Received: 27 April 2023 | Revised: 20 June 2023 | Accepted: 10 July 2023

DOI: 10.1111/ijpo.13068

ORIGINAL RESEARCH

Pediatric OBESITY WILEY

Longitudinal associations between diet quality, sedentary behaviours and physical activity and risk of overweight and obesity in preschool children: The ToyBox-study

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Funding information
European Commission, Grant/Award Number: 245200; Else Kröner-Fresenius-Foundation; LMU Medical Faculty; LMU University Hospitals

Summary

Background: Lifestyle behaviours related to diet and physical activity are associated with increased risk of obesity and evidence suggests that associations might be stronger when a synergetic effect is examined.

Objective: To examine the cross-sectional and longitudinal associations between diet, screen time (ST) and step recommendations and risk of overweight and obesity in European preschoolers participating in the ToyBox-study.

Methods: In this cluster-randomized clinical trial, 718 children (51.4% boys) from six European countries participated. Parents filled out questionnaires with information on socio-demographic status, step recommendations and ST.

Results: Longitudinal results indicate that participants having a low Diet Quality Index (DQI), not meeting ST and step recommendations at T0 and T1 had higher odds of having overweight/obesity at T1 (odds ratio [OR] = 1.116; 95% confidence interval [CI] = 1.104–2.562) than those children having a high DQI and meeting ST and step recommendations at T0 and T1. Similarly, participants having a high DQI, but not meeting ST and step recommendations at T0 and T1 had increased odds of having overweight/obesity (OR = 2.515; 95% CI = 1.171–3.021).

Conclusions: The proportion of participants having a low DQI, not adhering to both step and ST recommendations was very high, and it was associated with a higher probability of having overweight and obesity.

KEYWORDS
dietary quality; physical activity; preschoolers; sedentary behaviours, childhood obesity

1 | INTRODUCTION

Over the last four decades, the prevalence of overweight and obesity has increased in all age groups and is expected to continue increasing over the coming decades.[1] In Europe, 7.9% of preschool children and one in three school-aged children have overweight or obesity.[2] The health consequences of overweight and obesity extend from childhood to adulthood, making it increasingly difficult to prevent excess weight successfully in the long term[3] as children with excess weight in adolescence are more likely to have obesity as adults.[4] It is widely recommended that obesity prevention strategies focus on early childhood,[5] since those focusing on late childhood and adolescence are less effective given that lifestyle behaviours, such as eating and activity, are formed and established during the early years of life.[6,7]

Obesity is a multifactorial disease,[8] shaped by individual, sociocultural, community and other factors and follows a social gradient. Regarding lifestyle factors, evidence points to the synergetic effect of multiple lifestyle behaviours related to diet, physical activity (PA) and sedentary behaviours, collectively referred to as energy balance-related behaviours (EBRBs), associated with increased risk of overweight and obesity.[9] Previous studies in young population groups have examined patterns of EBRB and their association with obesity[10–12] and cardiovascular disease risk[13] in groups with unhealthy patterns. However, available literature in preschool children is scarce.

Previous results from the European multicentre ToyBox-study in preschool children indicated that low socioeconomic status was associated with consumption of high energy-dense foods, increased screen time (ST), and low levels of PA, but it did not address associations with obesity risk.[14,15] Low PA levels and high ST were also associated with energy-dense foods (sweets, desserts and salty snacks) and beverage consumption (fizzy drinks).[16,17]

The development of effective obesity prevention interventions is even more relevant in the post-COVID-19 era as scientific evidence from young population groups indicate changes in dietary–lifestyle behaviours accompanied by a reduction in PA levels and lower energy expenditure that negatively affect body composition.[18,19] Evaluating the synergetic effect of EBRB instead of individual lifestyle determinants might prove to be more effective in identifying and promoting a healthy lifestyle as well as more informative to assist in the development of successful childhood obesity prevention programs. Therefore, the objective of this study is to examine the cross-sectional and longitudinal associations (baseline, T0 and follow-up, T1) between diet, ST and step recommendations and risk of overweight and obesity in European preschoolers participating in the ToyBox-study.

