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Application of a composite scoring protocol to identify factors that contribute to the risk of overweight and obesity in Irish children

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Summary

Background: Investigations into the main drivers of childhood obesity are vital to implement effective interventions to halt the global rise in levels. The use of a composite score may help to identify children most at risk of overweight/obesity.

Objectives: To investigate the cumulative impact of factors associated with overweight/obesity risk in children.

Methods: Data were analysed from the Irish National Children's Food Survey II which included 600 children, aged 5–12-years. The risk factors examined included social class, parental, early life, lifestyle, and dietary components. A composite score was calculated which ranged from 0 (no risk factors for overweight/obesity) to 4 (4 risk factors for overweight/obesity).

Results: In model 1 (%BF) the four factors associated with overweight/obesity risk were having a parent with overweight/obesity (odds ratio 3.1; 95% confidence interval 1.9–4.8), having a high birth weight of ≥4 kg (2.5; 1.6–3.9), being from a low social class (2.3; 1.4–3.8) and low physical activity (1.9; 1.2–2.8). Children who scored 3–4 points on the composite score had a 10-fold (10.0; 4.2–23.9) increased risk of overweight/obesity compared to those with 0 points, a sevenfold (7.2; 3.9–13.5) increased risk compared to those with 1 point and a threefold (2.6; 1.4–4.8) increased risk compared to those with 2 points, with similar results observed in model 2 (BMI).

Conclusion: The use of a composite score is a beneficial means of identifying children at risk of overweight/obesity and may prove useful in the development of effective interventions to tackle childhood obesity.

KEYWORDS
children, composite score, determinants, obesity, risk factors

Abbreviations: %BF, Percentage body fat; BMI, Body mass index; ECHO, Ending Childhood Obesity; MET, Metabolic; NCFS II, National Children's Food Survey II; PA, Physical activity; SSBs, Sugar-sweetened beverages; ST, Screen time; WHO, World Health Organization.

1 | INTRODUCTION

To implement reliable and effective interventions for the prevention and treatment of childhood obesity, the role of modifiable risk factors in the development of this disease must be considered. With this in focus, the World Health Organization's report on Ending Childhood Obesity (WHO ECHO) outlines six main recommendations for governments to address when tackling this global issue.[1] These recommendations have been adopted by numerous obesity action policies across Europe, including the 'A Healthy Weight for Ireland: Obesity Policy and Action Plan 2016 – 2025'.[2] ECHO advises the promotion of healthy foods such as fruit and vegetables and reduced consumption of sugar-sweetened beverages (SSBs); promoting physical activity (PA) and movement, coupled with reducing time spent in sedentary activities such as watching television and playing video games. In addition, early life determinants are deemed important with a focus on birth weight and breastfeeding practices.[1] Lastly, the importance of inclusion of the family unit in weight management interventions was highlighted, as parents' own weight status, social class and perception of their child's weight have been shown to influence their children's lifestyle habits.[3–5]

The fact that more than one, and often all, of these risk factors can co-exist for many children is of great concern as their likelihood of having overweight/obesity is increased. Recently, a composite scoring protocol was utilized to ascertain the cumulative risk associated with non-adherence to healthy lifestyle recommendations in children from eight European countries including Estonia, Sweden, Germany, Belgium, Hungary, Italy, Spain and Cyprus. This composite score revealed that children who were less likely to adhere to the recommendations for PA, screen time (ST) and sleep, were at greater risk of having overweight or obesity in comparison to those who were more likely to adhere.[6]

Limited data exist on the individual and cumulative factors associated with an increased risk of overweight and obesity in Irish children. The aim of this study was to identify risk factors associated with overweight and obesity in Irish children, to ascertain whether the risk factors identified in this cohort are like those observed in similar population groups and to examine if a composite score is a useful approach to help understand the cumulative impact of multiple risk factors on the occurrence of overweight/obesity in children which could be utilized in global public health strategies.

