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Associations of movement behaviors, sleep time, and demographics with five wellbeing dimensions in Danish schoolchildren: a cross-sectional analysis

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Abstract

Background

Movement behaviors and sleep duration are associated with wellbeing in children; however, evidence regarding their relative contributions to different wellbeing dimensions remains limited. Therefore, this study explores the cross-sectional associations between device-measured movement and sleep behaviors and different wellbeing dimensions.

Methods

A total of 792 Danish schoolchildren aged 6–9 years were included in the analyses. Moderate-to-vigorous physical activity (MVPA), light physical activity (LPA), sedentary behavior (SB), and sleep time were measured using thigh-worn accelerometers (Axivity AX3) for seven consecutive days. Physical and psychological wellbeing were self-reported using the KIDSCREEN-VIDEO questionnaire. Internalizing problems, externalizing problems, and prosocial behavior were parent-reported using the Strengths and Difficulties Questionnaire. Linear regression models were used to estimate the proportion of variance in each wellbeing dimension explained by movement behaviors (MVPA, LPA, and SB), sleep time, demographic variables, and school class.

Results

The full models explained between 4.7% and 10.3% of the variance across the wellbeing dimensions. Movement behaviors and sleep time collectively accounted for the largest proportion of explained variance in physical wellbeing (3.9%). MVPA showed the strongest contribution to physical wellbeing and internalizing problems, whereas SB contributed most to externalizing problems. School class accounted for a similar proportion of variance in psychological wellbeing as the full model (~ 7.5%).

Conclusion

Movement behaviors and sleep time explained only a limited proportion of the variance in wellbeing among children, with behavior-specific associations across dimensions. These findings suggest that physical activity interventions may benefit specific dimensions of wellbeing rather than wellbeing more broadly and that peer and classroom environments are important. **Clinical trial registration**: ClinicalTrials.gov, NCT05940675; registered on 4 July 2023.

1.0 INTRODUCTION

Wellbeing is a complex, multidimensional construct encompassing both positive and negative aspects of feeling and functioning well across the physical, emotional, and social domains of everyday life (Cho and Fuk-Yuen Yu 2020; Gautam et al. 2024; Pollard and Lee 2003). Societies face substantial challenges due to the increasing prevalence of poor wellbeing and mental health problems among children and adolescents (Baranne and Falissard 2018; Pommerencke et al. 2023). Low wellbeing during childhood and adolescence has been

linked to school dropout (Ridder et al. 2013; Tong et al. 2023), academic difficulties (e.g., lower educational attainment and disruptive behavior), increased substance use, and self-harm throughout the life course (Esch et al. 2014; Ridder et al. 2013), as well as longer-term consequences such as economic instability, homelessness, and suicide (Erskine et al. 2015). These concerns underscore the importance of identifying modifiable factors that may support children's wellbeing.

Movement behaviors, including moderate-to-vigorous physical activity (MVPA), light physical activity (LPA), sedentary behavior (SB), and sleep duration, have been associated with a range of health benefits among children and adolescents (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). However, existing evidence has largely focused on their relationship with physical health outcomes, such as obesity, cardiometabolic risk, physical fitness, and musculoskeletal health (Wilhite et al. 2023). Although these factors may, in turn, influence emotional and social dimensions of wellbeing, evidence directly linking everyday movement behaviors and sleep duration to wellbeing, particularly across different wellbeing dimensions, remains limited and somewhat inconsistent (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Most previous studies have examined movement behaviors in isolation or focused primarily on combinations of MVPA and SB, with comparatively less attention given to sleep (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Nevertheless, studies that have included sleep suggest that longer total sleep time may be associated with more favorable wellbeing outcomes, suggesting a potential protective role (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024).

Given the multidimensional nature of wellbeing, it is important to understand whether movement behaviors and sleep duration are similarly associated with different aspects of wellbeing. Different dimensions of wellbeing have rarely been examined within the same study, limiting opportunities to compare how movement behaviors and sleep duration relate to different aspects of wellbeing (Ferreira et al. 2025; Wilhite et al. 2023). Furthermore, to our knowledge, only one systematic review has investigated the associations of movement behaviors and sleep duration with different dimensions of wellbeing among children (Ferreira et al. 2025). Together, these findings highlight a gap in understanding whether movement behaviors and sleep duration are differentially associated with distinct dimensions of wellbeing.

Another gap in the literature is the widespread reliance on self- or proxy-reported measures of movement behaviors and sleep time, which may introduce recall bias and reduce measurement precision (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Device-based measures, such as accelerometry, offer several advantages over these subjective approaches. For example, children, especially younger ones, are often unable to reliably recall their own physical activity (Reilly et al. 2008), and their movement patterns are typically spontaneous and unstructured, making it difficult for parents to report them accurately (Colley et al. 2012; Rowlands and Eston, n.d.). Indeed, one population-based survey found that parents reported approximately 70% more daily MVPA than accelerometry (Colley et al. 2012). Beyond bias avoidance, accelerometry is currently the only practical tool capable of simultaneously and continuously capturing all four movement

behaviors within a single 24-hour measurement period, enabling reliable estimates of time spent across different movement intensities, including MVPA, LPA, SB, and sleep time (Colley et al. 2012). Nevertheless, device-based measures have been used less frequently in studies examining wellbeing outcomes (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Similarly, wellbeing is often assessed using single-item measures, which limits content validity and precision (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). This heterogeneity in the measurement and operationalization of both movement behaviors and wellbeing complicates comparisons across studies and limits the understanding of how different movement behaviors and sleep duration relate to distinct dimensions of wellbeing (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024).

Therefore, the relative contributions of different movement behaviors and sleep time to wellbeing remain unclear, particularly across specific wellbeing dimensions. To address these gaps, the present study explores the cross-sectional associations between device-measured movement behaviors and total sleep time, and different dimensions of wellbeing in a large sample of Danish children aged six to nine years.