2 | METHODOLOGY

2.1 | Study protocol

The ToyBox-study (www.toybox-study.eu) is a cluster-randomized controlled trial aiming to prevent obesity in preschool children. It was conducted in six European countries, namely Belgium, Bulgaria, Germany, Greece, Poland and Spain. The detailed study protocol is described elsewhere.[20] The ToyBox-study is registered in Clinical.trials.gov (ID: NCT02116296) and adhered to the Declaration of Helsinki and the conventions of the Council of Europe on human rights and biomedicine. In all countries, ethical approval was obtained from their respective ethical committees and local authorities. Parents/caregivers were asked for written informed consent for the participation of their child in the study.

2.2 | Sampling

In total, 309 kindergarteners and 7056 children aged 3.5–6 years were recruited at T0 and 5529 children at T1 to participate in the Toybox-study. Data collection was carried out between May and June 2012 (T0) and between May and June 2013 (T1). ToyBox is a kindergarten-based, family-involved intervention during 24 weeks, which targets key behaviours related to early childhood obesity, that is, drinking, eating and snacking, PA and sedentary behaviour and their determinants, in preschool children.[20] For the purpose of this study, 718 preschool children, from the control group of the ToyBox-study,

with complete information on the food frequency questionnaire (FFQ) and pedometer outputs at T0 and T1 were included.

2.3 | Anthropometric measures

Trained researchers visited the kindergartens and measured children's body weight and height according to standardized protocols.[21] Body weight was measured in underwear and without shoes using an electronic scale (Type SECA 861 or SECA 813) to the nearest 0.1 kg, and body height was measured with a telescopic height instrument (Type SECA 225 or SECA 214) to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight (kg) divided by squared height (m^2). Weight status (normal weight, overweight and obese) was categorized based on the Cole et al. criteria.[22]

2.4 | Physical activity

Preschool children wore a motion sensor both at baseline and follow-up to objectively measure their steps per day. The devices were worn on the right hip (secured by an elastic waistband) for six consecutive days, including two weekend days.[23] The pedometer Omron Walking Style Pro pedometer (HJ-720IT-E2) was chosen to assess the number of steps per day, except in Belgium, where Actigraph accelerometers (type GT1M and GT3X(+)) were used. Step counts from the pedometer and the accelerometer were comparable and the evidence of validity in the ToyBox preschool children indicated high correlations (daily, $r = 0.89$) suggesting that the Omron Walking Style Pro pedometer is a valid and accurate measure to assess preschooler's steps per hour.[24] For the purposes of this analysis, the number of steps was further categorized into two categories, including ≥11 500 steps per day (if children followed the steps recommendations) and <11 500 steps per day (if children did not follow the steps recommendations). The selected step count cut-offs were based on De Craemer et al.[25]

2.5 | Screen time

Data on children's sedentary behaviours were collected via parentally reported questionnaire. Behaviours assessed included watching TV and/or DVDs and personal computer use. Parents reported frequency both for weekdays and weekend days. The frequency categories included: 'never', 'less than 30 min/day', '30 min to 1 h/day', '1–2 h/day', '3–4 h/day', '5–6 h/day', '7–8 h/day', '8 h/day' and 'more than 8 h/day'. Average hours per day of TV/video viewing and personal computer use (separately for weekdays and weekend days) were summed up to obtain the ST. For the purposes of this analysis and to obtain daily ST, average minutes per day were summed up and divided by 7 days, both for week- and weekend days. Data were further aggregated into two categories, including ≤1 h per day (if the children followed the recommendations) and >1 h per day (if the children did not follow the recommendations). Recommendations are based on the World Health Organization recommendations for preschool children including ≤1 h per day and >1 h per day.[26]

2.6 | Diet Quality Index

Parents reported the food and beverage consumption of their children using a validated 37-item semi-quantitative FFQ.[27] Based on this data, the Diet Quality Index (DQI) was calculated. The DQI is an index largely used in studies with similar characteristics to assess the overall quality of the diet[28,29] and consists of three components: (a) dietary quality, (b) dietary diversity and (c) dietary equilibrium. Dietary quality expresses whether the children made the optimal food quality choices within a food group. Dietary diversity expresses the degree of variation in the diet. The diversity component was obtained by giving points ranging from 0 to 9 when at least one serving of food from a recommended food group was consumed. Dietary equilibrium refers to the difference between the adequacy of the diet and the excess of the intake in the diet. To compute the overall DQI, scores from the three components were summed up and divided by 3, resulting in scores ranging from −33% to 100%. The DQI score was categorized based on quartiles, indicating that those participants with the score ≤35 points (below median) were considered with a low DQI score and >36 points (above median) were considered with a high DQI.

