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Associations between 24-h movement behaviors and health-related quality of life(HRQoL) in preschool children: a cross-sectional study

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Abstract

Purpose To investigate the association between preschool children's 24-h movement behaviors and health-related quality of life (HRQoL), exploring the impact of time reallocation among these behaviors and examining gender differences.

Methods This study analysed HRQoL and 24-h movement behaviors of 349 preschool children in three kindergartens in Beijing, China, selected through convenience sampling using a cross-sectional study design. A t-test and multivariate analysis of variance methods were used to investigate gender differences. The study examined the relationship between 24-h movement behaviors and HRQoL using component data analysis and component isochronic substitution model methods, with an investigation into gender differences in the overall association.

Results The study found a negative correlation between sedentary behavior (SB) and overall HRQoL score ($\gamma = -11.92$, $p < 0.05$) in the entire sample, particularly affecting physical health score ($\gamma = -14.39$, $p < 0.01$). Among boys, SB was negatively correlated with the HRQoL total score ($\gamma = -15.83$, $p < 0.05$), while sleep was positively correlated with psychosocial health scores ($\gamma = 17.814$, $p = 0.01$). However, there was no significant association found between 24-h movement behaviors and HRQoL in girls. When using the component isochronic substitution model, reallocating 30 min from sedentary behavior to sleep increased the total HRQoL score of preschool children by 0.865 points (95% CI 0.071, 1.658). In contrast, reallocating 30 min from sleep to sedentary behavior resulted in a decrease of 0.850 points (95% CI − 1.638, − 0.062) in the total HRQoL score.

Conclusions To improve preschool children's HRQoL, it is recommended to reduce their sedentary behavior time and increase their sleep time. Public health policymakers should consider this when developing 24-h movement behavior guidelines for preschoolers.

Keywords Sedentary behavior · Sleep · 24-h movement behaviors · Preschool children · Health-related quality of life

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Introduction

Health-related quality of life (HRQoL) is a multidimensional concept that encompasses the physical, mental, and social aspects of health [1]. Lower HRQoL levels, closely associated with increased risks of conditions like obesity/overweight, dental caries, and neurodevelopmental disorders (e.g., ASD) [2–4], may potentially impact the future physical development of preschool children [5], highlighting HRQoL's crucial role as a robust predictor of morbidity and mortality. Limited evidence on preschool children indicates that HRQoL significantly impacts their early development. A cross-sectional study revealed markedly lower physical, school performance, and overall HRQoL scores in preschoolers with developmental coordination disorder compared to typically developing children of the same age [6]. It is important to note that the HRQoL of preschool children decreases with age [1, 7]. Therefore, it is necessary to understand the HRQoL of preschool children, its influencing factors, and to explore effective means of improving their quality of life.

It is widely acknowledged that HRQoL is influenced not only by immutable factors, such as age, but also to a large extent by environmental factors, such as daily movement behaviors. Twenty-four-hour (24-h) movement behaviors include sleep, sedentary behavior (SB), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) [1]. Previous research has consistently shown a positive correlation between sleep duration and HRQoL scores in preschool children [8, 9]. However, there are conflicting findings regarding the association between physical activity (PA), SB, and HRQoL scores. While one cross-sectional study identified a link between PA, SB, and HRQoL scores [10], another found no association [11]. Limited research exists on the relationship between PA, SB, and HRQoL in preschool children, and current findings remain inconclusive.

Previous studies, previous studies, limited by analyzing movement behaviors separately in assessing the correlation between 24-h movement behaviors and HRQoL, often employed questionnaire methods to qualitatively assess physical activity [10], potentially contributing to uncertain association results [1]. The analyzing movement behaviors separately method overlooks the time constraint (i.e., 24-h) and the interdependence of 24-h movement behaviors data [12], where a change in the time of one activity will inevitably cause a change in the time of one or more remaining activities [12]. Therefore, exploring the relationship between the reallocation of activity time and HRQoL is particularly important. Twenty-four-hour movement behaviors constitute a set of component data, exhibiting significant multicollinearity among activity behavior times. Consequently, conventional statistical methods like multiple linear regression are not directly applicable for related research. Compositional data analysis (CoDA) recognizes the compositional nature of daily 24-h movement behaviors data and has been widely employed in investigating the correlation between daily 24-h movement behaviors and health indicators [13]. Additionally, the isometric log-ratio models can be utilized to explore the relationship between the reallocation of activity behavior time and HRQoL [13, 14].

Previous studies have demonstrated the widespread application of CoDA in examining the correlation between 24-h movement behaviors and HRQoL across children and adults, indicating that reallocating time from other behaviors to MVPA/sleep can enhance HRQoL scores [1, 15]. However, it remains uncertain whether this association extends to the preschool population. While only one compositional data analysis has shown a link between preschool children's 24-h movement behaviors and HRQoL [14], caution must be taken when generalizing the results of this study due to variations in policies, cultures, and activity patterns across countries, which may influence the association between 24-h movement behaviors and HRQoL [1]. Furthermore, studies have demonstrated that 24-h movement behavior patterns [16–18] and HRQoL [19, 20] differ between boys and girls. Considering these gender differences, previous research has emphasized the importance of employing CoDA to examine the association between daily time-use composition and HRQoL across genders [21]. To the best of the authors' knowledge, evidence of gender-related differences among preschoolers remains limited or unsubstantiated.