2.0 METHODS

2.1 *Study design, recruitment, and participants*

The current analyses are based on cross-sectional baseline data from a Danish cluster-randomized controlled trial, the Generation Healthy Kids project. Participants were recruited from three of the five regions in Denmark: the Capital Region, the Zealand Region, and the Region of Southern Denmark. Across three invitation rounds, 496 schools were invited, and 24 schools across 15 municipalities agreed to participate and were enrolled in the study. Schools constituted randomization units (clusters), while children constituted the units of analysis. Following the randomization process, one school allocated to the control group withdrew prior to the baseline assessment, resulting in 23 participating schools (12 intervention and 11 control schools), all included in the present analyses. At the individual level, eligible participants were children enrolled in 1st and 2nd grade (aged 6–9 years). All eligible children in the participating schools were invited. Parents or legal guardians (hereafter referred to as parents) received oral and written study information, and written informed consent was obtained prior to their participation. In total, 1,350 of the 2,006 eligible children (i.e., 67%) were enrolled before baseline assessments. A detailed description of the recruitment procedures, cluster allocation, participant enrollment, and flow of participants is provided elsewhere (Thomsen et al. 2024).

2.2 *Self-reported psychological and physical wellbeing*

Psychological and physical wellbeing were assessed using the video-formatted, age-adjusted, and validated Danish version of the KIDSCREEN-27 self-report measure: KIDSCREEN-VIDEO, which has been shown to be appropriate for Danish children aged six to ten years (Kurtzhals et al. 2025; Ravens-Sieberer et al. 2007). Each child completed the questionnaire on an iPad while wearing headphones, with trained research assistants present to provide support if necessary. The present study included two of the five dimensions measured by KIDSCREEN-27: *physical wellbeing* (five items) and *psychological wellbeing* (seven items). Physical wellbeing

assesses mobility, energy, relaxation, health, and physical discomfort, whereas psychological wellbeing assesses positive and negative feelings, worry and stress, life satisfaction, and optimism (Kurtzhals et al. 2025; Ravens-Sieberer et al. 2014). In accordance with the KIDSCREEN manual, each item was rated on a 5-point Likert scale, and item 1 of the physical wellbeing subscale was recoded such that responses of 1–2 were assigned a value of 1, responses of 3–4 a value of 2, and responses of 5 a value of 3 (Ravens-Sieberer et al. 2014). The two subscale scores were calculated as the means of the items within each subscale (after recoding item 1 in the physical wellbeing dimension) and standardized to a 0-100 scale, with higher scores indicating better wellbeing.

2.3 *Parent-reported emotional and behavioral difficulties*

Mental health problems were assessed using the parent-reported version of the Strengths and Difficulties Questionnaire (SDQ) (Goodman 2001). Permission to use the Danish electronic version of the SDQ was obtained through the Danish Committee for Health Information (Danish: *Komitéen for Sundhedsoplysning*).

The SDQ has been thoroughly validated in Danish populations (Niclasen et al. 2018, 2012). A link to a parent questionnaire, including the SDQ, was distributed via text message to participants' parents at baseline. The SDQ comprises 25 items assessing both negative and positive aspects of psychosocial functioning, including emotional problems (e.g., anxiety and somatic symptoms), conduct problems (e.g., lies and fights), hyperactivity/inattention (e.g., restlessness and impulsivity), peer problems (e.g., being targeted and rejected), and prosocial behavior (Goodman 2001). Each dimension consists of five items rated on a 3-point Likert scale ranging from 'not true' to 'certainly true'. Higher scores indicate greater emotional and behavioral difficulties, except for the prosocial subscale, where higher scores indicate greater socio-emotional skills (e.g., sharing, kindness, empathy, and helping others) (Goodman 1997; Youth in Mind 2016). Two composite dimensions - *externalizing problems* and *internalizing problems* – were calculated by summing two negative aspects of psychosocial functioning domains each, while prosocial behavior was analyzed separately (Goodman 1997; Youth in Mind 2016). Previous research suggests that the internalizing and externalizing subscales demonstrate better discriminant validity than the five SDQ subscales among children in general populations, where symptom levels tend to be low (Goodman et al. 2010; Niclasen et al. 2013), while also preserving the distinction between problem types that a total difficulties score obscures. Therefore, an externalizing problems score was derived by summing the conduct problems and hyperactivity/inattention subscales, reflecting outward-directed behavioral difficulties (e.g., aggression and defiance). The internalizing problems score was calculated as the sum of the emotional problems and peer problems subscales, reflecting inward-directed emotional difficulties (e.g., sadness and worry) (Goodman et al. 2010; Youth in Mind 2016). Scores for the three subscales were calculated as the means of the items within each respective scale and subsequently standardized to a 0–100 scale, with 100 representing the highest possible score.

2.4 *Movement behaviors and total sleep time*

Movement behaviors and total sleep time were measured using an accelerometer (Axivity AX3; Axivity Ltd, Newcastle, United Kingdom) worn on the right anterior thigh for 24 hours a day for seven consecutive days. Daily LPA and MVPA minutes were derived by generating Actigraph counts in 10-second epochs from the raw acceleration data. The thresholds for discriminating LPA and MVPA were 100 and 4940 counts per minute, respectively. The cut-points were identified using an internally conducted calibration study (Brønd et al. 2019). SB was identified using the method described by Brønd et al. (Brønd et al. 2020), which uses a simple decision

tree algorithm utilizing five acceleration derived outcomes, in which the inclination angle of 47.5 degrees discriminates between sitting and standing (Brønd et al. 2020). Total sleep time (TST) was estimated using a two-model machine learning method. The first model used 13 features to predict time in bed, with the circadian rhythm of walking bouts having the greatest importance. Based on the predicted time in bed, sleep- and wake-epochs of 30 seconds were classified using 11 features, with particular importance attached to, e.g., the standard deviation of the angle, the maximal standard deviation in the acceleration, and temperature. TST was defined as the time spent asleep within the time-in-bed window, excluding epochs classified as awake (Johansen et al. 2026). Any non-wear was detected using the method described by Skovgaard et al. (Skovgaard et al. 2023). A measurement day is considered valid if less than two hours of non-wear were identified. For TST, no non-wear is allowed from 12 PM to 12 PM the next day. At least three weekdays and one weekend day are required for a subject to be included in the analysis, and the weekday and weekend-specific mean values were combined into a weighted average using 5/7 for weekdays and 2/7 for weekend days.

