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The effect of screen advertising on children's dietary intake: A systematic review and meta-analysis

Simon J. Russell [ID] | Helen Croker | Russell M. Viner

UCL Great Ormond Street Institute of Child Health, University College London, London, UK

Correspondence
Simon J. Russell, UCL Great Ormond Street Institute of Child Health, University College London, London WC1N 1EH, UK.
Email: s.russell@ucl.ac.uk

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Summary

Evidence indicates that screen advertising for unhealthy food results in significant increases in dietary intake among children. This review was undertaken with the main aim of estimating the quantitative effect of screen advertising in experimental and nonexperimental conditions on children's dietary intake.

Systematic searches were undertaken of interdisciplinary databases. Studies from 1980 to April 2018, all geography and languages, were included; participants were children and adolescents aged between 2 and 18 years; the intervention was screen advertising; and the outcome was dietary intake. Meta-analyses were conducted for measured and nonmeasured outcomes.

Food advertising was found to increase dietary intake among children (age range 2-14, mean 8.8 years) in experimental conditions for television (TV) advertising and advergames. Meta-analysis revealed that children exposed to food advertising on TV (11 studies) and advergames (five studies) respectively consumed an average 60.0 kcal (95% confidence interval [CI], 3.1-116.9) and 53.2 kcal (95% CI, 31.5-74.9) more than children exposed to nonfood advertising. There was also an effect by body mass index (BMI). Findings from nonexperimental studies revealed that exposure to TV food advertising was positively associated with and predictive of dietary intake in children. Short-term exposure to unhealthy food advertising on TV and advergames increases immediate calorie consumption in children.

KEYWORDS

child and adolescent health, food advertising, obesity, policy

1 | INTRODUCTION

There is a substantial burden of illness and disease resulting from poor diet, which is estimated to account for 40.0% of non-communicable diseases across Europe.[1] Rates of childhood obesity have been rapidly increasing, and in 2016, there were an estimated 340 million children aged 5 to 19 in the world living with overweight or obesity.[2] Food and drink marketing is a vast global industry, and evidence indicates disproportionate marketing of products with high sugar, fat, and salt content.[3] Children are exposed to a high volume of marketing and advertising, a substantial proportion of which is for unhealthy foods.[4]

Television (TV) viewing among children has been found to predict obesity even when levels of physical activity are controlled for,[5] which suggests it is not just the effect of a sedentary lifestyle that increases the risk factors for weight gain. Research has shown that exposure to unhealthy food advertising, at least under experimental conditions, results in significant increases in food consumption, particularly energy-dense, low-nutrient foods, and that increases are greatest among children with obesity.[6-9]

This review sought to establish the effect size of screen advertising on children and adolescents' dietary intake, body mass index (BMI), or body composition by systemically reviewing the evidence in the available literature. We aimed to extend previous work by including data sources from business and economics databases and including nonexperimental studies. Meta-analyses were conducted, primarily on experimental studies between exposure to unhealthy food and nonfood advertising, where outcomes for dietary intake were provided in kcals or a convertible alternative.

2 | METHODOLOGY

We conducted a high-quality systematic review, adopting a rapid review methodology in collaboration with the Evidence for Policy and Practice Information Centre (EPPI-Centre) at the Social Science Research Unit of the UCL Institute of Education. EPPI-Reviewer 4 software was used to manage data and the review process, which facilitated a machine learning approach and has the potential to substantially reduce screening time.[10] This study was registered with PROSPERO (registration number CRD42018089228), and systematic review and meta-analyses were conducted and reported according to the PRISMA checklist.[11]

The practice and use of rapid systematic reviews are increasing because of limitations in terms of size and practicality of full reviews.[12] Some suggested methodological modifications include highly specific research questions, use of search tools/software, and use of only one reviewer.[13] While some studies suggest rapid reviews do not apply the same rigour as full systematic reviews,[14] rapid reviews are generally accepted to be useful and valid,[15] and that, despite measures to save time, compared with full reviews, incur no discernible impacts on derived conclusions.[13]