Therefore, to address this gap in the literature, the present study aims to investigate the association between preschool children's 24-h movement behaviors and HRQoL, while also examining the impact of reallocating time among these daily movement behaviors on HRQoL and exploring potential gender differences in these effects.

Methods

Participants

The cross-sectional survey was developed in urban and rural areas in Beijing, city of China within the SUNRISE project framework. The study's inclusion criteria are as follows: (1) aged between 3 and 6 years old; (2) parents and preschoolers who have been fully informed of the research content and have agreed to participate; and (3) complete and reliable data on pre-school children's age, gender, accelerometer-measured activity, sleep duration, physical examination, and HRQoL survey must be provided. Exclusion criteria: (1) suffering from chronic diseases such as arrhythmia, hypertension; (2) recently suffering from seasonal diseases such as colds, coughs, fevers; (3) overweight or obesity; (4) physical development, intelligence or Behavioral disorder; and (5) any disease or condition that may interfere with physical activity, such as a fracture or recent surgery. A total of 474 preschool children were recruited, of which 125 were excluded due to dropout or incomplete testing. Finally, 349 preschool children were included in the analysis.

The study received approval from the Ethics Committee of the Capital Institute of Pediatrics (No. SHERLL2021069) in accordance with the Declaration of Helsinki.

Sample size calculation

Sample size estimation was conducted using PASS 25.0 software to ensure statistical significance [22–25]. The power was set to 0.9, the α level to 0.05, ρ_0^2 to 0.25, ρ_1^2 to 0.50, and the number of control variables to 5. Considering a 30% data failure rate, at least 122 participants were estimated to be needed to detect medium to high effect sizes. Sample size estimates are important to ensure that the study has enough statistical power to draw reliable and meaningful conclusions.

Procedures

Parents or guardians must sign an informed consent form to participate, indicating understanding of the study's purpose, design, and procedures. Trained researchers conducted measurements using standard protocols.

The study was carried out from August to October 2022. All children with parental consent were assessed. Parents or guardians completed a questionnaire covering demographic information, the Pediatric Quality of Life Inventory (PedsQL), and sleep. Participants wore an accelerometer on their right waist for seven consecutive days, starting Friday morning and ending the following Friday afternoon, to monitor free-living PA and SB.

Measurement

Anthropometry

Height and weight were measured using a standardized procedure [26], employing a calibrated Seca 217 (Hamburg, Germany) for height and Seca 899 (Hamburg, Germany) for weight. Body mass index (BMI) and corresponding z-scores for BMI (zBMI) were calculated using the AnthroPlus software.

Assessment of physical activity, sedentary and sleep

The study utilized ActiGraph GT9X accelerometers (ActiGraph, Pensacola, FL, USA) to objectively measure subjects' daily PA and SB. This device, validated for accuracy and reliability, is widely employed in assessing preschool children's PA and SB [27]. Participants wore the accelerometer on their right waist for 7 consecutive days (5 weekdays and 2 weekends) while awake. The device was worn continuously, except during sleep and water-related activities like swimming and bathing. Trained parents and teachers assisted participants, given their young age, in donning and doffing the equipment throughout the wearing period. Participants wore the device continuously, except during sleep and water-related activities like swimming and bathing. Trained personnel provided verbal and written instructions to parents and teachers on device usage and placement. Given the subjects' young age, trained caregivers/parents assisted with device placement and removal. Parents maintained activity logs during monitoring to record wear time, removal instances, and reasons for non-wear. A WeChat group was created to remind parents about proper accelerometer usage, while trained childcare workers checked and adjusted the devices on children upon their entry and exit from kindergarten on weekdays.

The accelerometer data, captured and stored at 30 Hz, were integrated into 1-s epochs [28]. Data analysis was conducted using ActiLife software version 6.13.3. Valid wear time was defined as at least 8 h per day during waking hours, with valid data including a minimum of 4 days (3 weekdays and 1 weekend) [29]. A period of at least 20 min of consecutive zero counts was classified as awake non-wear time. Pate cut-points were applied to estimate SB (≤ 100 counts/s), LPA (101 ~ 1679 counts/s), and MVPA (≥ 1680counts/s) [28]. Minutes per day spent in SB, LPA, and MVPA were calculated by summing all corresponding intensity minutes divided by all valid days.

Caregivers reported preschoolers' sleep duration, including nighttime sleep and nap duration. The questionnaire included two specific questions: (1) 'On weekdays, how many hours does your child sleep each day?' and (2) 'On weekends, how many hours does your child sleep each day?'. Average sleep time was calculated using the formula: daily sleep time = ((weekday sleep time × 5) + (weekend sleep time × 2)) ÷ 7. This calculation method is commonly used in research on children's sleep and has received academic approval [30, 31]. Furthermore, caregivers reported children's nighttime sleep and nap schedules to exclude sleep duration from accelerometer data.