2 | METHODS

2.1 | Study design and participants

The current study used data from the National Children's Food Survey II (NCFS II), a cross-sectional food consumption survey carried out between 2017 and 2018 in the Republic of Ireland. In brief, the sample which included 600 children aged 5–12 years (boys: *n* 300; girls: *n* 300), was representative of the Irish population with respect to age, gender and urban/rural location according to the 2016 Irish census.[7] Further detail on participant recruitment, ethical approval and response rate have been previously published.[8] A total of 596 and 594 children had body mass index (BMI) and percentage body fat (%BF) measurements available respectively and were included in these analyses.

TABLE 1 Description of overweight/obesity risk factors for potential use in a composite score

Factor	Non-risk factor	Potential risk factor
Breastfeeding	Breastfed	Never breastfed
Birth weight	<4000 g	≥4000 g
Parental social class[a]	High social class	Low social class
Parent weight status	No parent with OW/OB	≥1 parent with OW/OB
Fruit and veg intake	≥400 g/day	<400 g/day
Sugar-sweetened beverage	Non-consumer	Consumer
Time of main meal	Before 8 PM	After 8 PM
Physical activity MET min	≥Median MET min/day[b]	<Median MET min/day[b]
Sleep duration	≥10 hours per night	<10 hours per night
Screen time	<2 h/day	≥2 h/day

Abbreviations: MET min, metabolic minutes; OW/OB, overweight/obesity.
[a]Parental social class was categorized as follows; a higher social class group (professional, managerial and technical workers, non-manual workers) and a lower social class (skilled manual workers and semi-skilled and unskilled workers) using the Irish Census definitions.[7]
[b]Median MET min/day = 480.

2.2 | Classification of overweight and obesity

Anthropometric measurements were carried out by trained research nutritionists using standardized techniques. Children were measured in light clothing, barefoot, with pockets emptied and after voiding. No allowance was made for the weight of clothing. Weight and percentage body fat (%BF) were taken in duplicate using a Tanita Body Composition Analyser BC-420MA (Tanita, Ltd, GB), to the nearest 0.1 kg. Height was measured taken to the nearest 0.1 cm through the use of the Leicester Height Measure (Seca, Birmingham, UK) stadiometer. Children were asked to stand in an upright position with his/her back to the backboard of the stadiometer. Their heels and buttocks were touching the backboard of the stadiometer, with their feet together, and the child's head positioned in the Frankfurt Plane. Overweight and obesity were classified for both BMI (kg/m^2) and %BF using established cut-offs as described by Cole and Lobstein (BMI) and McCarthy (%BF).[9,10] For these analyses overweight and obesity groups were combined as the *n* value in the obesity groups were low and would have led to a reduction in statistical power.

2.3 | Risk factors for overweight and obesity

To establish relevant factors for examination in this analysis an extensive review of the literature and recommendations for prevention and

reduction of childhood overweight and obesity was conducted.[11] Based on the outcome of this, several factors were considered in the analysis whereby data were available (Table 1). Factors included were as follows; Birth weight: the weight of each participant at birth with a weight ≥4000 g deemed high (foetal macrosomia); Breastfeeding: whether the child was breastfed or not in the first 6 months of life; Sleep: the average amount obtained per night, with optimal sleep duration defined using the 10-h guidance for school children[12]; Parental social class: which was based on the highest household occupation. Parental social class was divided into two groups: a higher social class group (professional, managerial and technical workers, non-manual workers) and a lower social class (skilled manual workers and semi-skilled and unskilled workers) using the Irish Census definitions[7]; PA: The Child and Youth Physical Activity Questionnaires collected the frequency and duration of activities that the child participated in over a seven-day period. These data were used to calculate the age group and gender-specific metabolic (MET) minutes associated with PA per day.[13] Although a higher duration and intensity of exercise is advised by the WHO[14] there is no recommendation for daily MET minutes for children. Therefore, the median MET minutes obtained by all children per day were calculated, with children who had MET minutes above the median considered to have a high PA level; ST: information on the time children spent watching television and playing computer/video games were used from the PA questionnaires to determine ST. The less than 2 hours per day recommendation for ST was the cut-off employed for this analysis[15]; Parent's weight status: the impact of parental weight status on that of their children's has been widely acknowledged in the literature.[16] Height and weight were collected in the same manner as for children and were used to calculate parental BMI for children whose parents had their height and weight measured (kg/m^2). Classification of overweight/obesity for parents was completed using the WHO BMI cut-offs[17]; Dietary intakes: data were collected using a 4-day weighed food diary and entered into Nutritics© Software Research Edition (Dublin, Ireland). For the current analysis, several dietary-related factors were calculated from these data; If intake of fruit and vegetables was in line with the 5–7 portions (400 g) per day recommendation,[18] If children were classified as consumers of SSBs (i.e., children were classified as a consumer if they consumed a SSB over the 4-day survey period or as a non-consumer if they consumed no SSBs [0 g] over the 4-day survey period). Strong evidence has linked SSB consumption with overweight/obesity in children,[19] if the timing of consumption of the main meal was after 8 PM on any day over the 4-day period, as consumption after 8 PM may be linked with overweight/obesity risk.[20]