2.1 | Eligibility criteria, information sources, and search strategy

Quantitative studies (experimental or nonexperimental "real world") were eligible for inclusion; population criteria were children and adolescents (aged between 2 and 18 years); all geography, languages, and studies between 1980 and April 2018 were included; intervention criteria were screen advertising (including TV, cinema, and internet/advergames); and outcomes were dietary intake, BMI, and body composition. Studies before 1980 were excluded as they were likely to have limited relevance to the current relationship between advertising exposure and obesity-related behaviours. Published reports and dissertations were not eligible as the peer review status of these publications is unclear.

In January 2018 and April 2018, systematic searches were undertaken of the following medicine, psychology, science, business, and economics electronic databases: PubMed/MEDLINE, Cochrane Library Web, CINAHL, SCOPUS, PsycINFO, JSTOR, Web of Science, ProQuest, Google Scholar, Emerald, EconBiz (including RePec), EconLit, Business Source Complete, and the World Advertising Research Centre (WARC). Relevant search terms were used for electronic databases, and combinations of key search words were used for Google scholar (provided as Supporting Information).

As part of the rapid review methodology, the primary reviewer (S.R.) conducted the initial searches (January 2018), imported records into reference manager software and EPPI-Reviewer 4, and removed duplicates; a secondary reviewer (H.C.) replicated the searches at a later time to check the total records found from each data source. Reference searches were also conducted on eligible articles and relevant systematic reviews. Supplementary searches (April 2018) were conducted by the primary reviewer. Articles were imported into EPPI-Reviewer 4 for screening, data extraction, and analysis.

2.2 | Study selection

Exclusion criteria were date (pre-1980), participant age group (adults), intervention (nonscreen forms of advertising or marketing), study type (reports, systematic reviews, or dissertations), and outcome measure (food choice, preference, pester power, food advertisement recall, etc). Articles were included if all other criteria were met and if studies gave a quantitative measure or estimate of the outcome variable (dietary intake, body composition, or BMI).

Two reviewers (S.R. and R.I.) independently screened on title and/or abstract for three days; discrepancies were jointly reconciled by reviewers. Predictive algorithms built into EPPI-Reviewer 4 software learned and applied reviewer decisions; the resulting model was applied to unscreened records throughout screening. Articles were intermittently refreshed to allow machine learning to prioritise unscreened items based on relevance denoted from include/exclude codes. After the allocated screening period, a model classifier was built within the software using include codes distinguished from exclude codes and applied to all unscreened items. Scores based on relevance (0-100) were generated for all unscreened articles.

Articles were retrieved via web and library services and via direct contact with authors; a total of seven papers could not be found and were excluded. Full-text screening was conducted by the primary reviewer only. Two papers were translated into English.

Experimental studies with measured outcomes were deemed suitable for meta-analysis if dietary intake in kcals was reported as an outcome (or kJ/g where conversion was possible), and groups of children exposed to food screen adverts (various low-nutrient/unhealthy foods or soft drinks) were compared with nonfood/neutral screen adverts (eg, toys). Nonexperimental/real-world studies were deemed suitable for meta-analyses if a quantitative relationship between food screen advert exposure and dietary intake was explored.

2.3 | Data extraction and items

Data were extracted by the primary reviewer (S.R.) using customised EPPI-Reviewer 4 extraction tools; data extraction was later replicated (H.C.). Meta-analyses were conducted using R software EPPI-Reviewer 4 and with STATA v15 for presentation purposes.[16] Corresponding authors were contacted where additional data were required; nine authors were contacted for additional information, of which eight responded and provided data.

Data extracted included study identification (authors, country, and year of publication), target group (children and/or adolescents),

sample description (sample size, participants mean age and range), study description (design), process evaluation (number of participants recruited to study conditions, how participants were allocated to groups), risk of bias within study, intervention data (TV or advergame), outcome type (measured or estimated dietary intake, BMI, or body composition), comparison type (food advertising vs nonfood advertising), and measures for dietary intake (kcal, kJ, grams, proportion consumed, correlation coefficient, regression coefficient).