2.5 *Demographic variables: sex, age, and socioeconomic status*

An electronic background questionnaire was distributed via text message to participants' parents prior to baseline assessments. The questionnaire included information on sex, age, and parental education level (Thomsen et al. 2024). The highest household education level was recoded into six categories of socioeconomic status (SES), that is, primary, secondary, vocational, short higher, medium higher, and long higher education (Christensen et al. 2014).

2.6 *Data analysis*

Descriptive statistics and analyses of population characteristics were conducted in RStudio version 2023.06 using the following packages: *corrplot*, *dplyr*, and *e1071*. Cronbach's alpha coefficients were calculated to assess the internal consistency of the KIDSCREEN-VIDEO and SDQ scales, with values exceeding 0.7 considered acceptable (Field 2017; Goodboy and Martin 2020). To evaluate the integrity of the wellbeing data, inconsistencies in responses were examined using crosstabulation to identify potential conflicts between items. Information on item response distributions is provided in Appendix 1. To explore the data distributions and identify potential outliers, we constructed histograms (see Appendix 2). Data were further examined for the remaining assumptions of linear regression – homoscedasticity and independence of errors – and were found to meet these assumptions (Field 2017); see Appendix 4.

To examine the degree to which movement behaviors and total sleep time contribute to population-level variation across five dimensions of wellbeing, that is, psychological wellbeing, physical wellbeing, internalizing problems, externalizing problems, and prosocial behavior, we compared their contributions with those of demographic variables and school class in explaining variation in each outcome. Linear regression models were used to explore associations, and the proportion of variance explained by each model was quantified using adjusted R^2 values. Four models were estimated: model 1 (M1), including movement behaviors, namely MVPA, LPA, and SB, as well as total sleep time; model 2 (M2) including demographics, that is, sex, age, and parental education level; model 3 (M3), including only school class; and a full model (M4) including all variables: demographics, school class, movement behaviors, and total sleep time. Next, the individual contributions of MVPA, LPA, SB, and total sleep time were assessed by estimating the change in adjusted R^2 associated with adding each variable to a base model that included sex, age, parental education level, and school class. associated with adding each variable to a base model that included sex, age, parental education

level, and school class. Finally, the relative contribution of each model to the full model was determined by expressing each adjusted R^2 value as a percentage of the full model's adjusted R^2 value. Analyses were conducted in RStudio version 2023.06 using the packages *effectsize, lm.beta*, and *lme4*. P-values below 0.05 were considered statistically significant.

2.7 *Ethical considerations*

The Generation Healthy Kids project was prospectively registered on ClinicalTrials.gov (Clinical Trial Number: NCT05940675) on 4 July 2023 (Version 1). The study procedures were reviewed and approved by the Regional Committees of Health Research Ethics for Southern Denmark (Reference: S-20220094). The project was also registered with and approved by the Capital Region's Center for Data Reviews (Reference: P-2023-70). All study procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable Danish regulations. Prior to the commencement of the study, oral and written information was provided to all school principals, teachers, and parents, and written informed consent was obtained from parents of all participants prior to enrollment.

3.0 RESULTS

3.1 *Descriptive characteristics*

Of 1,350 eligible participants across 23 schools, 558 were excluded due to incomplete data, leaving 792 for analysis. The characteristics of these participants are presented in Table 1. Fifty-eight percent were girls; 51% were first graders (age 6–7; 403 participants; 50 of the 96 classes); 49% were second graders (age 8–9; 389 participants; 46 of the 96 classes), and the mean age was 7.8 years (SD = 0.60; range 6–9 yrs.). Approximately 70% of the children came from families with medium to high socioeconomic status, characterized by parents with higher educational attainment, whereas approximately 4% were from families with low educational attainment (no tertiary education). A comparison of participants with complete and incomplete data indicated no statistically significant differences in sex or age ($p > 0.05$). However, participants with incomplete data were more likely to have parents with lower levels of education ($p = 0.002$), suggesting a potential bias toward higher socioeconomic status in the analyzed sample.

Data for LPA, MVPA, SB, and sleep time were normally distributed (Appendix 2). Data for wellbeing outcomes indicate non-normality; however, such distributions are typical of a healthy general population, in which most children report good psychological and physical wellbeing. Similarly, in a general or healthy population, most parents report that their children exhibit few emotional and behavioral difficulties and high levels of prosocial behavior. Data from a clinical population would likely exhibit markedly different distribution patterns.