2.4 | Development of the composite score

In order to investigate the combined risk associated with possession of a multitude of factors, a composite score was adapted from Kovács and colleagues.[6] Only factors deemed to be significantly associated with overweight/obesity individually within the current cohort were included in the overall composite score. The minimum composite score that a child could obtain was 0, which reflected possession of no risk factors for overweight/obesity. The maximum composite score that a child could obtain was 4 which reflected possession of all risk factors associated with overweight/obesity (Table 1). Due to the low numbers of children who had three or four risk factors these categories were combined in the final composite score model leaving four categories within the composite score (0 points, 1 point, 2 points and 3–4 points).

TABLE 2 Characteristics of Irish children who participated in NCFS II

Demographics	case *n* / total *n*	% (*n*)
Prevalence of OW/OB (BMI)	596/600	14.9 (89)
Prevalence of OW/OB (%BF)	594/600	23.9 (142)
Age (years)[a]	600/600	8.5 (2.3)
Gender (female)	600/600	50.0 (300)
Risk factors		
Child not breastfed	597/600	37.9 (226)
High birth weight (≥4000 g)	585/600	20.2 (118)
Low social class	596/600	16.3 (97)
Parent with OW/OB	549/600	59.9 (329)
Fruit and veg intake <400 g/day	600/600	91.3 (548)
Sugar-sweetened beverage consumer	600/600	49.2 (295)
Main meal after 8 PM	600/600	15.7 (94)
Low physical activity (MET min/day)	597/600	49.7 (298)
Sleep <10 h/day	600/600	63.0 (378)
Screen time >2 h/day	585/600	30.3 (177)

Abbreviations: %; percentage; %BF, percentage body fat; BMI, Body mass index; n, number of children; NCFSII, The National Children's Food Survey II; OW/OB, overweight/obesity.
[a]Presented as mean ± SD.

2.5 | Statistical analysis

Statistical analysis was performed using the IBM SPSS© statistics software package version 24. Binary logistic regression analysis was used to examine whether the individual variables and composite score were associated with the risk of overweight/obesity. Binary logistic regression analysis was selected as the data met the following assumptions: the dependent variables were dichotomous, these analyses incorporated one or more categorical independent variables and the dependent variable groups were mutually exclusive.[21] Both BMI and %BF classification were broken into dichotomous variables (0; below the cut-off for overweight/obesity or 1; on or above the cut-off for overweight/obesity) and were entered as the dependent variable into individual models. Each model controlled for age and gender to minimize any potential variation based on those variables. Each factor's association with the risk of overweight and obesity was initially assessed

TABLE 3 The association between early life, parental, lifestyle, and dietary components with overweight and obesity risk in Irish children