2.4 | Assessment of quality

Experimental studies were required to have a nonfood advert control group; studies that used neutral TV (no adverts) or no TV as control conditions were not included, or subgroups were omitted from analyses. Within study, quality was generally assessed, but direct comparisons could not be drawn because study designs varied. Allocation method of participants was recorded for all between-subject studies. General assessments of quality were undertaken between studies; however, rigorous appraisal was not possible owing to the variety of research objectives between studies. While data may have been appropriate for meta-analysis, the primary focus of the study may not have been in relation to the effect of food advert exposure on dietary intake.

Risk of bias at study level for experimental papers was assessed by the primary reviewer using Cochrane methods.[17] Sources of bias were assessed in terms of selection bias, performance bias, attrition bias, reporting bias, and other sources of bias, including study design. To detect publication bias, the regression test of Egger et al[18] for funnel plot asymmetry was used with trim and fill method.[19] Both tests were run using R software within EPPI-Reviewer 4.

2.5 | Measures and data synthesis

2.5.1 | Experimental studies

To be included in meta-analyses, studies were required to compare the effect of food screen advert exposure with nonfood screen advert exposure, as measured by mean difference (kcals or convertible outcome) with 95% confidence intervals (CIs). Heterogeneity was determined using the I^2 statistic. Owing to study design and measure inconsistency, the DerSimonian-Laird random-effects model was used for meta-analysis for experimental studies. Separate meta-analyses were conducted for TV and advergame interventions. Within- and between-subject studies were combined, and sensitivity analyses were conducted to assess the impact on overall effect size.

For the main analyses and where possible, groups were combined to give an overall comparison for each study; age, sex, BMI groups, and groups by child characteristics (eg, level of inhibition) were combined. Data from substudies were not included where interventions/preloads were administered (eg, "protective messages"/glucose drinks). Outcome food groups were also combined to give total dietary intake. Within- and between-subject studies were also combined in meta-analyses. Where required and appropriate, the Satterthwaite approximation was used to combine standard error values for two groups. Studies with more than two relevant groups were included as separate data points (two studies).

Screen advertisements were considered to be a consistent intervention. All adverts were for low-nutrient/energy-dense products; however, brands and products advertised varied, as did the advert break and total advert duration. Data for a "light" food (low energy) advert condition were excluded;[20] data for branded and unbranded food adverts were combined; data from a control condition where a celebrity endorser was shown in a nonfood context were excluded;[7] and data for healthy food adverts were excluded.[21] Data from healthy food adverts and no advergame control data were excluded;[22,23] data for advergames with food adverts/nonfood adverts with a protective message intervention were excluded.[24] Data for combined media (the effect of TV adverts with advergame) were excluded since the effect was inconsistent for TV or advergame analyses.[25]

In terms of the outcome, total intake of food groups were combined in analyses to give an overall measure of dietary intake. All studies appropriate for meta-analysis (n = 16) provided one or more unhealthy food product for participants to consume ad libitum. Five studies also provided healthy food products, including fruit[22,23] or fruit and wholegrain snacks;[8,9,26] intake of such products was included in the analyses as the outcome was considered at a caloric rather than a nutrient level. Branded and nonbranded food groups were combined.[27] Studies were conducted with various levels of participant satiety; all such data were pooled providing conditions were consistent within studies.

