiometabolic risk factors, and to clarify whether body fat is a mediator or primary cause (i.e., children with overweight have less PA and sleep as well as more ST leading to increased cardiometabolic risk). Yet, it is evident that interventions promoting healthy body composition in childhood are warranted in order to support cardiovascular health in later life. Although we have earlier found that most children participating in the PANIC study did not meet the dietary recommendations,[31] dietary factors did not explain the observed associations of meeting the PA guidelines with cardiometabolic risk factors. However, there may still be some residual confounding by dietary factors in the associations found, so diet needs to be taken into account in future studies dealing with the associations of movement behaviors with cardiometabolic risk factors.

Contrary to the longitudinal findings, we observed cross-sectionally that meeting all the guidelines in which PA was included was associated with lower overall cardiometabolic risk (i.e., CRS) and more favourable levels of individual risk factors (i.e., lower insulin, DBP, and WC, and higher HDL cholesterol). Our findings are in line with previous reports[13,14] suggesting that meeting multiple guidelines may have a positive effect in reducing cardiometabolic risk. However, we also showed that the observed associations were explained by differences in body fat. Therefore, body fat should be taken into account when investigating associations of adherence to movement behaviors with cardiometabolic risk factors in future studies.

We found that meeting the guidelines for ST and sleep or the guidelines for ST alone were inversely associated with insulin at baseline, and these associations remained significant also after adjustment for body fat. Carson and colleagues[13] have previously reported that meeting the guidelines for ST and sleep was associated with a lower WC. It is notable that the somewhat different methodologies in assessing ST and sleep may partly explain the differences in the results. Assessing ST using self-report can be problematic due to the multitude of platforms and the sporadic and multi-tasking nature of ST in children. Thus, there is a need to clarify associations of different types of ST (e.g., passive or active use, use for entertaining or educational purposes) with cardiometabolic risk factors. The results of a previous review[32] suggested that adequate sleep duration in children and adolescents is associated with lower cardiometabolic risk.[32] Possible reasons for these findings include alterations in the regulation of appetite and glucose as well as sympathovagal balance, but these mechanisms are largely based on observations from studies among adults.[32] One of the reasons for a weak association between sleep and cardiometabolic risk factors in our study may be that the children were from a general population, and thus most of them had no diseases and had a relatively healthy lifestyle in terms of PA and sleep. Therefore, more research are warranted in populations with lower physical activity levels and higher levels of sedentary time.

The strengths of the present study include the valid assessment of free-living PA and sleep by individually calibrated combined movement and heart rate sensing, comprehensive measurement of cardiometabolic risk factors and use of a continuous CRS instead of arbitrary cut-offs for single risk factors, and the assessment of body composition using whole-body dual-energy X-ray absorptiometry. In addition, the ST included all types of ST (i.e., watching television and videos, using computer and playing video and console games, and using mobile phone and playing mobile games) instead of restricting ST only to TV viewing. Finally, body size and composition in the study sample were similar than in children of the large national reference population[25] increasing generalization of the results to other children of the same age in Finland.

A weakness of our study is that 60% of the children were included in the intervention group and participated in six family-based intervention visits during the 2-year follow-up. However, there were no statistically significant differences in movement behaviors or cardiometabolic risk factors between children in the intervention and those in the control group. Moreover, the result did not differ essentially when the data were adjusted for the study group. This limits the conclusion about causality between the observed associations. We also assessed ST using a questionnaire filled out by the parents that has not been validated in Finnish children. It is possible that the questionnaire may have led to misreporting times spent in different types of activities, and further, total minutes spent in ST and the proportion of children meeting the ST guidelines.

In conclusion, over half of the children met all three 24-hour movement guidelines at baseline, while the proportion decreased to one-fourth at 2-year follow-up. Meeting the guidelines at baseline increased the odds of meeting the guidelines over 2-year follow-up compared to not meeting the guidelines, except sleep, at baseline. Furthermore, meeting most of the guidelines was cross-sectionally and longitudinally associated with overall cardiometabolic risk and several individual risk factors. However, the associations were in part explained by differences in BF%.

PERSPECTIVES

Our study shows that meeting the 24-hour movement behavior guidelines, all except sleep, at baseline increased the odds of meeting the guidelines at 2-year follow-up. Furthermore, the findings of our cross-sectional and longitudinal analyses emphasize the need to promote movement behaviors, especially physical activity, in order to support cardiovascular health of the young children. Yet, there is a need to longer follow-up studies examining the factors related to higher adherence to the guidelines in long term. Such knowledge would be highly valuable, not only for researchers, but also for clinicians in promoting health of young children and their families.