	%BF (model 1)				BMI (model 2)			
			95% CI				95%CI	
	p	Odds ratio[a]	Lower	Upper	*p*	Odds ratio[a]	Lower	Upper
Individual contributing factor								
Child not breastfed	0.012	1.67	1.12	2.49	0.145	1.43	0.89	2.53
High birth weight[b]	**≤0.001**	2.46	1.55	3.91	**≤0.001**	2.81	1.71	4.63
Low social class[b]	**0.001**	2.31	1.42	3.77	**0.004**	2.22	1.29	3.82
Parent with OW/OB[b]	**≤0.001**	3.05	1.92	4.84	**≤0.001**	5.59	2.88	10.86
Fruit and veg intake <400 g/day	0.922	1.04	0.51	2.13	0.695	1.18	0.51	2.73
Sugar-sweetened beverage consumer	0.569	1.12	0.76	1.66	0.887	1.03	0.65	1.63
Main meal after 8 PM[b]	0.029	1.81	1.06	3.09	0.028	1.87	1.07	3.29
Low physical activity <median MET min/day[b]	**0.003**	1.86	1.24	2.80	0.054	1.59	0.992	2.55
Sleep <10 h/day	0.142	1.38	0.89	2.13	0.074	1.64	0.95	2.81
Screen time >2 h/day	0.263	1.28	0.83	1.96	0.614	1.14	0.69	1.90

Abbreviations: %BF, percentage body fat; 95% CI, 95% confidence interval; BMI, body mass index; MET, metabolic; OW/OB, overweight/obesity.
[a]Model adjusted for age, sex.
[b]Included in composite score.
p values in bold remained significant after adjustments were made for multiple comparison (0.05/10 = statistical significance at $p < 0.005$).

individually and then, if deemed significant ($p \leq 0.005$) after adjustments were made for multiple comparisons,[21] in combination as part of the composite score. A sensitivity analysis was undertaken which examined the association between individual risk factors in children with obesity only compared to those without obesity. Two separate binary logistic analyses were completed, one for %BF (Model 1) and one for BMI (Model 2). Both approaches involved the calculation of the odds ratio and 95% confidence intervals (>1 increased risk, <1 reduced risk) with an odds ratio deemed statistically significant at $p \leq 0.05$. Pseudo R^2 values were calculated to ascertain the proportion of the variation in these data explained by each model and to investigate the performance of each model against each other. Pearson's χ^2 tests were used to examine if a difference in composite score occurred across weight status groups with a *p*-value of ≤0.05 being indicative of a statistically significant difference between weight status categories. Pearson χ^2 was selected as both weight status and composite score variables were categorical which consisted of two or more categorical, independent groups.[21]

3 | RESULTS

The demographics of the children who participated in NCFS II are presented in Table 2. The prevalence of overweight and obesity in this cohort was 15% using the BMI definition and 24% using the %BF definition. The proportion of boys and girls within the sample cohort was equal, and the mean age of children was 8.5 years. The prevalence of the identified risk factors for overweight and obesity in this cohort indicated that 38% of children had never been breastfed, 20% had a high birth weight, 16% were from a low social class, 60% had a parent with overweight or obesity, 91% had fruit and vegetable intakes of <400 g/day, 49% consumed an SSB over the 4-day survey period, 16% consumed the main meal after 8 PM, 50% had a PA MET level below the cohort median of 480 MET min/day, 63% slept for <10 h/day and 30% engaged in ST for greater than 2 hours per day.