In terms of participants, where overall totals were not reported, groups were combined where it was reasonable to do so in order to give overall effect sizes for each study. Sex groups were combined,[28] BMI groups were combined,[25] perceived high- and low-maternal encouragement groups were combined,[20] and high- and low-inhibition groups were combined. Where it was not reasonable or statistically possible to combine groups, subgroups within studies were included as separate data points.[24,28,29]

2.5.2 | Nonexperimental studies

Secondary meta-analysis for nonexperimental studies was conducted for correlation coefficients for food advert exposure and nonmeasured outcomes of dietary intake. Intake of low-nutrient high-calorie foods was pooled, including self-reported measures or estimates of energy-dense food products,[30,31] unhealthy advertised foods,[32] fast food and soft drink consumption,[33] and unhealthy snacks.[34] There were insufficient data and lack of homogeneity for meta-analyses to be conducted for regression coefficients.

2.6 | Additional analyses

The association between the effect size of dietary intake following TV advert exposure and the exposure duration was plotted and tested using Spearman's rank correlation coefficient. Exposure time was not calculated for advergames as, in many studies, the playing time was specified, but the playing speed varied between participants; therefore, children would not have been exposed to the same amount of food cues over the given time. Also, food cues were not always embedded into the game (peripheral to the child's attention); therefore, an exposure duration/effect size relationship was not explored. Subgroup

analyses of experimental data were undertaken to analyse the impact of TV food advert exposure on dietary intake by BMI. Children with overweight/obesity were grouped and compared with children with healthy weight; significance was tested using chi-square test. Data were analysed using R software within EPPI-Reviewer 4 and STATA v15.

3 | RESULTS

3.1 | Study selection

Figure 1 shows the flow chart of the review process. Searches yielded a total of 5545 articles (5378 from initial searches and 167 from supplementary searches in April 2018); 379 articles were included for full-text screening of a total of 1460 articles manually screened; 3703 were excluded by the machine learnt predictive algorithm. Application of the classifier provided articles with scores ranging from 1 to 72 which were sorted descending and screened; three articles were included as a result of this process (study scores were 72, 67, and 61), and all studies with scores of 60 and below were excluded. A total of 382 articles were screened on full text; 25 articles were included

with measured outcomes for dietary intake (11 studies suitable for meta-analysis for TV advertising and five studies suitable for meta-analysis for advergames); and 14 articles were included with nonmeasured (ie, estimated or self/parent-reported) outcomes for dietary intake (five studies were suitable for correlation meta-analysis and five for regression meta-analysis; however, the required data for meta-analysis of regression coefficients could not be retrieved).

3.2 | Study description and results

A summary of experimental and nonexperimental study information is provided in Tables 1 and 2.