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Conflict of interest

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Figure legends

Figure 1. Proportion of children adhering to the 24-hour movement guidelines at baseline

Figure 2. Proportion of children adhering to the 24-hour movement guidelines at 2-year follow-up

Table 1. Characteristics of children (N=485)

	At baseline			At 2-year follow-up		
	N	%	Mean (SD)	N	%	Mean (SD)
Sex (%, boys)	485	51.3		485	51.3	
Age (years)	485		7.6 (0.4)	426		9.8 (0.4)
Height (cm)	485		129 (5.7)	426		141 (6.3)
Weight (kg)	484		26.9 (5.0)	426		34.4 (7.3)
BMI-SDS† (kg/m^2)	484		-0.2 (1.1)	426		-0.1 (1.1)
Overweight or obese‡	63	13.0		73	17.1	
Body fat (%)	476		19.9 (8.2)	406		23.4 (9.2)
Parental education level§						
Low	94	19.4		62	14.8	
Medium	217	44.8		196	46.7	
High	173	35.7		162	38.6	
Study group (intervention)	192	39.6		192	39.6	
Actiheart wearing time in days	475		4.6 (1.5)	390		3.9 (1.1)
24-hour movement behaviors						
Moderate-to-vigorous physical activity (min/day)	450		115 (64.3)	373		100 (56.2)
Screen time (min/day)	484		101 (52.1)	419		122 (57.3)
Sleep duration (h/night)	470		9.7 (0.5)	380		9.2 (0.6)
Cardiometabolic risk factors						
CRS	463		0.06 (3.6)	406		0.04 (3.5)

Waist circumference (cm)	485	56.8 (5.9)	426	61.3 (7.3)
Insulin (mU/l)	464	4.5 (2.4)	407	6.1 (3.5)
Glucose (mmol/l)	474	4.8 (0.4)	413	5.0 (0.4)
TG (mmol/l)	474	0.6 (0.2)	413	0.6 (0.3)
HDL cholesterol (mmol/l)	474	1.6 (0.3)	413	1.6 (0.3)
SBP (mmHg)	484	100 (7.3)	426	101 (7.6)
DBP (mmHg)	484	61.5 (7.1)	426	61.4 (7.8)

Abbreviations: BMI-SDS, body mass index SD score; CRS, cardiometabolic risk score; TG, triglycerides; HDL, high-density lipoprotein; SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation.

† According to Saari et al. (2011) ‡ According to Cole et al. (2012) § Low indicates ≤ vocational school, medium indicates polytechnic, and high indicates university degree.

Table 2. Cross-sectional associations between meeting the 24-hour movement guidelines and cardiometabolic risk factors at baseline.