Assessment of the health-related quality of life

The study utilized the validated PedsQL 4.0 scale [32] to assess HRQoL of children aged 3–6 years, a scale that has demonstrated reliability and validity in Chinese preschool children [33]. Among these instruments, the PedsQL 4.0 (2–4 years old version) and PedsQL 4.0 (5–7 years old version) consist of 21 and 23 items, respectively. They are structured into four dimensions, assessing physical functions (8 items), psychosocial health including emotional functions (5 items), social functions (5 items), and school functioning (3 or 5 items) in preschool children. All items are categorized into five levels: never (level 0), almost never (level 1), sometimes (level 2), often (level 3), and always (level 4). The corresponding scores for these levels are 100, 75, 50, 25, and 0, respectively. Parents were tasked with reporting the frequency of events for each item based on their child's activity over the past month. The scale scores are calculated based on two main dimensions: psychosocial health and physical health. The psychosocial health score comprises emotional functions, social functions, and school functioning, while the physical health score focuses solely on physical functions. To calculate the psychosocial health score, item scores from emotional functions, social functions, and school functioning are summed and divided by the total number of items in these subscales. For the physical health score, the item scores for the physical functioning dimension are summed and divided by the total number of items in that dimension. Similarly, the total HRQoL score is determined by summing all item scores and dividing by the total number of items across the scale. The HRQoL total score and each aspect score range from 0 to 100, with higher scores indicating better overall HRQoL as well as specific aspect scores.

Statistical analyses

All statistical analyses were conducted using R software (version 4.1.3). Continuous variables were reported as mean ± standard deviation, while categorical variables were expressed as percentages. Compositional data description and analysis were conducted utilizing the compositional (version 2.0–4) and robcompositional (version 2.3.1) software packages. The component mean and variation matrix are employed to illustrate the central tendency and discrete trend of daily 24-h movement behaviors data, respectively. Specifically, the component mean is normalized by calculating the geometric mean of the duration of each activity to ensure a total sum of 1440 min [34]. When the value in the component variation matrix approaches 0, it indicates a stronger interdependence among activity behaviors [14, 35]. The t-test examined demographic differences between genders, while multivariate analysis of variance (MANOVA) assessed variations in 24-h movement behaviors times across genders.

This study employed daily activity behavior time as the independent variable and HRQoL, along with its various dimensions, as dependent variables. It utilized a compositional data analysis to investigate the relationship between daily 24-h movement behaviors times and HRQoL, including its dimensions. Prior to analysis, activity behavior times are converted into coordinate systems using the 'compositional' package (3 coordinates). These are then incorporated into regression models to assess each activity's impact on HRQoL [1]. Four linear regression models were created for each outcome variable. Each activity behavior component was represented through a set of three isometric log-ratio (ILR) coordinates before being entered into the models, to capture the cumulative relative impact of each movement, four distinct regression models were executed for each HRQoL outcome. Since the first isometric log-ratio (ILR) coordinate contains information about the components of the first movement behavior relative to the other movement behaviors, this study only reports the γ coefficient of the first ILR coordinate to describe the strength and direction of the association [34, 36].

Following the recommendations of Dumuid et al. [35], this study employed the component isotemporal substitution model to estimate the absolute change in health-related quality of life (HRQoL) resulting from reallocating time between different activity behaviors. Specifically, the estimated change in the overall HRQoL score is derived by adjusting activity behavior components, such as adding 15 min to sleep time, maintaining MVPA and LPA levels, and reducing sedentary behavior by 15 min, and comparing it to the baseline HRQoL score. In line with previous research, HRQoL changes were estimated in 5-min intervals for reallocations of 5 to 30 min between behaviors[34]. GraphPad Prism 9 software was then employed to illustrate the dose–effect relationship of HRQoL with replacement time, graphing the estimated absolute change against replacement time. In the analyses involving all participants, adjustments were made for age, sex, and zBMI, while in sex-stratified analyses, adjustments were made for age and zBMI. Statistically significant changes in HRQoL estimates were identified by 95% confidence intervals excluding 0.

Results

Descriptive statistics

The study enrolled 474 preschool children, of whom 125 were excluded due to dropout or incomplete tests, resulting in a final sample of 349 preschool children for analysis(Fig. 1). Table 1 summarizes the characteristics of the preschool children included. The analysis revealed that sleep time constituted the largest proportion (approximately 47.19%) of the total activity time among the tested children, followed by SB (39.58%), LPA (7.68%), and MVPA (5.55%). Multivariate analysis showed boys had significantly higher levels of LPA, MVPA, and sleep time compared to girls, while their SB time was significantly lower ($p < 0.01$).

Table 2 presents the variation matrix of 24-h movement behaviors time data. It reveals that for both boys and girls, the connection between sleep and SB demonstrated the strongest interdependence, while the relationship between MVPA and SB displayed the weakest interdependence.