3.3 | Experimental studies

3.3.1 | Participants

Across all studies, participants were aged 2 to 14 years, with the exception of one study[35] (adolescent females aged 16-18). For TV meta-analyses, the age range for the 11 included studies was 2 to 14 years (seven studies reported age ranges of between 7 and 12), the mean
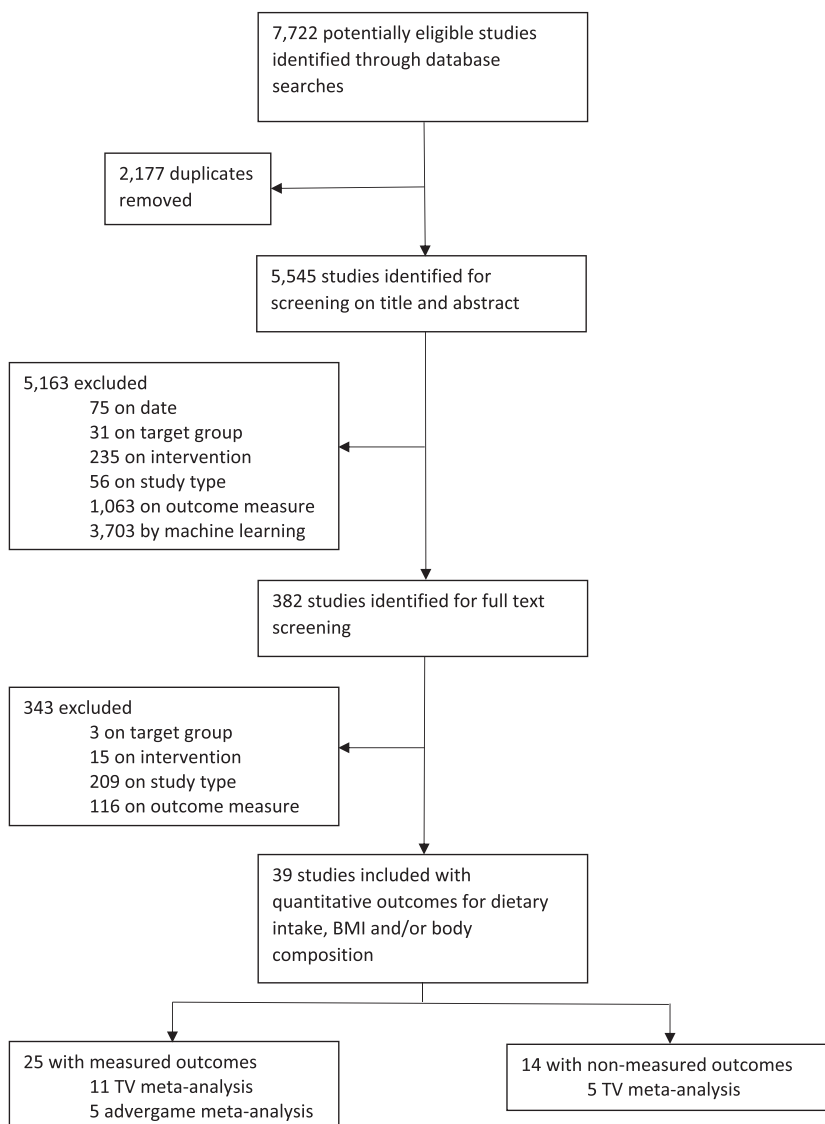
FIGURE 1 Flow chart of searches, screening, and study inclusion process