2.7 | Statistical analysis

All statistical analyses were performed using the Predictive Analytics Software (IBM SPSS Statistics for Windows) Version 20. The analysis was done for the control group of the participants and no differences by sex were detected when using a *t* test for continuous variables and χ^2 test for categorical variables. Initially and to evaluate changes to the adherence of EBRBs between T0 and T1, six groups were established, reflecting differential combinations of meeting or not meeting DQI, ST and/or PA recommendations. After establishing the potential combinations of the EBRBs patterns, a logistic regression model analysis was performed to examine the associations between the EBRBs patterns and the risk of overweight and obesity. The reference group for the analysis referred to participants having a high DQI and meeting ST and step recommendations at T0 or T1 (at cross-sectional and longitudinally, respectively). The model was adjusted for sex, country and maternal education. All statistical tests and corresponding *p* values lower than 0.05 were considered statistically significant.

3 | RESULTS

Table 1 presents the descriptive information of the sample included in the analysis. There were significant differences between T0 and T1 regarding age and BMI categories. Significant differences between T0 and T1 were also found for the number of steps per day and ST recommendations.

Table 2 presents the results of the logistic regression analysis (BMI as categorical variable) between patterns of EBRBs and risk of overweight and obesity for the sample at T0 and T1. Participants that had a high DQI score, met step recommendations but did not meet ST

TABLE 1 Descriptive characteristics of European preschool children participating in the ToyBox-study at baseline (T0) and follow-up (T1) ($n = 718$).

	T0 Mean (SD)	T1 Mean (SD)	*p* Value
Age (years)	4.74 (0.4)	5.71 (0.3)	**0.003**
	N (%)		
Sex			
Boys	364 (51.4)		0.152
Girls	354 (48.6)		
Maternal education (years)			
<7–12	98 (13.5)		0.104
13–16	288 (40.1)		
>16	327 (45.6)		
BMI categories[a]			
Normal weight	611 (85.2)	615 (85.7)	**<0.001**
Overweight	85 (11.6)	75 (10.1)	
Obesity	21 (2.5)	31 (3.6)	
Steps/day 718			
<11.500	656 (91.4)	682 (95.0)	**0.004**
≥11.500	62 (8.6)	36 (5.0)	
Screen time			
≤1 h/day	211 (29.4)	187 (26.0)	**0.037**
>1 h/day	507 (70.6)	531 (72.3)	
DQI score			
Low score (≤35)	544 (75.8)	554 (77.2)	0.480
High score (>36)	174 (24.2)	164 (22.8)	

Abbreviations: BMI, body mass index; DQI, Diet Quality Index; T0, baseline period; T1, follow-up period. Statistically significant values are in bold.
[a]BMI according to Cole's cut-off.[22]

recommendations had lower odds of having overweight/obesity (odds ratio [OR] = 0.946; 95% confidence interval [CI] = 0.345–0.989) to those children having a high DQI and meeting ST and step recommendations. Furthermore, those participants that had a low DQI score, did not meet ST recommendations but met step recommendations had decreased odds of having overweight/obesity (OR = 0.401; 95% CI = 0.134–0.898). On the other hand, participants that had a low DQI score and did not meet ST and step recommendations had increased odds of having overweight/obesity (OR = 2.03; 95% CI = 1.034–3.616) as compared to children that had a high DQI and met ST and step recommendations at T0. In the same table, but in the follow-up, participants that had a low DQI score, did not meet ST and step recommendations or the participants had a high DQI score and did not meet ST and step recommendations had increased odds of having overweight/obesity (OR = 1.062; 95% CI = 1.010–2.221 and OR = 2.483; 95% CI = 1.085–2.189; respectively) compared to those participants that had a high DQI and met ST and step recommendations at T1. In the same line, participants that had a low DQI score, meet ST recommendations but did not meet step recommendations also had increased odds of having overweight/obesity (OR = 1.496; 95% CI = 1.211–3.323) compared to those participants that had a high DQI and met ST and step recommendations at T1.