Twenty-four-hour movement behaviors and health-related quality of life

Table 3 presents the results of the compositional linear regression analysis of the associations between 24-h movement behaviors and HRQoL. After adjusting for age, gender, and zBMI, SB maintains a significant negative correlation with the total HRQoL score in the overall sample ($\gamma = -11.92$, *95% CI* − 21.56, − 2.27), particularly pronounced in the physical function dimension ($\gamma = -14.39$,

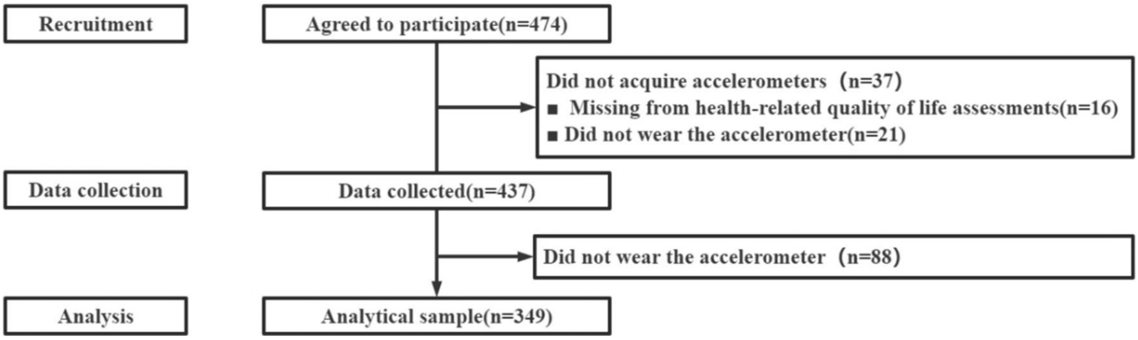

Fig. 1 Diagram of the participants examined in the present study

Table 1 Participant characteristic

	All (n = 349)	Boys (n = 186)	Girls (n = 163)	*p*
Age, year	4.92 ± 0.82	4.96 ± 0.80	4.88 ± 0.85	0.36
Weight, kg	18.98 ± 3.51	19.28 ± 3.71	18.64 ± 3.25	0.09
Height, cm	110.14 ± 7.47	110.79 ± 7.51	109.41 ± 7.38	0.10
BMI, kg/m^2	15.54 ± 1.53	15.59 ± 1.56	15.50 ± 1.50	0.58
zBMI	0.11 ± 1.01	0.13 ± 1.06	0.08 ± 0.96	0.61
Accelerometer wear time, min/d	684.45 ± 49.22	684.73 ± 46.61	684.13 ± 52.18	0.91
HRQoL-related scores				
Total HRQoL	85.62 ± 11.57	86.17 ± 10.40	87.50 ± 10.33	0.23
Physical health score	88.76 ± 11.61	88.93 ± 11.30	88.57 ± 11.99	0.78
Psychosocial health score	85.62 ± 11.57	84.55 ± 11.69	86.84 ± 11.35	0.07
24-h movement behaviours' compositional mean; min/d (%)				
SB	569.99(39.58%)	559.47(38.85%)	582.48(40.45%)	**< 0.01**
LPA	110.58(7.68%)	115.06(7.99%)	105.39(7.32%)	**< 0.01**
MVPA	79.91(5.55%)	84.31(5.85%)	74.92(5.20%)	**< 0.01**
Sleep	679.53(47.19%)	681.16(47.30%)	677.21(47.03%)	**< 0.01**

BMI body mass index, *zBMI* body mass index z-score, *SB* sedentary behavior, *LPA* light physical activity, *MVPA* moderate-to-vigorous physical activity, *HRQoL* health-related quality of life

95% CI − 25.07, − 3.72). Unexpectedly, there was no significant association found between MVPA and total HRQoL scores.

To thoroughly investigate the relationship between 24-h movement behaviors and HRQoL among preschool children of different genders, separate component linear regression models were utilized for boys and girls. After adjustment for age and zBMI in boys, a notable negative correlation was observed between SB and the total HRQoL score (γ = − 15.83, *95% CI* − 28.52, − 3.14), as well as with the psychosocial health scores (γ = − 16.42, *95% CI* − 30.74, − 2.09). Additionally, a significant positive correlation was found between sleep duration and psychosocial scores (γ = 17.814, *95% CI* 1.89, 33.74). No significant links were observed between SB, LPA, MVPA, and sleep duration with total HRQoL scores and psychosocial health scores in girls.

Time allocation and health-related quality of life in preschool children's 24-h movement behaviors

Table 4 delineates the estimated change in HRQoL resulting from reallocating 30 min of activity time from the activities listed in columns to those in rows, while holding other activities constant. In the total sample, after adjusting for age, gender, and zBMI, reallocating time from SB to sleep was associated with a significant increase of 0.865 points (*95% CI* 0.071, 1.658) in the total HRQoL score among preschool children, whereas reallocating time from sleep to SB resulted in a decrease of 0.850 points (*95% CI* − 1.638, − 0.062).