TABLE 1 Summary of experimental studies with measured outcomes

Author, Country	Participants	Design	Advertising Intervention	Comparison	Outcome	Relevant Results	Risk of Bias
Anderson et al[28] Canada	N = 50 Age range = 9-14 Mean age = not stated	Experimental (laboratory), within subject, random assignment, four sessions 1 week between each	30-minute cartoon with 4 × 2-minute unhealthy food adverts	4 × 2 minute nonfood adverts	Post-intervention, ad libitum consumption of pizza (kcal), 30 minutes	TV food adverts significantly increased intake of food for girls with overweight/obesity only	Low
Anschutz et al[36] Netherlands	N = 120 Age range = 8-12 Mean age = 9.8	Experimental (school), between subject, random assignment	20-minute nature film with three food adverts +2 nonfood adverts	Five nonfood adverts	During-intervention, ad libitum consumption of peanut M&Ms (grams), 20 minutes	TV food adverts significantly increased intake of food in boys	Low
Anschutz et al[20] Netherlands	N = 121 Age range = 8-12 Mean age = 10.4	Experimental (school), between subject, random assignment	20-minute nature film with four food adverts +1 nonfood advert (total 5 minutes)	Five nonfood adverts (total 5 minute), Four "light" calorie food +1 nonfood advert (total 5 minutes)	During-intervention, ad libitum consumption of chocolate coated peanut (grams), 20 minutes	TV food adverts had no significant main effect on intake of food	Low
Boyland et al[27] United Kingdom	N = 181 Age range = 8-11 Mean age = 10.0	Experimental (school), between subject, random assignment	20-minute cartoon with 45 seconds branded food advert or savoury food advert	45-second celebrity endorser in nonfood context, 45 second nonfood advert	Post-intervention, ad libitum consumption of potato crisps, labelled branded and non-branded (grams)	TV food adverts significantly increased intake of branded food only	Low
Dawson et al[37] United States	N = 80 Age range = not stated Mean age = 6.2	Experimental (research trailer), between subject, random assignment	2 × 30-second adverts low-nutrition food	2 × 30-second adverts for pronutrition food, or nonfood advert	Post-intervention, stimulus food which children were forbidden to eat, 20 minutes	TV food adverts had no significant effect on intake of food	High
Dovey et al[21] United Kingdom	N = 120 Age range = 5-7 Mean age = 6.0	Experimental (school), within subject, two sessions 1-month washout	14-minute cartoon with five unhealthy food adverts (total 2 minutes)	Four nonfood adverts, three healthy food adverts (total 2 minutes)	Post-intervention, ad libitum consumption of crackers, jelly sweets, chocolate, crisps, grapes and carrots (kcal), 15 minutes	TV food adverts significantly increased intake of food	Low
Emond et al[38] United States	N = 60 Age range = 2-5 Mean age = 4.1	Experimental (behavioural laboratory), between subject, random assignment	14-minute children's TV show with nine food adverts (total 3 minutes)	Six nonfood adverts (total 3 minutes)	During-intervention, ad libitum consumption of crackers and corn snacks (kcal), 14 minutes	TV food adverts significantly increased intake of food	Low
Folkvord et al[22] Netherlands	N = 270 Age range = 8-10 Mean age = 8.9	Experimental (school), between subject, random assignment	5-minute advergame with food cues	Advergame with nonfood cues, healthy food cues, no game control	Post-intervention, ad libitum consumption of jelly candy, chocolate, bananas and apples (kcal), 5 minutes	Advergames with food adverts significantly increased intake of food	Low
Folkvord et al[29] Netherlands	N = 261 Age range = 7-10 Mean age = 7.8	Experimental (school), between subject, random assignment	5-minute advergame with food cues	Advergame with nonfood cues	During-intervention, ad libitum consumption of jelly candy and chocolate (kcal), 6 minutes	Advergames with food adverts significantly increased intake of food	Low
Folkvord et al[39] Netherlands	N = 92 Age range = 8-9 Mean age = 8.4	Experimental (school), between subject, random assignment	5-minute advergame with food cues	Advergame with nonfood cues	Post-intervention, ad libitum consumption of jelly candy and chocolate (kcal), 5 minutes	Advergames with food adverts significantly increased intake of food	Low

(Continues)

TABLE 1 (Continued)