Table 3 presents the findings of the longitudinal analysis as derived from the logistic regression analysis examining EBRBs patterns and risk of having overweight/obesity. Participants that had a low DQI, did not meet ST and step recommendations, both at T0 and T1 was very high (55%) and had increased odds of having overweight/obesity (OR = 1.766; 95% CI = 1.104–2.562) as compared to participants that had a high DQI and met ST and step recommendations both at T0 and T1. Similarly, participants that had a high DQI, did not meet ST and step recommendations both at T0 and T1 had increased odds of having overweight/obesity (OR = 2.515; 95%

TABLE 2 Logistic regression analysis assessing cross-sectional associations between patterns of energy balance-related behaviours and risk of overweight and obesity at baseline (T0) and follow-up (T1).

	Baseline (T0)			Follow-up (T1)		
	N	OR	CI	*N*	OR	CI
DQI+ ST+ Steps+	39	Ref	Ref	25	Ref	Ref
DQI− ST− Steps−	340	**2.03**	**1.034–3.616**	364	**1.062**	**1.010–2.221**
DQI+ ST− Steps−	115	0.691	0.143–3.341	118	**2.483**	**1.085–2.189**
DQI+ ST− Steps+	22	**0.946**	**0.345–0.989**	12	3.578	0.564–1.898
DQI+ ST+ Steps−	53	1.341	0.815–1.932	47	0.977	0.873–2.299
DQI− ST+ Steps−	113	0.608	0.300–2.335	123	**1.496**	**1.211–3.323**
DQI− ST− Steps+	26	**0.401**	**0.134–0.898**	6	0.781	0.490–1.247
DQI− ST+ Steps+	10	0.333	0.184–1.545	17	0.317	0.076–0.969

Note: DQI+: participants with a high Diet Quality Index score. DQI−: participants with a low Diet Quality Index score. ST+: participants met screen time recommendations. ST−: participants did not meet screen time recommendations. Steps+: participants met step recommendations. Steps−: participants did not meet step recommendations. Odds ratios (ORs) and 95% confidence intervals (CIs). Reference group: participants with high DQI and meeting screen time and step recommendations at T0 or T1. Analysis adjusted for sex, country and maternal education. Statistically significant values are in bold.

TABLE 3 Logistic regression analysis assessing longitudinal associations between patterns of energy balance-related behaviours at baseline and follow-up and risk of overweight and obesity at baseline (T0) and follow-up (T1).

Baseline	Follow-up	*N*	OR	CI
DQI+ ST+ Steps+	**DQI+ ST+ Steps+**	33	**Ref**	**Ref**
DQI− ST− Steps−	**DQI− ST− Steps−**	389	**1.766**	**1.104–2.562**
DQI− ST− Steps+	**DQI− ST− Steps+**	6	1.644	0.021–2.767
DQI+ ST− Steps−	**DQI+ ST− Steps−**	115	**2.515**	**1.171–3.021**
DQI− ST− Steps+	**DQI+ ST− Steps−**	35	**0.767**	**0.017–0.956**
DQI+ ST− Steps−	**DQI− ST− Steps+**	51	1.003	0.333–1.443

Note: DQI+: participants with a high Diet Quality Index score. DQI−: participants with a low Diet Quality Index score. ST+: participants met screen time recommendations. ST−: participants did not meet screen time recommendations. Steps+: participants met step recommendations. Steps−: participants did not meet step recommendations. Odds ratios (ORs) and 95% confidence intervals (CIs). Reference group: participants with high DQI and meeting screen time and step recommendations at T0 and T1. Analysis adjusted for sex, country and maternal education. Statistically significant values are in bold

CI = 1.171–3.021). On the other hand, participants that had a low DQI, did not meet ST recommendations but met step recommendations at T0 and T1 had a high DQI score, did not meet ST and step recommendations, had decreased odds of having overweight/obesity (OR = 0.767; 95% CI = 0.017–0.956) as compared to participants that had a high DQI and met ST and step recommendations in both times.

4 | DISCUSSION

The current study examined determinants of childhood overweight/obesity based on three patterns of EBRB, that is, diet quality, ST and PA, in the European preschool-aged children participating in the ToyBox-study. The novelty of this study includes the examination of adherence to PA and ST recommendations and dietary quality in two time points and their synergetic effect on risk of overweight and obesity in preschoolers adding to the scarce literature on this topic. Evaluating the synergetic effect of EBRBs instead of individual lifestyle behaviours might prove to be more effective in identifying and promoting a healthy lifestyle as well as more informative to assist in the development of successful childhood obesity prevention programs.