Cardiometabolic risk factors		Meeting guidelines						
		All guidelines	PA and ST	PA and sleep	ST and sleep	PA	ST	Sleep
		B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)
CRS	**Model 1**	-1.49 (-2.15, -0.83)***	-1.34 (-2.01, -0.67)***	-1.45 (-2.19, -0.72)***	-1.01 (-1.71, -0.31)**	-1.66 (-2.48, -0.84)***	-0.82 (-1.57, -0.07)*	-0.68 (-1.81, 0.46)
	Model 2	-1.33 (-1.98, -0.68)***	-1.16 (-1.83, -0.50)***	-1.44 (-2.17, -0.71)***	-0.89 (-1.59, -0.19)*	-1.66 (-2.49, -0.84)***	-0.66 (-1.42, 0.10)	-0.73 (-1.85, 0.39)
WC	**Model 1**	-3.19 (-4.25, -2.14)***	-3.17 (-4.24, -2.10)***	-3.59 (-4.76, -2.42)***	-1.36 (-2.51, -0.21)*	-4.36 (-5.64, -3.07)***	-1.19 (-2.42, 0.04)	-1.27 (-3.13, 0.58)
	Model 2	-2.87 (-3.92, -1.82)***	-2.87 (-3.95, -1.81)***	-3.74 (-4.89, -2.59)***	-0.96 (-2.11, 0.19)	-4.71 (-5.98, -3.43)***	-0.70 (-1.94, 0.53)	-1.19 (-3.02, 0.64)
Insulin	**Model 1**	-0.90 (-1.35, -0.45)***	-0.84 (-1.30, -0.38)***	-0.91 (-1.41, -0.40)***	-0.66 (-1.14, -1.19)**	-1.08 (-1.64, -0.52)***	-0.58 (-1.10, -0.07)*	-0.43 (-1.21, 0.35)
	Model 2	-0.83 (-1.28, -0.38)***	-0.75 (-1.20, -0.29)**	-0.80 (-1.31, -0.30)**	-0.71 (-1.19, -0.23)**	-0.95 (-1.52, -0.38)**	-0.60 (-1.12, -0.09)*	-0.48 (-1.25, 0.29)
Glucose	**Model 1**	-0.02 (-0.09, 0.05)	0.00 (-0.07, 0.07)	-0.02 (-0.10, 0.06)	-0.06 (-0.13, 0.01)	0.00 (-0.08, 0.09)	-0.04 (-0.12, 0.04)	-0.06 (-0.18, 0.06)
	Model 2	-0.01 (-0.08, 0.06)	0.01 (-0.06, 0.08)	-0.04 (-0.12, 0.04)	-0.03 (-0.10, 0.05)	-0.03 (-0.12, 0.06)	-0.01 (-0.08, 0.08)	-0.05 (-0.17, 0.07)
TG	**Model 1**	-0.04 (-0.09, 0.01)	-0.04 (-0.09, 0.00)	-0.04 (-0.09, 0.01)	-0.04 (-0.09, 0.01)	-0.06 (-0.12, 0.00)*	-0.05 (-0.10, 0.01)	-0.01 (-0.09, 0.07)
	Model 2	-0.04 (-0.08, 0.01)	-0.04 (-0.09, 0.01)	-0.03 (-0.08, 0.02)	-0.04 (-0.09, 0.01)	-0.04 (-0.10, 0.01)	-0.05 (-0.10, 0.01)	-0.01 (-0.09, 0.07)
HDLc	**Model 1**	0.07 (0.01, 0.13)*	0.07 (0.02, 0.13)*	0.07 (0.01, 0.14)*	0.03 (-0.03, 0.09)	0.12 (0.05, 0.19)**	0.03 (-0.03, 0.10)	-0.03 (-0.13, 0.07)
	Model 2	0.07 (0.01, 0.13)*	0.08 (0.02, 0.14)*	0.06 (-0.00, 0.13)	0.04 (-0.03, 0.10)	0.11 (0.04, 0.18)**	0.04 (-0.02, 0.11)	-0.03 (-0.13, 0.07)
SBP	**Model 1**	-1.23 (-2.58, 0.12)	-0.83 (-2.20, 0.55)	-0.85 (-2.35, 0.65)	-1.49, -2.92, -0.06)*	-0.45 (-2.12, 1.22)	-1.27 (-2.80, 0.27)	-1.19 (-3.48, 1.11)
	Model 2	-1.01 (-2.37, 0.36)	-0.53 (-1.92, 0.86)	-0.78 (-2.30, 0.74)	-1.40 (-2.86, 0.05)	-0.33 (-2.03, 1.38)	-1.05 (-2.61, 0.52)	-1.28 (-3.59, 1.03)
DBP	**Model 1**	-1.65 (-2.97, -0.32)*	-1.47 (-2.82, -0.12)*	-1.68 (-3.15, -0.21)*	-0.56 (-1.97, 0.85)	-1.81 (-3.45, -0.18)*	-0.42 (-1.93, 1.09)	-0.43 (-2.69, 1.84)
	Model 2	-1.40 (-2.74, -0.06)*	-1.22 (-2.59, 0.14)	-1.79 (-3.28, -0.30)*	-0.23 (-1.67, 1.21)	-1.97 (-3.64, -0.30)*	-0.02 (-1.56, 1.53)	-0.50 (-2.77, 1.78)

Abbreviations: CRS, cardiometabolic risk score; WC, waist circumference; DBP, diastolic blood pressure; HDL, high-density lipoprotein; SBP, systolic blood pressure; TG, triglyceride; PA, physical activity, ST, screen time. CRS was calculated as the sum of z-scores of WC + insulin + glucose + TG - HDL cholesterol + mean of SBP and DBP.