Table 2
presents descriptive statistics and internal consistency coefficients of the five wellbeing dimensions. Nearly all internal consistency coefficients were acceptable to good (α = 0.7–0.8), exceeding the threshold of 0.7. Exceptions were the physical wellbeing dimension of the KIDSCREEN-VIDEO and the prosocial behavior scale of the SDQ, which showed slightly lower reliability (α = 0.68 and 0.63, respectively). **[INSET TABLE 1 AROUND HERE]**

Table 1. Sample characteristics

	Complete (*n* = 792)	**In-complete (*n* = 558)**	**Group difference**
	n (%) or M (SD)		**P-value[b]**
Sex			0.149
Girls	402 (50.8)	261 (47.0)	
Boys	390 (49.2)	297 (53.0)	
Age (years)	7.82 (0.6)	7.80 (0.6)	0.477
Movement behaviors (min/day)			
Moderate-to-vigorous physical activity	77.79 (28.9)	–	–
Light physical activity	322.13 (52.5)	–	–
Sedentary behavior	384.56 (62.3)	–	–
Sleep time (hours/night)	9.05 (0.6)	–	–
Socioeconomic status[a]			0.002*
Primary education	10 (1.3)	17 (4.7)	
Secondary education	22 (2.8)	20 (5.5)	
Vocational education	101 (12.8)	47 (13.0)	
Short higher education	95 (12.0)	43 (12.0)	
Medium higher education	281 (35.6)	116 (32.0)	
Long higher education	280 (35.5)	121 (33.0)	

Note. *N* (%); number of individuals (percentage). M (SD); Mean (± standard deviation). Sleep time; Total sleep time (TST). [a]The socioeconomic status is based on the highest parental education level within a family unit. [b]The values, or distributions, between individuals included in this paper and those excluded due to incomplete data were compared. Pearson's Chi-squared tests were performed for sex and socioeconomic status, and Wilcoxon rank-sum tests were used for body mass index and age. An asterisk (*) indicates a statistically significant difference between participants included in the analysis and those excluded due to incomplete data ($p < 0.05$).

[INSET Table 2 **AROUND HERE]**

Table 2
Characteristics of wellbeing dimensions (N = 792)

	M (SD)	Skewness	Kurtosis	α	Range[a]
KIDSCREEN-VIDEO					
Physical wellbeing	67.42 (19.90)	-0.55	0.14	0.68	0-100
Psychological wellbeing	73.95 (16.97)	-0.98	1.19	0.78	0-100
Strength and difficulties questionnaire					
Internalizing problems	16.58 (14.55)	1.17	1.70	0.73	0–95
Externalizing problems	21.83 (17.41)	0.86	0.30	0.80	0–80
Prosocial behavior	85.65 (15.89)	-1.26	1.44	0.63	11–100

Note. N: number of individuals. M (SD); Mean (± standard deviation). α; Cronbach's Alpha values. [a]Range refers to the range of the respective scores in the dataset, i.e., the minimum and maximum within this dataset. Histograms for all outcome variables are enclosed in Appendix 2.

3.2 *Explained variance in the six wellbeing outcomes*

The full models, which included movement behaviors, total sleep time, demographics, and school class, explained between 4.7% and 10.3% of the variance in the five wellbeing outcomes. The lowest variance explained was in prosocial behavior, whereas the highest was in internalizing problems. The first models, which included only movement behaviors and total sleep time, explained the greatest proportion of variance in physical wellbeing (3.9%), followed by internalizing and externalizing problems (2.3% each). The second model, which included only demographic variables (sex, age, and parental education level), explained the greatest proportion of variance in internalizing problems (4.0%). The third model, which included only school class, accounted for the largest proportion of variance in psychological wellbeing (7.5%). Figure 1 illustrates the adjusted R^2 values for the models across all five wellbeing outcomes.

[INSET FIGURE 1 **AROUND HERE]**

Note

M1 includes movement behaviors (moderate-to-vigorous physical activity, light physical activity, and sedentary behavior) and sleep time; M2 includes demographic variables (sex, age, and parental education level); M3 includes school class; and M4 includes the full model, i.e., demographic variables, school class, movement behaviors, and sleep time. Asterisks indicate statistical significance for the respective model: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.3 *Relative contributions to the explained variance in the six wellbeing outcomes*

Some reduced models showed a high relative contribution when compared to the full model. Models with an adjusted R^2 exceeding 45% of the full model value were considered to indicate a substantial contribution.

These included movement behaviors and total sleep time (M1) for physical wellbeing and externalizing problems; demographics (M2) for externalizing problems and prosocial behavior; (M3) school class for psychological wellbeing and internalizing problems. Notably, the school class model (M3) explained nearly as much variance in psychological wellbeing as the full model, suggesting that school class is a key factor for this outcome. Conversely, models with an adjusted R^2 below 10% of the full model value were considered to indicate a low contribution. These included movement behaviors and total sleep time (M1) for psychological wellbeing, and school class (M3) for both externalizing problems and prosocial behavior. An overview of the relative contributions of the reduced models compared with the full model is provided in Table 3.

[INSET Table 3 **AROUND HERE]**

Table 3
Relative contributions across wellbeing outcomes

Outcome	**Full model explained variance (%)**	**Substantial relative contribution > 45%**	**Moderate relative contribution 10–45%**	**Low relative contribution < 10%**	**Specific movement & sleep contributors**
Psychological wellbeing	7.45%	Class	Demographics	Movement & Sleep	-
Physical wellbeing	8.47%	Movement & Sleep	Demographics; Class	-	MVPA (+), SB (-)
Externalizing problems	4.96%	Demographics; Movement & Sleep	-	Class	SB (-)
Internalizing problems	10.3%	Class	Demographics; Movement & Sleep	-	MVPA (-)
Prosocial behavior	3.60%	Demographics	Movement & Sleep	Class	-

Note. Relative contributions were categorized as substantial (> 45%), moderate (10–45%), or low (< 10%) based on the proportion of variance explained by each predictor block in the full model. Demographics include sex, age, and parental education level. MVPA; moderate-to-vigorous physical activity. SB; sedentary behavior. Positive (+) and negative (−) signs indicate the direction of the association based on standardized regression coefficients. For physical wellbeing, higher scores indicate better wellbeing, whereas for internalizing and externalizing problems, higher scores indicate more problems. Only the movement and sleep variables contributing most to the explained variance are shown. Detailed regression coefficients are presented in Appendix 5.