Following adjustment for age and zBMI, reallocating time from SB to sleep significantly increased boys' total HRQoL score by 1.229 points (*95% CI* 0.178, 2.279) and psychosocial health dimension by 1.448 points (*95% CI* 0.262, 2.634), while reallocating time from sleep to SB

Table 2 Compositional variation matrix for SB, LPA, MVPA, and sleep

	SB	LPA	MVPA	Sleep
All				
SB	0.00	0.04	0.09	0.02
LPA	0.04	0.00	0.04	0.04
MVPA	0.09	0.04	0.00	0.08
Sleep	0.02	0.04	0.08	0.00
Boys				
SB	0.00	0.04	0.10	0.02
LPA	0.04	0.00	0.04	0.03
MVPA	0.10	0.04	0.00	0.09
Sleep	0.02	0.03	0.09	0.00
Girls				
SB	0.00	0.03	0.06	0.02
LPA	0.03	0.00	0.03	0.03
MVPA	0.06	0.03	0.00	0.06
Sleep	0.02	0.03	0.06	0.00

SB sedentary behavior, *LPA* light physical activity, *MVPA* moderate-to-vigorous physical activity

significantly decreased boys' total HRQoL score by 1.211 points (*95% CI* – 2.253, – 0.168) and psychosocial health score by 1.437 points (*95% CI* – 2.615, – 0.260).

Figure 2 illustrates that in the total sample size, the change in total HRQoL scores increases with the reallocation of time from SB to sleep, and vice versa, mirroring similar trends observed among preschool boys, where both total HRQoL scores and psychosocial health scores increase with such reallocation.

Discussion

To our knowledge, this study represents the first endeavor to scrutinize the cross-sectional associations between 24-h movement behaviors and the comprehensive HRQoL scores, along with its sub-dimensions, among Chinese preschoolers. The results underscore a robust linkage among SB, sleep patterns, and HRQoL in preschoolers. Employing a composition approach through the application of the component isochronous substitution model, the investigation unveiled a noteworthy enhancement in the overall HRQoL score subsequent to equitably redistributing time originally allocated to SB towards sleep activities. In the gender subgroup analyses, this correlation was notably accentuated within the cohort of boys, exhibiting substantial increments primarily in psychosocial health scores. This observation implies the vulnerability of boys' HRQoL to daily fluctuations in 24-h movement behaviors.

Table 3 Compositional time use and its association with HRQoL

	Total HRQoL score		Physical health score		Psychosocial health score	
	γ (95% CI)	*p*	*γ (95% CI)*	*p*	*γ (95% CI)*	*p*
All						
SB	– 11.92 (– 21.56, – 2.27)	**0.016***	– 14.39 (– 25.07, – 3.72)	**0.008****	– 10.06 (– 20.95, 0.83)	0.070
LPA	5.11 (– 5.84, 13.69)	0.423	6.92 (– 3.89, 17.72)	0.209	2.16 (– 8.86, 13.18)	0.700
MVPA	– 0.21 (– 7.31, 6.90)	0.954	2.40 (– 5.47, 10.26)	0.549	– 1.56 (– 9.58, 6.46)	0.702
Sleep	8.20 (– 2.25, 18.65)	0.124	5.08 (– 6.49, 16.65)	0.388	9.47 (– 2.33, 21.26)	0.116
Boys						
SB	– 15.83 (– 28.52, – 3.14)	**0.015***	– 13.19 (– 26.99, 0.61)	0.061	– 16.42 (– 30.74, – 2.09)	**0.025***
LPA	5.11 (– 8.96, 19.18)	0.475	9.56 (– 5.74, 24.87)	0.219	2.538 (– 13.35, 18.43)	0.753
MVPA	– 1.95 (– 11.39, 7.49)	0.685	1.89 (– 8.38, 12.15)	0.717	– 3.937 (– 14.59, 6.72)	0.467
Sleep	12.68 (– 1.43, 26.77)	0.078	1.74 (– 13.60, 17.08)	0.823	17.814 (1.89, 33.74)	**0.029***
Girls						
SB	– 6.29 (– 21.46, 8.88)	0.414	– 16.47 (– 33.65, 0.72)	0.060	– 0.79 (– 17.82, 16.24)	
LPA	0.92 (– 13.04, 4.88)	0.896	3.92 (– 11.90, 19.73)	0.625	– 0.83 (– 16.51, 14.84)	
MVPA	3.18 (– 8.12, 4.48)	0.579	2.60 (– 10.21, 15.40)	0.690	3.533 (– 9.15, 16.22)	
Sleep	2.19 (– 13.89, 8.26)	0.788	9.96 (– 8.25, 28.17)	0.282	– 1.91 (– 19.96, 16.13)	

The analysis was conducted using multivariable linear regression models within the framework of compositional data analysis, and the results are presented ***γ*** (95% confidence intervals)

Models were adjusted for sex, age, and zBMI

SB sedentary behavior, *LPA* light physical activity, *MVPA* moderate-to-vigorous physical activity, *HRQoL* health-related quality of life

*p < 0.05; **p < 0.01

The bold values indicate statistical significance

Table 4 Projected changes in HRQoL following the redistribution of time by 30 min among behaviors are observed in the total sample