Values are unstandardized regression coefficients (B) with their 95% confidence intervals (95% CI) from linear regression analyses providing estimates of meeting the guidelines (not meeting as a reference group) associated with change in the cardiometabolic risk factors (CRS, WC [cm], insulin [mU/l], glucose [mmol/l], TG [mmol/l], HDL [mmol/l], SBP [mmHg], DBP [mmHg]). The Model 1 was unadjusted and Model 2 was adjusted for age, sex, parental education, and research group. * p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001. In Model 1 N for CRS was 428, for WC 448, for insulin 429, for glucose, TG, and HDL cholesterol 439, and for SBP and DBP 447. In Model 2, N for CRS was 427, for WC 447, for insulin 428, for glucose, TG, and HDL cholesterol 438, and for SBP and DBP 446.

Table 3. Associations between the number of guidelines met and cardiometabolic risk factors.

Cardiometabolic risk factors at baseline	Number of guidelines met at baseline		
	2 vs 0 or 1	3 vs 0 or 1	3 vs 2
	B (95% CI)	B (95% CI)	B (95% CI)
CRS	-0.54 (-1.76, 0.69)	-1.76 (-2.95, -0.57)**	-1.23 (-1.92, -0.53)**
WC	-1.24 (-3.19, 0.70)	-3.87 (-5.76, -1.99)***	-2.63 (-3.74, -1.52)***
Insulin	-0.60 (-1.44, 0.24)	-1.32 (-2.13, -0.50)**	-0.72 (-1.19, -0.24)**
Glucose	-0.10 (-0.23, 0.02)	-0.09 (-0.22, 0.03)	0.01 (-0.06, 0.09)
TG	-0.06 (-0.15, 0.03)	-0.08 (-0.17, -0.00)*	-0.03 (-0.07, 0.03)
HDL cholesterol	0.02 (-0.09, 0.13)	0.09 (-0.02, 0.19)	0.07 (0.00, 0.13)*
SBP	-0.56 (-3.09, 1.96)	-1.46 (-3.91, 0.99)	-0.90 (-2.35, 0.55)
DBP	0.83 (-1.66, 3.31)	-0.74 (-3.14, 1.67)	-1.56 (-2.99, -0.14)*
	Number of guidelines met at baseline		
Cardiometabolic risk factors at 2-year follow-up	**2 vs 0 or 1**	**3 vs 0 or 1**	**3 vs 2**
	B (95% CI)	**B (95% CI)**	**B (95% CI)**
CRS	-0.82 (-2.12, 0.49)	-1.72 (-2.99, -0.46)**	-0.91 (-1.67, -0.15)*
WC	-1.91 (-4.45, 0.64)	-4.36 (-6.83, -1.89)**	-2.45 (-3.94, -0.97)**
Insulin	-0.90 (-2.18, 0.38)	-1.54 (-2.78, -0.30)*	-0.64 (-1.38, 0.10)
Glucose	0.01 (-0.13, 0.14)	-0.04 (-0.18, 0.09)	-0.05 (-0.13, 0.03)
TG	-0.08 (-0.19, 0.02)	-0.08 (-0.18, 0.02)	0.00 (-0.06, 0.06)
HDL cholesterol	-0.00 (-0.12, 0.12)	0.04 (-0.08, 0.15)	0.04 (-0.04, 0.11)
SBP	1.01 (-1.78, 3.80)	0.77 (-1.95, 3.48)	-0.25 (-1.87, 1.38)
DBP	1.32 (-1.59, 4.24)	0.08 (-2.75, 2.92)	-1.24 (-2.94, 0.46)

Abbreviations: CRS, cardiometabolic risk score; DBP, diastolic blood pressure; HDL, high-density lipoprotein; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference. CRS was calculated as the sum of z-scores of WC + insulin + glucose + TG - HDL cholesterol + mean of SBP and DBP.

Values are unstandardized regression coefficients (B) with their 95% confidence intervals (95% CI) from linear regression analyses providing estimates of the number of meeting the guidelines (lower number as a reference group) associated with change in the cardiometabolic risk factors (CRS, WC [cm], insulin [mU/l], glucose [mmol/l], TG [mmol/l], HDL [mmol/l], SBP [mmHg], DBP [mmHg]). All models were adjusted for age, sex, parental education, and study group at baseline. * p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001.

Table 4. Prospective associations between meeting guidelines at baseline and cardiometabolic risk factors at 2-year follow-up.