3.4 *Incremental contribution of individual movement behaviors and sleep time*

For physical wellbeing, internalizing problems, and externalizing problems, adding MVPA, LPA, SB, or total sleep time to a base model including sex, age, parental education level, and school class resulted in adjusted R^2 changes ranging from 0.014 to 0.039. For physical wellbeing and internalizing problems, MVPA showed the largest increase in adjusted R^2 compared with LPA, SB, and total sleep time, whereas for externalizing problems, SB showed the largest increase. Figure 2 illustrates the change in adjusted R^2 when each variable is

added to the base model across the five wellbeing outcomes. The direction and magnitude of the associations are presented in Appendix 5.

[INSET FIGURE 2 **AROUND HERE]**

Note

MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; and SB, sedentary behavior. Individual contributions were examined by estimating the change in adjusted R^2 when adding each variable separately to a base model that included sex, age, parental education level, and school class. Asterisks indicate statistical significance for the respective model: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.0 DISCUSSION

4.1 *Summary of key results*

This study provided insights into the relative contributions of individual and behavioral factors to multiple dimensions of wellbeing in children aged six to nine years. Movement behaviors (MVPA, LPA, and SB) and total sleep time collectively accounted for only a small proportion of the variance across the distinct wellbeing dimensions, indicating that these factors, while relevant, are unlikely to be the primary determinants of wellbeing among children aged six to nine years. Among these, MVPA showed the strongest associations with physical wellbeing and internalizing problems, whereas SB contributed most to externalizing problems, highlighting behavior-specific associations across wellbeing dimensions. Demographic factors explained the largest share of variance in internalizing problems, yet their contribution remained modest, reinforcing their limited explanatory relevance. Notably, school class explained a similar proportion of variance in psychological wellbeing as the full model, suggesting that classroom-level differences may reflect broader social and contextual influences not captured by the measured individual-level factors.

This study extends the existing literature by examining how accelerometer-measured movement behaviors and sleep time relate to multiple dimensions of wellbeing and by comparing their relative contributions with those of demographic factors. The findings indicate that wellbeing dimensions may have distinct behavioral and contextual correlates. Collectively, however, these factors explained only a limited proportion of the variance, suggesting that wellbeing in schoolchildren is shaped by a broader range of influences beyond those included in the present study.

4.2 *Role of movement behaviors and sleep time*

The total variance explained across the five wellbeing outcomes ranged from 4.7% to 10.3%, which is consistent with the small effect sizes reported in systematic reviews and meta-analyses examining associations between movement behaviors and/or sleep time and wellbeing among children and adolescents (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Movement behaviors and sleep time collectively explained the greatest share of variance in physical wellbeing (3.9%), internalizing problems (2.3%), and externalizing problems (2.3%). These findings align with evidence showing that higher MVPA and lower SB are associated with more favorable wellbeing across a range of dimensions (Carson et al. 2017; Chaput et al. 2016;

Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). However, the limited variance explained suggests that additional social and environmental influences may contribute importantly to wellbeing in this age group. Supporting this interpretation, prosocial behaviors showed the lowest proportion of explained variance across all wellbeing dimensions, highlighting their developmental nature and likely dependence on unmeasured relational and social-contextual factors.

Systematic reviews have indicated that SB (Wilhite et al. 2023) and sleep time (Bourke et al. 2025) exert a stronger influence on wellbeing in adolescents than in children, while another review suggested that adequate sleep, higher MVPA, and lower SB are beneficial for wellbeing regardless of age (Groves et al. 2024). Furthermore, age-specific evidence suggests that these associations may differ between children and adolescents. Among adolescents (12–17 years), meeting all three 24-hour movement recommendations (i.e., physical activity, screen time, and sleep time) has been associated with lower odds of depressive symptoms, whereas among children (6–11 years), certain combinations of movement behaviors, sleep practices, and screen time appeared more beneficial than meeting all recommendations simultaneously (Zhu et al. 2019). These inconsistencies may reflect that movement behaviors and sleep time are differentially associated with specific dimensions of wellbeing, and that the influence of these behaviors varies across age groups.

4.3 *Differential roles of MVPA and SB across wellbeing dimensions*

Results showed that MVPA contributed more distinctly than other movement behaviors to internalizing problems and physical wellbeing, whereas SB contributed more distinctly to externalizing problems. These findings suggest that different movement behaviors may be associated with specific wellbeing dimensions. However, the mechanisms underlying these differential associations remain unclear. One possible explanation is that different behaviors occur in different social and environmental contexts, which may influence wellbeing in distinct ways. Nevertheless, the findings broadly align with previous evidence indicating that adherence to all three movement behavior recommendations (physical activity, screen time, and sleep time) is associated with fewer emotional and behavioral difficulties among children and adolescents (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024).

Evidence indicates that MVPA is an important determinant of physical health outcomes in children and adolescents, while SB appears to play a more secondary role, and sleep duration may contribute mainly through its interaction with the other two behaviors (Carson et al. 2017; Chaput et al. 2016; Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Saunders et al. 2016; Stai et al. 2025; Wilhite et al. 2023; Zhao et al. 2024). Consistent with this evidence, the present study showed a stronger contribution of MVPA to physical wellbeing than to psychological wellbeing, suggesting that MVPA is more proximately related to physical or somatic dimensions of wellbeing among children, whereas psychological wellbeing may depend more on social and contextual experiences. Related to this, a prospective longitudinal study of Norwegian children (6–10 years) found that higher MVPA predicted fewer depressive symptoms two years later, whereas SB did not predict depression, and depression did not predict MVPA, suggesting a directional effect of MVPA on internalizing problems, rather than reverse causality (Zahl et al. 2017).

Emerging evidence indicates that certain types of SB are important for different dimensions of wellbeing, including anxiety symptoms, depressive symptoms, internalizing problems, and externalizing problems (Wilhite et al. 2023; Sampasa-Kanyinga et al. 2020; Ferreira et al. 2025). This may explain the differential associations of SB across wellbeing dimensions observed in the present study, as SB contributed more to externalizing problems than to more inwardly directed emotional problems, such as internalizing problems and psychological wellbeing. These findings suggest that distinguishing between types of SB may be particularly important when examining behavioral and outwardly expressed difficulties.