	SB	LPA	MVPA	Sleep
Total HRQoL score				
SB		− 1.605 (− 4.434, 1.224)	− 0.445 (− 3.299, 2.408)	**− 0.850 (− 1.638, − 0.062)***
LPA	1.374 (− 0.828, 3.576)		0.900 (− 3.673, 5.473)	0.495 (− 1.647, 2.638)
MVPA	0.501 (− 1.434, 2.436)	− 1.133 (− 5.436, 3.170)		− 0.378 (− 2.449, 1.693)
Sleep	**0.865 (0.071, 1.658)***	− 0.769 (− 3.543, 2.005)	0.391 (− 2.597, 3.379)	
Physical health score				
SB		− 2.536 (− 5.667, 0.596)	− 1.616 (− 4.774, 1.542)	− 0.838 (− 1.710, 0.034)
LPA	2.112 (− 0.325, 4.549)		0.461 (− 4.600, 5.523)	1.239 (− 1.132, 3.611)
MVPA	1.335 (− 0.806, 3.477)	− 1.235 (− 5.997, 3.528)		0.463 (− 1.829, 2.755)
Sleep	0.864 (− 0.014, 1.742)	− 1.706 (− 4.777, 1.364)	− 0.787 (− 4.094, 2.521)	
Psychosocial health score				
SB		− 1.039 (− 4.232, 2.155)	0.190 (− 3.031, 3.412)	− 0.817 (− 1.707, 0.072)
LPA	0.920 (− 1.566, 3.406)		1.086 (− 4.076, 6.249)	0.079 (− 2.340, 2.497)
MVPA	0.040 (− 2.145, 2.224)	− 1.024 (− 5.881, 3.834)		− 0.802 (− 3.140, 1.536)
Sleep	0.825 (− 0.070, 1.721)	− 0.238 (− 3.370, 2.894)	0.991 (− 2.382, 4.365)	

Values shows the estimated percentage change in HRQoL when the behaviour in the rows was substituted for the behaviour in the columns

SB sedentary behavior, *LPA* light physical activity, *MVPA* moderate-to-vigorous physical activity, *HRQoL* health-related quality of life

*$p < 0.05$

The bold values indicate statistical significance

Moreover, our study found that boys engage in greater PA, including more vigorous PA, than girls during the preschool period, consistent with previous research [37]. This variation may be attributed to sociocultural factors, familial expectations and support, as well as peer interactions. Societal perceptions and gender stereotypes may shape the activity patterns of boys and girls, as traditional norms often prescribe boys to be stronger and more active, while girls are expected to be quieter and gentler, potentially resulting in boys being more active and girls more sedentary [38]. Families may have disparate expectations and encouragements for boys' and girls' physical activity, as research indicates that parents are inclined to motivate boys more towards physical activity while less so for girls [39], potentially leading to a gender difference in activity levels. It has been shown that preschool children's behavior was strongly influenced by their peers [40], with the highest proportion of time being spent on physical activity when they were with active peers, and less time being spent on physical activity when they were with quiet peers.

The current study aligns with findings from the sole existing isochronous substitution modeling analysis conducted on preschoolers [14], both indicating that reallocating time dedicated to SB to sleep yields a notable enhancement in total HRQoL scores among preschool-aged children. This finding is further supported by several previous component analysis studies in children and adolescents [1, 41]. Regarding physiological mechanisms, this phenomenon could be attributed to the potential effect of increased sleep duration on maintaining or enhancing connectivity within the prefrontal control network and the limbic system, particularly the amygdala [42–44]. Consequently, this connectivity enhancement may mitigate negative biases and emotional responses [45], consequently leading to an increase in HRQoL among preschoolers. Viewed from a psychological perspective, the recognition exists that adequate sleep triggers positive responses in emotion regulation, potentially augmenting the levels of HRQoL among preschoolers [44, 46], thereby contributing, to a certain extent, to the understanding of the findings in the present study. Notwithstanding, it is imperative to acknowledge the prevailing focus of current research on sleep behaviors and their implications for HRQoL, primarily emphasizing sleep duration [1, 47], while neglecting other dimensions such as sleep quality, which similarly wield considerable impact on HRQoL. The integration of these overlooked dimensions presents an opportunity to enrich our comprehension of the intricate interplay between sleep and HRQoL [9, 47, 48]. Consequently, it is imperative that future research endeavors delve more comprehensively into the intricate impact of sleep on HRQoL among preschool children.

The present study has not found an association between reallocating time from moderate-to-vigorous physical activity (MVPA) or light physical activity (LPA) and other active behaviors with HRQoL scores, which contradicts the findings of Chen et al. [14]. The inconsistency observed may be attributed to several factors: (1) disparities may arise due to variations in aspects such as the magnitude and nature