Cardiometabolic risk factors		Meeting guidelines: All guidelines	PA and ST	PA and sleep	ST and sleep	PA	ST	Sleep
		B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)
CRS	Model 1	-1.19 (-1.90, -0.48)**	-1.29 (-2.01, -0.57)***	-1.33 (-2.12, -0.54)**	-0.58 (-1.34, 0.17)	-1.63 (-2.51, -0.75)***	-0.53 (-1.34, 0.28)	-0.57 (-1.77, 0.63)
	Model 2	-1.07 (-1.78, -0.36)**	-1.14 (-1.86, -0.41)**	-1.29 (-2.08, -0.50)**	-0.53 (-1.29, 0.24)	-1.59 (-2.48, -0.70)**	-0.39 (-1.21, 0.43)	-0.62 (-1.82, 0.58)
WC	Model 1	-3.36 (-4.79, -1.93)***	-3.46 (-4.91, -2.02)***	-3.36 (-4.95, -1.77)***	-1.83 (-3.36, -0.30)**	-4.27 (-6.03, -2.52)***	-1.64 (-3.29, 0.01)	-1.16 (-3.63, 1.30)
	Model 2	-2.83 (-4.23, -1.43)***	-2.99 (-4.41, -1.57)***	-3.65 (-5.18, -2.11)***	-1.04 (-2.55, 0.47)	-4.86 (-6.57, -3.16)***	-0.68 (-2.31, 0.95)	-1.13 (-3.52, 1.26)
Insulin	Model 1	-0.89 (-1.60, -0.17)*	-1.20 (-1.92, -0.49)**	-1.02 (-1.82, -0.23)*	-0.35 (-1.10, 0.41)	-1.59 (-2.47, -0.71)***	-0.53 (-1.34, 0.27)	0.06 (-1.14, 1.26)
	Model 2	-0.82 (-1.52, -0.12)*	-1.07 (-1.77, -0.36)**	-0.72 (-1.50, 0.06)	-0.51 (-1.26, 0.23)	-1.19 (-2.07, -0.31)**	-0.65 (-1.45, 0.14)	0.05 (-1.13, 1.22)
Glucose	Model 1	-0.05 (-0.12, 0.03)	-0.04 (-0.11, 0.04)	-0.04 (-0.12, 0.05)	-0.04 (-0.12, 0.04)	-0.01 (-0.10, 0.08)	-0.02 (-0.11, 0.06)	-0.05 (-0.18, 0.07)
	Model 2	-0.05 (-0.12, 0.03)	-0.04 (-0.11, 0.04)	-0.05 (-0.13, 0.04)	-0.03 (-0.11, 0.05)	-0.03 (-0.13, 0.06)	-0.01 (-0.09, 0.08)	-0.04 (-0.17, 0.09)
TG	Model 1	-0.02 (-0.08, 0.04)	-0.02 (-0.08, 0.03)	-0.05 (-0.11, 0.01)	-0.00 (-0.06, 0.06)	-0.05 (-0.13, 0.02)	0.01 (-0.06, 0.07)	-0.04 (-0.13, 0.06)
	Model 2	-0.01 (-0.07, 0.04)	-0.02 (-0.08, 0.04)	-0.05 (-0.11, 0.02)	-0.00 (-0.06, 0.06)	-0.05 (-0.12, 0.03)	0.01 (-0.06, 0.07)	-0.05 (-0.14, 0.05)
HDLc	Model 1	0.04 (-0.03, 0.10)	0.05 (-0.02, 0.12)	0.03 (-0.05, 0.10)	0.02 (-0.05, 0.08)	0.07 (-0.02, 0.15)	0.02 (-0.05, 0.10)	-0.04 (-0.15, 0.07)
	Model 2	0.04 (-0.03, 0.10)	0.05 (-0.02, 0.12)	0.01 (-0.06, 0.09)	0.02 (-0.05, 0.09)	0.05 (-0.04, 0.13)	0.03 (-0.05, 0.11)	-0.04 (-0.15, 0.07)
SBP	Model 1	-0.34 (-1.86, 1.19)	-0.21 (-1.75, 1.33)	-0.07 (-1.76, 1.61)	-0.29 (-1.89, 1.32)	0.46 (-1.42, 2.33)	-0.26 (-1.98, 1.46)	-1.00 (-3.57, 1.56)
	Model 2	-0.05 (-1.58, 1.48)	0.25 (-1.30, 1.81)	0.11 (-1.58, 1.80)	-0.15 (-1.78, 1.47)	0.91 (-0.99, 2.82)	0.10 (-1.64, 1.85)	-1.42 (-3.98, 1.15)
DBP	Model 1	-0.98 (-2.55, 0.59)	-0.97 (-2.56, 0.62)	-1.48 (-3.21, 0.26)	0.48 (-1.18, 2.13)	-1.74 (-3.67, 0.18)	0.56 (-1.21, 2.34)	-0.77 (-3.41, 1.87)
	Model 2	-0.98 (-2.58, 0.62)	-1.01 (-2.63, 0.62)	-1.58 (-3.34, 0.19)	0.58 (-1.12, 2.28)	-1.97 (-3.95, 0.02)	0.66 (-1.17, 2.48)	-0.71 (-3.40, 1.98)