For example, evidence indicates that meeting screen time and sleep time recommendations, either alone or in combination with PA, may be more strongly associated with reduced internalizing and externalizing problems, as well as fewer depressive symptoms, in children and adolescents, than meeting PA recommendations alone (Sampasa-Kanyinga et al. 2020, 2021). Interestingly, these studies primarily focused on screen-based SB, suggesting that specific types of SB (e.g., social media use, reading books, classroom teaching, and gaming) may differentially influence wellbeing dimensions.

4.4 *Limited role of total sleep time across wellbeing dimensions*

Total sleep time did not show a clear association with any of the wellbeing outcomes. These null findings are inconsistent with evidence indicating that longer total sleep time is associated with more favorable wellbeing across a range of dimensions (Bourke et al. 2025; Chaput et al. 2016; Ferreira et al. 2025; Groves et al. 2024; Sampasa-Kanyinga et al. 2020; Wilhite et al. 2023). A recent systematic review and meta-analysis demonstrated that the association between sleep time and socioemotional outcomes, including internalizing problems, externalizing problems, and prosocial behaviors, was stronger among adolescents than among children (Bourke et al. 2025), which may partly explain the present findings. Bourke et al. suggested that these age-specific differences may be due to developmental changes, such as variations in gray matter volume during this transition, or to adolescents' greater autonomy over their sleep, which may influence their sleep patterns (Bourke et al. 2025). These findings may also indicate that total sleep time shows less variability in younger children, who may already obtain sufficient sleep. Differences in sleep measurement methods may also contribute to inconsistencies across studies, as child- or parent-reported total sleep time may likely overestimate actual total sleep time relative to (more objective) device-based measures (Li et al. 2021; Short et al. 2013). Additionally, sleep quality may represent an important but unmeasured factor related to wellbeing. For example, evidence has shown that poor sleep is consistently associated with lower HRQoL, physical wellbeing, psychological wellbeing, school functioning, and psychosocial health among children and adolescents (Ferreira et al. 2025).

4.5 *Role of demographic factors and school class across wellbeing dimensions*

Demographic variables, including sex, age, and parental education, showed limited overall explanatory power across wellbeing dimensions. This is consistent with prior research suggesting that the influence of these factors, especially sex differences, becomes more pronounced during puberty, as this transition includes physiological puberty but also major social-context changes (e.g., primary-to-secondary transition, increased peer salience) (Patalay and Fitzsimons 2018). In parallel, school-based studies have shown that wellbeing dimensions cluster within schools and may sometimes also vary markedly across classes (Butler et al. 2022). In the present study, school class emerged as a potentially important contextual factor for psychological

wellbeing, further implying that children's experiences and psychological wellbeing (how they feel) are shaped by the social units they inhabit, such as shared classrooms, rather than by individual demographics or behavioral factors.

Previous evidence indicates that classroom characteristics, including peer dynamics and class climate, influence psychological wellbeing, both internationally (Camacho et al. 2025) and in a Danish context (Nandrup et al. 2025). These findings support the notion that classroom social environments may play an important role in shaping psychological wellbeing during early childhood. Nevertheless, the negligible contribution of school class to physical wellbeing, externalizing problems, and prosocial behavior underscores that contextual school factors may be more relevant for subjective psychological wellbeing dimensions than for others.

4.6 *Strengths and limitations*

A clear strength of this study is the large sample size, along with the use of continuous, device-based measures of movement behaviors and total sleep time, which allow for a more accurate and detailed assessment of their relative contributions across distinct wellbeing dimensions and are not subject to recall bias. This approach enables the detection of more subtle associations and provides a more differentiated understanding of how these behaviors relate to specific aspects of wellbeing. In the existing literature, there is substantial heterogeneity in how MVPA, LPA, SB, and sleep duration, as well as wellbeing, are measured, categorized, analyzed, and reported (Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Wilhite et al. 2023; Zhao et al. 2024). For example, most studies dichotomize movement behaviors using guideline-based thresholds, which potentially limits the ability to examine dose–response relationships, for instance, by equating children with very low levels of MVPA to those just below the recommended threshold of 60 minutes per day (Ferreira et al. 2025; Sampasa-Kanyinga et al. 2020; Wilhite et al. 2023; Zhao et al. 2024). This approach may obscure more nuanced associations among movement behaviors, total sleep time, and wellbeing outcomes, thereby supporting our rationale for using continuous measures. This study is one of the few that assessed distinct dimensions of wellbeing for comparison, thereby enhancing its comprehensiveness. KIDSCREEN-VIDEO and SDQ have both been validated for the relevant age group and demonstrated acceptable to good internal consistency ($\alpha \geq 0.7$). Only the physical wellbeing and prosocial behavior subscales showed internal consistency slightly below the conventional threshold; however, these values remain within an acceptable range for exploratory research.

The results need to be interpreted with several limitations in mind. First, the cross-sectional design precludes causal inferences regarding the observed associations, and reverse causation may partly explain the relationships identified between movement behaviors and different dimensions of wellbeing. Specifically, children with psychological, behavioral, social, or physical difficulties may differ systematically in their engagement in movement behaviors, potentially influencing the observed associations. For example, the present study found that SB was more strongly associated with externalizing problems than MVPA, although this relationship may partly reflect that children with outwardly expressed behavioral difficulties are more likely to engage in SB. Future research should therefore investigate the associations between movement behaviors, total sleep time, and distinct wellbeing dimensions using longitudinal and experimental designs to provide more robust evidence. Another limitation relates to the socioeconomic composition of the sample. Most participants were from middle- to high-SES backgrounds, with only a small proportion (~ 4%) representing low-SES families. This imbalance may reflect both selective consent and participation, potentially introducing

selection bias. Furthermore, children with incomplete data were more likely to have parents with lower educational attainment, suggesting additional selection related to SES. Together, these factors may limit the generalizability of the findings to more socioeconomically disadvantaged populations and may have led to an underestimation of the associations between movement behaviors, total sleep time, and wellbeing. Nevertheless, no significant differences were observed between included and excluded participants in sex, age, or body mass index, supporting the internal validity.