After adjustments were made for multiple comparisons logistic regression analysis identified four risk factors as being significantly associated with overweight/obesity in the NCFS II cohort ($p \leq 0.005$). Having a parent with overweight/obesity (%BF odds ratio 3.1; 95% confidence interval 1.9–4.8; $p \leq 0.001$, BMI odds ratio 5.6; 95% confidence interval 2.9–10.9; $p \leq 0.001$), having a high birth weight of ≥4 kg (%BF odds ratio 2.5; 95% confidence interval 1.6–3.9; $p \leq 0.001$, BMI odds ratio 2.8; 95% confidence interval 1.7–4.6; $p \leq 0.001$), being from a low social class (%BF odds ratio 2.3; 95% confidence interval 1.4–3.8; $p = 0.001$, BMI odds ratio 2.2; 95% confidence interval 1.3–3.8; $p = 0.004$) and low physical activity (%BF odds ratio 1.9; 95% confidence interval 1.2–2.8; $p = 0.003$) (Table 3). Two other factors were also found to be linked with a significantly increased risk of overweight/obesity: not being breastfed and consumption of the main meal after 8 PM. However, after adjustments were made for multiple comparisons, they were deemed no longer statistically significant and were not included in the composite score. Non-compliance with the recommendations for ST, sleep duration and fruit and vegetable intake, alongside consumption of SSBs were not significantly associated with an increased risk of overweight and obesity in this cohort and therefore were not included in the composite score. Results of the sensitivity analysis examining children with obesity only corroborated what was found in the primary analyses and identified not being breastfed as a factor significantly associated with the risk of obesity in children after adjustments were made for multiple comparisons (Table S1).

The four factors outlined above were included in the composite score to examine the association between having none, one, two or

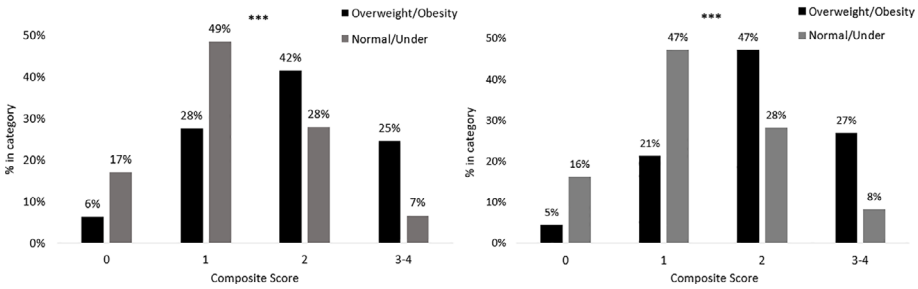

FIGURE 1 Percentage of Irish children within each composite score category based on %BF (A) and BMI (B) derived weight status group. ***denotes a statistically significant difference at $p \leq 0.0001$ between weight status groups as determined by the χ^2 test. %BF, percentage body fat; BMI, body mass index.

TABLE 4 The association between composite score and overweight/obesity risk in Irish children

	%BF (model 1)[a]						BMI (model 2)[a]					
	OW/OB % (*n*)	U/N	*p*	OR	95% CI Lower	95% CI Upper	OW/OB % (*n*)	U/N	*p*	OR	95%CI Lower	95%CI Upper
Composite score												
0 point [b]	6 (9)	17 (77)	-	-	-	-	5 (4)	16 (82)	-	-	-	-
1 point	27 (39)	48 (219)	0.415	1.39	0.63	3.04	21 (19)	47 (240)	0.342	1.71	0.56	5.21
2 points	42 (59)	28 (126)	0.001	3.82	1.75	8.31	47 (42)	28 (143)	0.001	6.23	2.14	18.14
3–4 points	25 (35)	7 (30)	≤0.001	10.03	4.21	23.88	27 (24)	8 (42)	≤0.001	13.24	4.26	41.10
Composite score												
0 point	6 (9)	17 (77)	0.415	0.72	0.33	1.58	5 (4)	16 (82)	0.342	0.58	0.19	1.77
1 point[b]	27 (39)	48 (219)	-	-	-	-	21 (19)	47 (240)	-	-	-	-
2 points	42 (59)	28 (126)	≤0.001	2.75	1.71	4.43	47 (42)	28 (143)	≤0.001	3.64	2.03	6.53
3–4 points	25 (35)	7 (30)	≤0.001	7.23	3.89	13.46	27 (24)	8 (42)	≤0.001	7.73	3.85	15.50
Composite score												
0 point	6 (9)	17 (77)	0.001	0.26	0.12	0.57	5 (4)	16 (82)	0.001	0.16	0.06	0.47
1 point	27 (39)	48 (219)	≤0.001	0.36	0.23	0.59	21 (19)	47 (240)	≤0.001	0.28	0.15	0.49
2 points[b]	42 (59)	28 (126)	-	-	-	-	47 (42)	28 (143)	-	-	-	-
3–4 points	25 (35)	7 (30)	0.002	2.63	1.43	4.84	27 (24)	8 (42)	0.019	2.12	1.13	3.98
Model summary	Cox and Snell		Nagelkerke				Cox and Snell		Nagelkerke			
R^2	0.136		0.203				0.090		0.158			