Author, Country	Participants	Design	Advertising Intervention	Comparison	Outcome	Relevant Results	Risk of Bias
Folkvord et al[23] Netherlands	N = 218 Age range = 7-10 Mean age = 8.9	Experimental (school), between subject, random assignment	Advergame with food cues	Advergame with non-food cues, healthy food cues, no game control	Post-intervention, ad libitum consumption of jelly candy, chocolate, bananas and apples (kcal), 5 minutes	Intake of energy-dense snacks after playing advergames with food adverts was not associated with BMI two years later	Low
Folkvord et al[24] Netherlands and Spain	N = 597 Age range = 6-12 Mean age = 8.9	Experimental (school), between subject, random assignment	5-minute advergame with food cues	Advergame with food cues with protective message, advergame with non-food cues with, and without protective message	During-intervention, ad libitum consumption of jelly candy and chocolate (kcal), 5 minutes	Advergames with food adverts significantly increased intake of food in both the Netherlands and Spain	Low
Gilbert-Diamond et al[40] United States	N = 200 Age range = 9-10 Mean age = 9.9	Experimental (laboratory), between subject, random assignment	34 minute TV show with 7.7 minute of food adverts, 3.1 minutes of neutral adverts	TV with 7.7-minute toy advertising and 3.1-minute neutral adverts	During-intervention, ad libitum consumption of 4 snack foods, 34 minutes	TV food adverts significantly increased intake of advertised foods	Low
Gorn and Goldberg[41] Canada	N = 151 Age range = 8-10 Mean age = not stated	Experimental (community setting), between subject, random assignment	Cartoon with various number (1-6) of 30-second food (ice cream) adverts	TV without advertising	Post-intervention, selection and consumption of ice cream, 15 minutes	Consumption behaviour was not reported to vary greatly between the conditions	High
Gregori et al[42] Mexico	N = 120 Age range = 3-6 and 7-10 Mean age = not stated	Experimental (schools), between subject, random assignment	22-minute cartoon with one, two, or three adverts (duration not specified)	TV without advertising and no TV.	During-intervention, ad libitum consumption of commonly commercialised chocolate product	There was no significant differences between advertising conditions and intake of food	High
Halford et al[8] United Kingdom	N = 93 Age range = 5-7 Mean age = 6.3	Experimental (school), within subject, random assignment, two sessions 2-week washout	10-minute cartoon with a 10 food-related adverts	10 nonfood-related adverts	Post-intervention, ad libitum consumption of jelly sweets, snack-a-jacks, crisps, chocolate and grapes (kcal), no time constraint	TV food adverts significantly increased total intake of food	Low
Halford et al[9] United Kingdom	N = 59 Age range = 9-11 Mean age = 10.2	Experimental (school), within subject, random assignment, two sessions 2-week washout	10-minute cartoon with a 10 food-related adverts (5 minutes total)	10 nonfood-related adverts (5 minutes)	Post-intervention, ad libitum consumption of jelly sweets, snack-a-jacks, crisps, chocolate and grapes (grams), no time constraint	TV food adverts significantly increased total intake of food	Low
Halford et al[26] United Kingdom	N = 42 Age range = 9-11 Mean age = 10.4	Experimental (school), within subject, random assignment, two sessions 2-week washout	A cartoon containing various food adverts	Nonfood adverts	Post-intervention, ad libitum consumption of a selection of foods (low-fat savoury, low-fat sweet, high-fat sweet and high-fat savoury; grams), no time constraint	TV food adverts increased intake of all food types except low-fat savoury	Low
Harris et al[43] United States	N = 118 Age range = 7-11 Mean age = 8.8	Experimental (school or camp), between subject, random assignment	14-minute cartoon with 4 × 30-second food adverts	4 × 30-second nonfood adverts	During-intervention, ad libitum consumption of "goldfish" crackers (grams), 14 minutes	TV food adverts significantly increased intake of food	Low

(Continues)

TABLE 1 (Continued)

Author, Country	Participants	Design	Advertising Intervention	Comparison	Outcome	Relevant Results	Risk of Bias
Jeffrey et al[44] United States	N = 47 Age range = 4-5 Mean age = not stated	Experimental (laboratory), unclear assignment	12 minutes with six adverts for low nutrition foods	Six high-nutrition foods or six nonfood adverts	Post-intervention, *ad libitum* consumption from 12 different foods (grams converted to kcal)	Low nutrition adverts increased intake of low nutrition foods	High
Lorenzoni et al[45] Georgia	N = 60 Age range = 3-11 Mean age = 6.0	Experimental (school), between subject, random assignment	22 minutes of cartoon with one, two, or three adverts	No TV, TV with no adverts	During-intervention, ad libitum consumption of a chocolate-based snack (kcal), 22 minutes	There was no significant difference in intake of food between the advert conditions	High
Norman et al[25] Australia	N = 160 Age range = 7-12 Mean age = 9.3	Experimental (holiday camp), within subject, random assignment	Cartoon with food adverts (10 × 30-second) and 5-minute advergame	Nonfood adverts/advergames	Post-intervention, ad libitum consumption of high-fat savoury, low fat savoury, high fat sweet, Low fat sweet foods, fruit and vegetables (kJ), 15 minutes	Multiple-media advertising (TV and advergame) increased intake of food to a greater extent than either medium alone	Low
Norman et al[46] Australia	N = 160 Age range = 7-12 Mean age = 9.3	Experimental (holiday camp), within subject, random assignment	6 × 10-minute cartoon with food adverts (10 × 30-second) and 5-minute advergame	Nonfood adverts/advergames	Post-intervention, ad libitum consumption of high-fat savoury, low fat savoury, high fat sweet, low fat sweet foods, fruit and vegetables (kJ), 15 minutes	TV food adverts significantly increased intake of food in all children in the multiple media condition; an increased effect was reported Among children whose parents reported pressuring children to eat	Low
Putnam et al[47] United States	N = ~132 Age range = 4-5 Mean age = 4.8	Experimental (childcare facility), between subject, random assignment	Advergame with food adverts	Advergame with nonfood adverts	Post-intervention, selection and consumption of healthy or unhealthy snacks, no time constraint but limited food items	There were no significant differences in intake of food by advert condition	Low
Warren et al[35] United States	N = 91 Age range = U.S. high school grades 11 and 12 Mean age = not stated	Experimental (school), between subject, random assignment	39-minute "sad" movie with four diet food adverts (90 seconds total)	Four nonfood adverts (90 seconds total)	During-intervention, ad libitum consumption of peanut M&Ms, 39 minutes	Diet food adverts increased dietary intake among high restraint participants	High