5.0 CONCLUSION

This study expands on the scarce evidence regarding associations between accelerometer-measured movement behaviors and total sleep time and distinct dimensions of wellbeing in children aged six to nine years. The results indicate that movement behaviors and sleep time explain only a small proportion of the variance across dimensions of psychological wellbeing and psychosocial functioning, and slightly more variance in physical wellbeing. Thus, suggesting that several wellbeing dimensions in children are likely to be influenced by additional social and contextual factors beyond those included in the present analysis. Furthermore, the results suggest that certain movement behaviors, including MVPA, LPA, and SB, contribute more strongly to distinct dimensions of wellbeing; MVPA is more strongly associated with internalizing problems (negative association) and physical wellbeing (positive association), whereas SB is mainly associated with externalizing problems (negative association). The modest explanatory value of the included factors highlights the need for future research to identify other potentially important and modifiable factors, such as social dynamics in the school, leisure, and family environments. Future PA interventions should carefully consider which specific dimensions of wellbeing they aim to promote, as different movement behaviors appear to be associated with distinct wellbeing dimensions among children. This knowledge may help support the development of targeted interventions tailored to specific wellbeing outcomes and population groups.

Declarations

Ethics approval and consent to participate:

The study procedures were reviewed and approved by the Regional Committees of Health Research Ethics for Southern Denmark (Reference: S-20220094). The project was also registered with and approved by the Capital Region's Center for Data Reviews (Reference: P-2023-70). All study procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable Danish regulations. Written informed consent was obtained from the parents or legal guardians of all participants prior to enrolment.

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

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Author Contribution

The authors contributed to this work as follows, in accordance with the CRediT taxonomy. All authors reviewed and approved the final version of the manuscript. MK: Project administration, Conceptualization, Methodology, Formal analysis, Investigation, Data curation and analysis, Visualization, Writing – original draft preparation, Writing – review & editing. PB: Conceptualization, Writing – review & editing, Supervision. PSM: Investigation, Data curation. MSJ: Investigation, Writing – review & editing. NHP: Investigation, Data curation. MNL: Investigation, Data curation. PGSM: Investigation. KPO: Investigation. AG: Funding Acquisition. JLJ: Conceptualization, Funding Acquisition. JCB: Data curation, Software, Writing – review & editing, Supervision. PK: Conceptualization, Funding Acquisition. WV: Formal analysis, Supervision. GN: Conceptualization, Methodology, Funding Acquisition, Writing – review & editing, Supervision.

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Data Availability

The data analyzed in this study were obtained from the baseline assessment of the Generation Healthy Kids project. The datasets are not publicly available due to ethical and data protection restrictions.

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50. List of abbreviations LPA. Light physical activity MVPA: Moderate-to-vigorous physical activity R^2: Adjusted coefficient of determination SB: Sedentary behavior SD: Standard deviation SDQ: Strengths and Difficulties Questionnaire SES: Socioeconomic status TST: Total sleep time.