Abbreviations: CRS, cardiometabolic risk score; WC, waist circumference; DBP, diastolic blood pressure; HDL, high-density lipoprotein; SBP, systolic blood pressure; TG, triglyceride; PA, physical activity, ST, screen time. CRS was calculated as the sum of z-scores of WC + insulin + glucose + TG - HDL cholesterol + mean of SBP and DBP.

Values are unstandardized regression coefficients (B) with their 95% confidence intervals (95% CI) from linear regression analyses providing estimates of meeting the guidelines (not meeting as a reference group) associated with change in the cardiometabolic risk factors (CRS, WC [cm], insulin [mU/l], glucose [mmol/l], TG [mmol/l], HDL [mmol/l], SBP [mmHg], DBP [mmHg]). The Model 1 was unadjusted and Model 2 was adjusted for age, sex, parental education, and research group. * p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001. In Model 1 N for CRS was 369, for WC 389, for insulin 370, for glucose, TG, and HDL cholesterol 376, and for SBP and DBP 389. In Model 2, N for CRS was 368, for WC 388, for insulin 369, for glucose, TG, and HDL cholesterol 375, and for SBP and DBP 388.

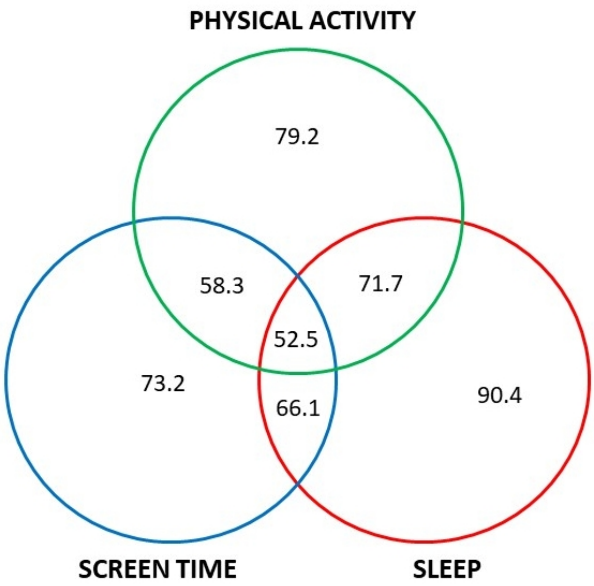

Figure 1. Proportion of children adhering to the 24-h movement guidelines at baseline (N=448)

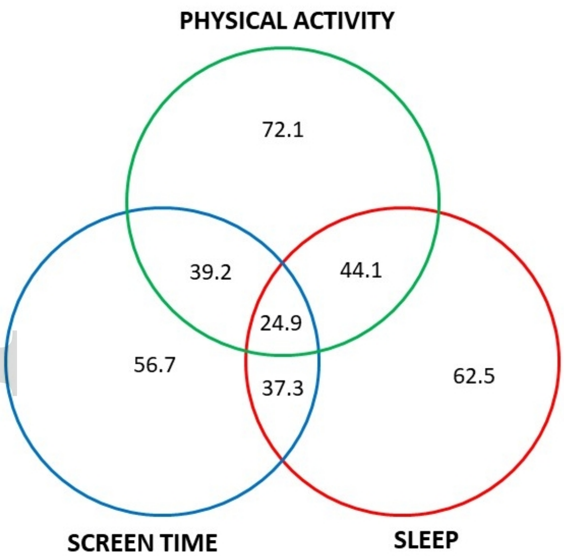

Figure 2. Proportion of children adhering to the 24-h movement guidelines at 2-year follow-up (N=365)