Abbreviations: %, percentage of children; %BF, percentage body fat; 95% CI, 95% confidence interval; BMI; body mass index; n, the actual number of children; OR, odds ratio; OW/OB, overweight/obesity; U/N, under/normal.

[a]Models adjusted for age and sex.

[b]Reference category.

p represents statistical significance at $p < 0.05$.

three-four of these factors and the risk of overweight/obesity. A significant difference in composite score based on weight status group was observed as children who had overweight, and obesity were more likely to have a higher composite score (Figure 1; both $p \leq 0.001$).

The prevalence of overweight/obesity and the association with the composite score are presented in Table 4. Children who had a score of 3–4 points were; 10 times more likely in model 1 (odds ratio 10.0; 95% confidence interval 4.2–23.9; $p \leq 0.001$) and 13 times more likely in model 2 (odds ratio 13.2; 95% confidence interval 4.3–41.1; $p \leq 0.001$) to have overweight and obesity than those who had a score of 0 points, 7 times more likely in model 1 (odds ratio 7.23; 95% confidence interval 3.9–13.5; $p \leq 0.001$) and 8 times more likely in model 2 (odds ratio 7.73; 95% confidence interval 3.9–15.5; $p \leq 0.001$) to have overweight and obesity compared to those with 1 point and, 3 times more likely in model 1 (odds ratio 2.6; 95% confidence interval 1.4–4.8; $p = 0.002$) and twice as likely in model 2 (odds ratio 2.1; 95% confidence interval 1.1–3.9; $p = 0.019$) to be classified as having overweight or obesity in comparison to those with 2 points. Pseudo R^2 values for both models are also presented in Table 4 and demonstrate that model 1 (%BF) was the best model to fit this set of data.

4 | DISCUSSION

This analysis reveals a strong relationship between birth weight, parental weight, social class and physical activity and the risk of

overweight/obesity in Irish school-aged children. Application of a composite score demonstrated that possession of 1 or more risk factors was associated with a significant increase in the risk of overweight/obesity. Children who had 3–4 risk factors were between 10 and 13 times more likely to have overweight/obesity compared to those with no risk factors and were between 2 and 8 times more likely to be classified as having overweight/obesity in comparison to those with 1 or 2 risk factors respectively.

A key element of the 'Healthy Ireland Framework' and the 'WHO ECHO Report' is to 'reduce health inequalities' such as those associated with being from a lower socioeconomic group.[1,22] In the current study, social class was a significant predictor of overweight/obesity risk as children from a low social class were twice as likely to have this disease. This relationship between social class and overweight/obesity has been observed elsewhere; data of children from across 22 European countries highlighted the widening social disparities in weight status, with a higher level of inequality in household income being related to a higher risk of overweight in children.[23] In Ireland, it has been demonstrated that lower maternal education, household income and attending disadvantaged schools were significantly associated with higher BMI and increased prevalence of overweight/obesity in children.[3,24] Whilst amongst UK based children, the prevalence of obesity was more than double for children living in deprived areas in comparison to those living in affluent areas.[25] It is clear that health inequalities with respect to socioeconomic status are still a major concern across Europe. Despite this recognition, the evidence suggests that efforts to tackle this crisis are not having the desired impact as children from low socioeconomic backgrounds are continually at an increased risk of overweight/obesity.