In this study, almost half of the sample of preschool children had a low DQI and did not meet ST and step recommendations or had a high DQI but did not meet ST and step recommendations cross-sectionally or longitudinally. The results of observational studies examining the association between diet and overweight/obesity showed that low-quality diet is associated with increased risk of obesity and metabolic syndrome.[30–32] A systematic review showed a positive association between poor dietary quality and high body fat indices.[33,34] The results of this study are in line with other studies. A study that included Pakistani children (5–12 years of age) found that children with eating habits characterized, for example, eating fast food and snacks and having a sedentary lifestyle were significantly more likely to have overweight and obesity.[35]

In our study, sedentary lifestyle that included television viewing and personal computer game use showed a significant positive association with the risk of having overweight/obesity, and is consistent with previous studies.[36–38] One explanation could be that increased television viewing has been associated with a higher energy intake.[39] In another study carried out with the ToyBox sample, it was found that sedentary behaviours were associated with the consumption of energy-dense foods and fizzy drinks.[39]

Regarding PA, the results indicated that compliance with the steps recommendations in preschool children appears to be a protective factor against obesity. Studies that have used objective PA assessment methods continue to report low step counts and levels of PA in children with obesity.[40] Walking, as part of regular activities of daily living, is an ideal activity for increasing energy expenditure and therefore a way to prevent childhood obesity; therefore more PA interventions are needed in this population.[41]

When EBRBs behaviours were combined and analyzed longitudinally, the results showed that almost 43% of the preschool children with a low DQI and low adherence to step recommendations and ST in T0 and T1 were at increased risk of having overweight and obesity. The probability of having overweight and/or obesity was stronger when the behaviours were studied in a synergistic; for this reason, the authors consider that the potential synergy between EBRBs should be examined in obesity prevention interventions, by addressing multiple behaviours simultaneously.

In this population, in those children with a low DQI, meeting steps recommendations seem to be related to decreased risk of overweight and obesity and hence, its protective role should be examined in other population groups not having an optimal diet. In fact, lifestyle interventions are more likely to be successful if they emphasize reduction increasing participation in addition to improving diet quality.[42,43]

This study has several strengths including a longitudinal design with random selection of schools and objective measures of weight and height. The sample is large and consists of a culturally and socioeconomically diverse population of preschool children from six different countries across Europe. Information through questionnaires was assessed via standardized and harmonized procedures.[23]

This study has some limitations as well. Information on dietary intake should be interpreted with caution so that it was collected via parental self-reported questionnaires, which are prone to over- or underreporting. Future studies should be complemented using

biomarkers of intake. Pedometers were used to assess PA; however, pedometers are not the gold standard in measuring preschool child PA. In the ToyBox-study, however, a good agreement between the pedometer and accelerometer measures was observed ($r = 0.89$). The used categories of BMI to define overweight and obesity are mainly based on statistical criteria; however, several studies observed an association between weight status and obesity-related complications.

5 | CONCLUSION

This study examined the relationship between diet quality and adherence to step and ST recommendations with the probability to have overweight/obesity. In this sample of preschool children, it was found that adherence to EBRBs recommendations was associated with decreased odds of having overweight/obesity. Preschool children and their parents should try to increase family time spent at activities promoting PA and to minimize the time spent on ST or being sedentary. The findings indicate that public health obesity prevention efforts should apply an integrated approach to PA and dietary intake from early childhood. In conclusion, in European preschool children, the proportion of participants having a low DQI, not adhering to both step and ST recommendations was very high, and it was associated with a high probability of developing overweight and obesity.

ACKNOWLEDGEMENTS

The ToyBox-study was funded by the Seventh Framework Programme (CORDIS FP7) of the European Commission under grant agreement number 245200. The content of this article reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained herein. BK is the Else Kröner Senior Professor of Paediatrics at LMU—University of Munich, financially supported by Else Kröner-Fresenius-Foundation, LMU Medical Faculty and LMU University Hospitals.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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How to cite this article: Miguel-Berges ML, Mouratidou T, Santaliestra-Pasias A, et al. Longitudinal associations between diet quality, sedentary behaviours and physical activity and risk of overweight and obesity in preschool children: The ToyBox-study. *Pediatric Obesity*. 2023;18(10):e13068. doi:10.1111/ijpo.13068