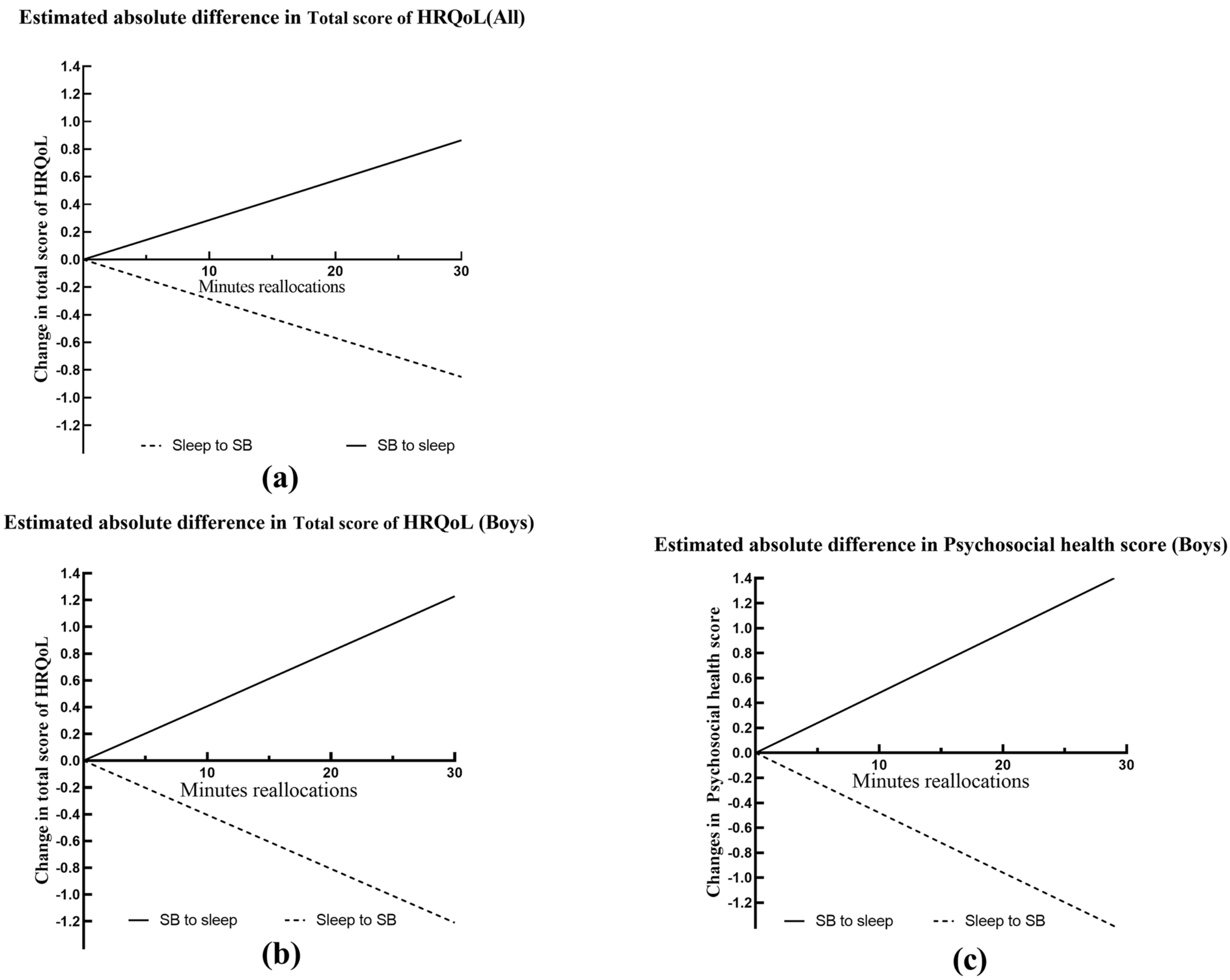

Fig. 2 Asymmetry in predicted changes in HRQoL related to the reallocation of time between SB and sleep. **a** indicates a dose-relationship plot of total HRQoL scores after time reassignment for the total population; **b** indicates a dose-relationship plot of total HRQoL scores after time reassignment for the boys' group; **c** indicates a dose-relationship plot of psychosocial health scores after time reassignment for the boys' group; and HRQoL indicates health-related quality of life

of daily activity behaviors exhibited by preschoolers across different nations; (2) different methods of measuring PA and SB, Chen et al. used a questionnaire method to subjectively assess PA and SB, which is different from the objective accelerometer-based assessment method in the present study, with a certain degree of subjective bias; (3) differences in the methods for partitioning time for daily 24-h movement behaviors, with Chen et al. employing a three-classification method (i.e., PA, SB, and sleep), contrasting the four-classification method utilized in the current study, may also contribute to the incongruity in findings, potentially impacting the consistency of the analysis results to some extent; and (4) the temporal contexts of the data collection are different, Chen et al. who collected their data prior to the COVID-19 outbreak, whereas the present study collected their data during the COVID-19 epidemic in which the data were collected. Previous studies have indicated a notable reduction in levels of PA, particularly MVPA, among preschool children during the epidemic compared to the pre-epidemic period [49], potentially resulting in an inadequate allocation of 30 min insufficient to meet the minimum "threshold" for MVPA to exert a health effect [50]. This notion finds support in a recently published study, which similarly discovered that reallocating 30 min from another behavior to MVPA did not lead to significant changes in HRQoL scores among preschool children [1]. The results of this study do not contradict the guidelines for daily 24-h movement behaviors in preschool children, as the health effects of daily movement behaviors in the preschool years may manifest themselves in childhood and adolescence. In previous studies, it has been established that while one study demonstrated no association between MVPA and HRQoL during the preschool years [51], another study uncovered a significant positive correlation between MVPA and HRQoL during the school-age years (7–9 years) [41]. Although no association between MVPA and HRQoL was found in the preschool years, it is important to consider that MVPA has been shown to have a facilitating effect on executive functioning and HRQoL in preschoolers [14, 34]. Therefore, despite the absence of a direct link in the current study, it remains advisable to decrease sedentary behavior time and enhance MVPA time in preschoolers.