Preconception and pregnancy care, alongside early childhood diet and PA, are key areas identified in the ECHO report as important considerations to tackle childhood overweight/obesity.[1] Within the current study a high birth weight (≥4000 g) was associated with an increased risk of overweight/obesity in childhood. This was similar to results reported by Yu and colleagues, who observed a 2.1-fold increased risk of obesity from childhood to adulthood in those with high birth weight.[26] Although breastfeeding was also found to be a significant determinant of overweight/obesity in this cohort the result was no longer statistically significant after adjustments were made for multiple comparisons. Nonetheless, evidence from the WHO European Childhood Obesity Surveillance Initiative from 22 countries demonstrated a higher prevalence of overweight/obesity in children never breastfed in comparison to those who had been breastfed.[27] Public health strategies need to renew focus on increasing breastfeeding rates in Ireland and in other countries where rates are low, to protect against the development of overweight/obesity in childhood. The importance of the role of the family unit is embedded in global public health advice to prevent and reduce overweight/obesity. An association between overweight/obesity risk and having at least one parent with overweight/obesity was observed in the current study, which has been echoed in research elsewhere. Findings from the Canadian Health Survey found that as a child's average BMI increased, so too did that of their parents and that children of parents with obesity were at an increased risk of overweight/obesity themselves[16] with similar outcomes observed in Italian and Irish children.[3,28] Although genetic factors are at play, it is clear that parents have a major role in influencing their child's weight status through facilitation of a healthy lifestyle for their family environment.[5]

Another predominant public health message with respect to obesity is the role of PA and sedentary behaviour as both contribute to the maintenance of energy balance.[29] Despite recent evidence from meta-analysis supporting an increased risk of overweight/obesity in children who did not adhere to the 2-h ST recommendation,[30] no association between overweight/obesity and ST was observed in the current analysis. This may have occurred for several reasons: underreporting of ST by participants, a lack of statistical power to detect a difference or owing to the cut-off time of 2 h utilized. Perhaps if a higher cut-off was applied, an association may have been observed similar to Kenney and colleagues where teens who watched a minimum of 5 h of TV a day, had a 78% increased risk of having obesity in comparison to teens who did not watch TV.[31] However, a protective role between the presence of overweight/obesity and accumulated MET minutes for PA was observed. Similarly, a multinational cohort study of children aged 9–11 years concluded that increased time spent undertaking moderate to vigorous and vigorous PA was related to lower odds of obesity irrespective of sedentary behaviour.[32] Evidence supports a strong relationship between sleep duration and risk of obesity, with the risk of overweight/obesity decreasing by 21% with every 1 h/day increase in sleep obtained by children and adolescents.[33] Sleep duration did not significantly impact overweight/obesity risk in the present study; however, the observational nature of the research did not allow for sophisticated methods of measuring sleep duration such as wearable devices or sleep monitors, which may have led to the lack of association observed owing to the possibility of misreporting.

Food-based dietary guidelines are a further element ingrained in obesity prevention policies worldwide. In Ireland, it is recommended to consume between 5 and 7 portions of fruit and vegetables per day and limit intake of SSBs.[18] Considering that less than 10% of children in the total cohort adhered to the fruit and vegetable recommendation, it was not surprising that no association with overweight/obesity risk was found. Perhaps if the risk was examined on the basis of volume consumed compared to non-consumers a positive association would have resulted as observed elsewhere.[34] There is strong evidence linking consumption of SSBs to weight gain, although not observed within this cohort. Studies that have identified a positive association between SSB intake and risk of overweight/obesity examined the amount of SSB consumed rather than consumers versus non-consumers as was the approach undertaken here. Nonetheless, this relationship has led to the introduction of a sugar tax levy on SSBs in countries including Ireland and the UK, with the hope that industry reformulation of these products will ensue.[35,36]

Although not embedded in public health guidance an area of emerging research with respect to obesity risk is the timing of meal consumption, as this has a potential influencing factor on energy regulation as it is thought that unusual feeding times can cause disruption

to the circadian system.[37] In the current study, consumption of the main meal (participant defined) after 8 PM on any day over the survey period was associated with an increased risk of overweight/obesity before adjustments were made for multiple comparisons. This finding contrasts with that observed in a cohort of children aged 4–10 years who participated in the National Diet and Nutrition Survey in the UK. Coulthard and Pot did not find an association between consuming the evening meal before or after 8 PM and the risk of overweight/obesity observed.[38] Although the observed association was weak findings here support the protective role of the consumption of the main meal before 8 PM and demonstrate that while further research is required in this field it could be incorporated into multifaceted public health advice for the prevention of overweight/obesity in children.