Figures

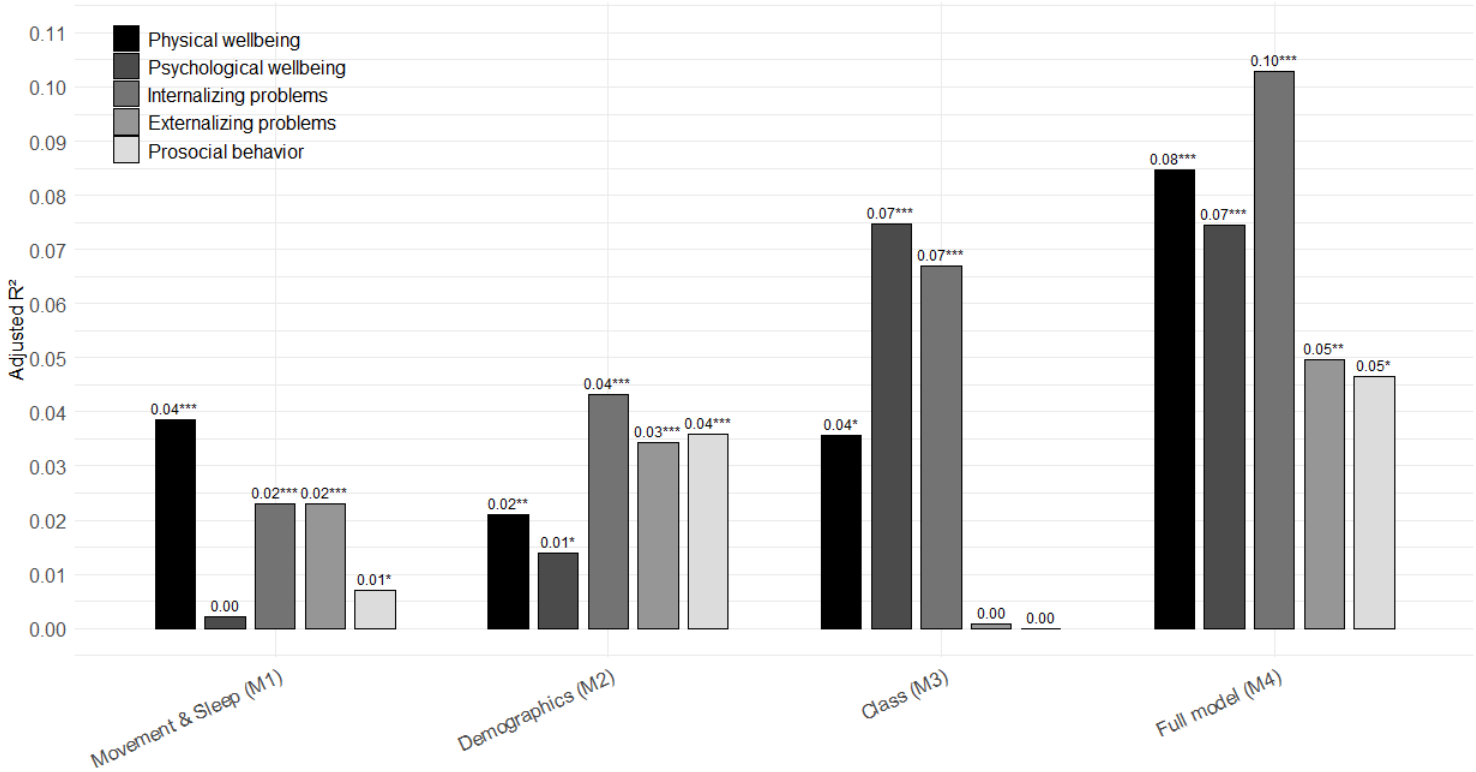


Figure 1

Adjusted R^2 for linear regression models across wellbeing outcomes

Note. M1 includes movement behaviors (moderate-to-vigorous physical activity, light physical activity, and sedentary behavior) and sleep time; M2 includes demographic variables (sex, age, and parental education level); M3 includes school class; and M4 includes the full model, i.e., demographic variables, school class, movement behaviors, and sleep time. Asterisks indicate statistical significance for the respective model: * p < 0.05, ** p < 0.01, *** p < 0.001.

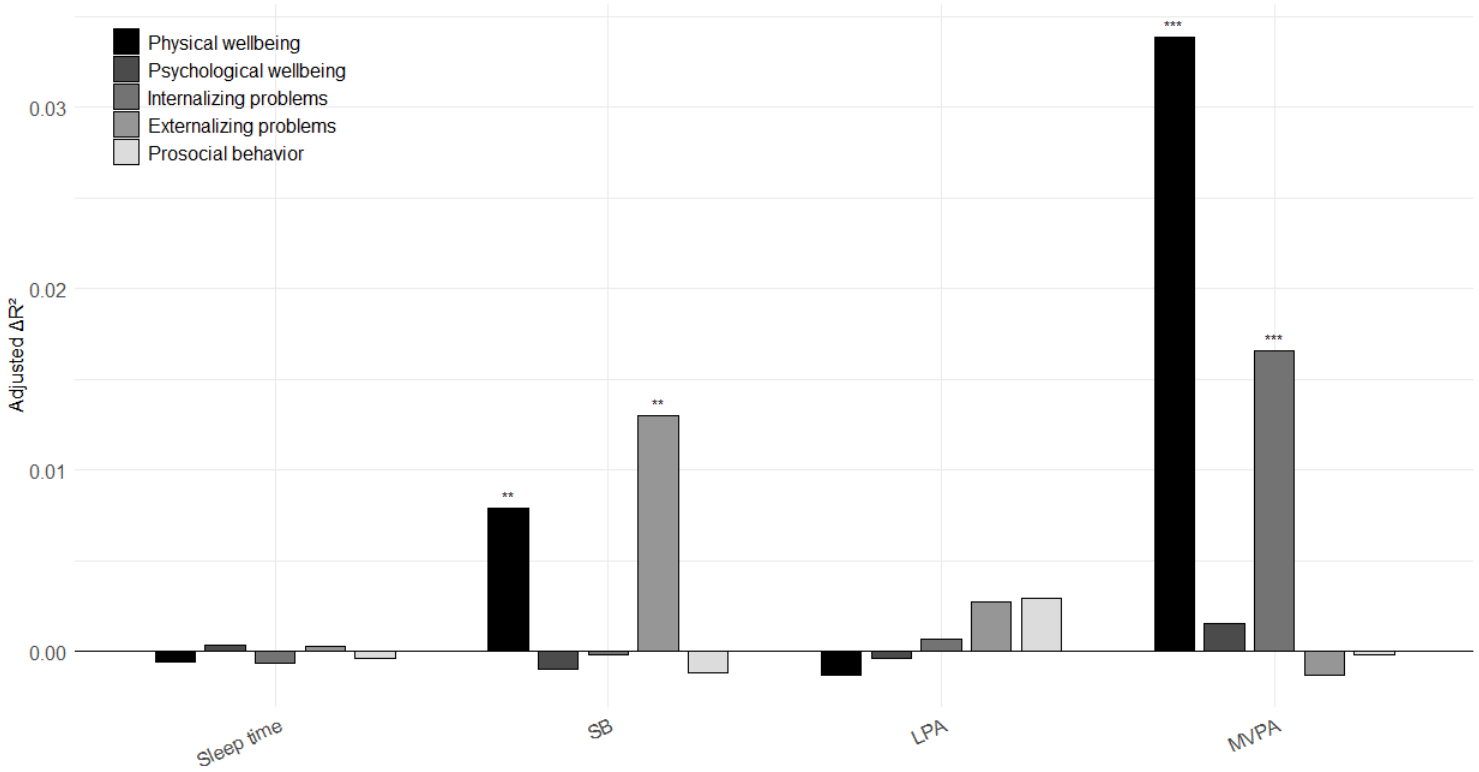


Figure 2

Change in adjusted R^2 for associations across all wellbeing outcomes

Note. MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; and SB, sedentary behavior. Individual contributions were examined by estimating the change in adjusted R^2 when adding each variable separately to a base model that included sex, age, parental education level, and school class. Asterisks indicate statistical significance for the respective model: * p < 0.05, ** p < 0.01, *** p < 0.001.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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