In order to delve deeper into the effects of SB and sleep on HRQoL and to consider potential gender differences, the present study employed component isochronous substitution models for separate analysis of boys and girls. While the HRQoL scores of boys exhibited a significant decrease when the time allotted for sleep was redistributed to SB, there was no notable alteration observed in the HRQoL scores of girls. Possible reasons for this phenomenon include the following: (1) it may stem from individual differences in HRQoL, which can vary among preschoolers of the same gender based on factors such as lifestyle, health status, and psychological characteristics; (2) it may arise from disparities in the initial timing of SB, as previous research has indicated significantly lower SB time in preschool boys compared to girls [37, 52, 53], coupled with a noted correlation between SB time and HRQoL [14], where preschoolers with prolonged sedentary behavior exhibited lower HRQoL scores; and (3) it may be attributed to variances in PA levels between boys and girls, supported by evidence indicating a positive correlation between PA and HRQoL [10], alongside findings suggesting higher PA levels among boys than girls [37], which could partly elucidate our observations. Additionally, it's essential to consider that disparities in activity preferences could also could also play a contribution role. Girls tend to favor indoor activities [54], where they allocate more time engaging in static games, while boys exhibit a higher tendency towards outdoor activities [55]. Although this study identified gender differences in the association between 24-h movement behaviors and HRQoL, its cross-sectional design limits causal interpretation. Future research, especially longitudinal and experimental studies, is essential to more thoroughly explore and confirm the presence of these gender differences.

Derived from the outcomes of this investigation, it is suggested that gender-specific strategies pertaining to activity behaviors be incorporated into public health policies and childcare practices. Specifically targeting girls, it is advisable to promote increased physical activity and reduced sedentary behavior to enhance their HRQoL. Through the implementation of these interventions, a more effective promotion of the overall health and well-being of preschool children can be achieved, thereby establishing a sturdy foundation for their future development.

The present study, characterized by numerous strengths, stands as a significant contribution to the realm of 24-h movement behaviors research in preschool children. Firstly, through the utilization of accelerometers for the measurement of preschoolers' PA and SB, the current study has effectively acquired high-quality data on children's daily movement behaviors. This methodology, distinguished by its objectivity and accuracy, surpasses traditional self-report or observational methods. Secondly, our study utilized compositional data analysis, an advanced statistical method, enabling the consideration of interdependencies among various movement behaviors in our analysis [11, 51]. Employing this method enhances the precision and reliability of the analysis results, offering novel insights into comprehending the intricate interactions of 24-h movement behaviors in preschool children. Thirdly, this study provides a nuanced discussion of the respective benefits of LPA and MVPA to provide a more complete understanding of how different activity intensities affect preschoolers' HRQoL. More significantly, as far as we are aware, this study is the first to specifically investigate the relationship between preschool children's 24-h movement behaviors and their HRQoL as well as its sub-dimensions. This research fills a void in the current body of literature and offers robust evidence to confirm the validity of the link between 24-h movement behaviors and HRQoL. While this study offers novel insights into the relationships among SB, sleep, and HRQoL in preschool children, we acknowledge the intricate nature of these connections. Drawing generalizable conclusions from the sample in this study may prove challenging. Nonetheless, the present study undoubtedly furnishes crucial additional evidence for research on the correlation between 24-h movement behaviors and HRQoL in Chinese preschool children.

Certainly, it's important to acknowledge the limitations of this study. One notable limitation is that the correlation between MVPA and LPA with HRQoL was less pronounced, as indicated by the broader 95% confidence intervals. These findings could be attributed to the study's limited sample size and the inherent variability within the sample. Furthermore, the cross-sectional design restricts our ability to infer causality between movement behaviors and HRQoL. Future research efforts should focus on increasing the sample size to enhance the accuracy of predictions regarding HRQoL after redistributing movement behaviors, thus strengthening the reliability of the findings. Another limitation is the potential for subjective bias in the use of questionnaires to investigate sleep duration in preschool children. But, the reliability and validity of the questionnaire were validated [31]. Future research could benefit from utilizing accelerometry to track both daytime and nighttime behaviors. Additionally, it's important to recognize that the data concerning sleep duration and HRQoL were obtained from parental reports, potentially introducing subjective biases. However, it's crucial to note that the survey methodology employed for sleep assessment and the validity and reliability of the PedsQL questionnaire, widely recognized for measuring quality of life in school-aged children, have been rigorously validated [31, 32].

Conclusion

Our findings underscore the notion that a blend of 24-h movement behaviors can enhance HRQoL in preschool children. Furthermore, the study revealed that substituting SB time with increased sleep time significantly enhanced HRQoL among preschool children, whereas reducing sleep time to accommodate increased SB time resulted in a gradual decline in HRQoL. This finding underscores the crucial role of sleep in preserving HRQoL in preschool children and highlights the potential adverse impact of inadequate sedentary behavior on HRQoL in this demographic. Broadly, these findings support the notion that existing guidelines and interventions, such as reducing sedentary time, can enhance HRQoL in preschool children. LPA and MVPA, although not significantly associated with HRQoL in this study, moving time out of SB into that behaviour may still be more beneficial than continuing to spend that time sedentary.

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Data availability The datasets generated during and/or analysed during the current study are obtainable from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the Capital Institute of Pediatrics (No. SHERLL2021069).

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