Four factors were included in the composite score in the present study, with only 14% of children found not to possess any risk factors for overweight/obesity. The use of this approach highlighted the increased risk of overweight/obesity for children who had a score of 1 or more points. This is comparable to that described in a large European-wide study where adherence by school-aged children to an increasing number of healthy lifestyle behaviours including diet, PA, sleep, and ST was associated with a lower risk for having overweight/obesity.[6] Furthermore, an accentuated increased risk of overweight/obesity was observed in children who had 2 or more risk factors in comparison to those who had 1 or no risk factors. Correspondingly, in the IDEFICS study, adherence to 4 or more lifestyle factors was associated with a subsequent lower chance of having overweight or obesity.[6] Here the difference in adherence across Europe was highlighted with children from Northern European countries displaying greater adherence to such behaviours and overall lower rates of overweight/obesity. Furthermore, evidence from a systematic review of 14 studies in children aged 5–17 years examined the impact of having a combination of high PA, longer sleep duration and low sedentary behaviour and overweight/obesity risk which demonstrated that this combination of behaviours was related to more desirable body adiposity and cardiometabolic health which draws similarity to the present analysis.[39] These findings emphasize the efficacy of exploring the combined risk associated with multiple factors and the likelihood of overweight/obesity occurrence.

Recommendations for adhering to healthy lifestyle behaviours are entrenched in public health guidance both on a national level and across leading global organizations. Our findings support those messages ingrained in both 'The Irish Obesity Action Plan 2016-2025' and in the WHO ECHO report. A stabilization in rates of childhood overweight/obesity has been observed across some European countries including Ireland, yet rates globally continue to rise particularly in children from low socioeconomic backgrounds.[40,41] Further robust effort is required to sustain a long-term reduction in these rates. This analysis contributes an important evidence base for clinicians and public health bodies to provide individuals with actionable and tangible means to readily change habits and behaviours necessary to minimize the risk for children to develop overweight/obesity.

This study presents many strengths including the comprehensive database for this age group encompassing several variables which may influence weight status in childhood and the use of two methods to define weight status which yielded similar associations with risk factors. However, many of these variables were self-reported including PA and dietary intake data thereby highlighting a limitation. Moreover, this analysis did not examine differences in determinants of weight status based on gender and age groups due to the limited sample size to conduct such an analysis. As these data included in this study were observational, it cannot ascertain cause-effect relationships, therefore future work in the form of randomized control trials and prospective cohort studies is needed to further investigate the aetiology of this complex metabolic disease.

In conclusion, this analysis supports that no single factor is responsible for childhood obesity, its origin is indeed multifaceted. When devising strategies to prevent and treat this disease, it is necessary to consider a wide range of factors some of which stem from early life and are influenced by parents' own behaviours. The use of a composite score is a plausible means of identifying children at risk of overweight/obesity and may prove useful in the development of effective interventions to tackle childhood obesity.

AUTHOR CONTRIBUTIONS

Breige McNulty, Albert Flynn, Anne Nugent, John Kearney and Janette Walton contributed to the design and implementation of the study and are principal investigators on the project. Maria Buffini, Laura Kehoe and Aisling O'Donnell were involved in subject recruitment and data collection. Aisling O'Donnell and Breige McNulty were involved in data analysis and illustrated the manuscript. All authors reviewed and approved the final manuscript.

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CONFLICT OF INTEREST

No conflict of interest was declared.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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