TABLE 2 Summary of nonexperimental studies with nonmeasured outcomes

Author, Country	Participants	Design	Advertising Intervention	Outcome	Main Results	Risk of Bias
Andreyeva et al[48] United States	N = 9760 Age range = 5-14 Mean age = 11.2	Early Childhood Longitudinal Survey–Kindergarten Cohort (ECLS-K), the Nielsen Company data	Television advertising of cereals, fast food restaurants and soft drinks	Soft drink consumption	Exposure to incremental TV adverts for sugar-sweetened carbonated soft drinks was associated with a rise in children's consumption of soft drinks	Low
Bolton[49] United States	N = 262 Age range = 2-11 Mean age = not stated	Cross-sectional household survey supplying demographic data, 16-day television diary, 7-day food diary, and attitudinal measures	Television advertising exposure calculated from self-report television viewing figures and television station broadcast data	Snacking frequency, caloric intake, nutrient efficiency, nutrient balance	Effects of television food advertising were found but the impact was small in comparison with that of other factors	High
Bora et al[50] South Korea	N = 2419 Age range = 11-13 Mean age = not stated	Cross-sectional self-report questionnaire with height, weight, television viewing times, food preferences and food intake; television network food advertising data	Television food advertisements, energy-dense and nonenergy-dense food categories	Overweight/obesity	Energy-dense food advertising may be associated with an increased risk of obesity And energy-dense food preference and intake	Low
Buijzen[31] Netherlands	N = 234 (parents) Age range = 4-12 Mean age = 7.8	Cross-sectional household diary-survey, self-report TV viewing preferences, parental communication measures, food diary	Television advertising exposure calculated from broadcast data	Consumption of advertised energy-dense food products	Parental restrictions of advertising exposure are effective in countering the impact of food advertising among younger children	Low
Buijzen et al[30] Netherlands	N = 234 Age range = 4-12 Mean age = 7.9	Cross-sectional household diary-survey, self-report TV viewing preferences, food diary	Television advertising exposure calculated from broadcast data	Consumption of advertised brands, consumption of energy-dense products, consumption overall	Advertising exposure was related to overall food consumption in lower income families	Low
Chou et al[51] United States	N = 6034 and 7069 Age range = 3-18 Mean age = not stated	Longitudinal survey data, BMI	Fast-food restaurant TV advertising, data from competitive media reporting	BMI	An advertising ban for unhealthy foods would reduce the number of children with overweight by an estimated 18% for 3-11 seconds and 14% for 12-18 seconds	Low
Díaz-Ramírez et al[32] Mexico	N = 365 (mothers) Age range = 8-5 m Mean age = not stated	Interview and questionnaire parent self-report measures for food frequency consumption	Exposure to mainstream TV programming and associated advertising	Food frequency consumption of advertised foods	Advertising frequency was significantly positively associated with consumption of advertised foods	High
Giese et al[33] Finland, Germany, Romania	N = 825, 1055, and 971 Age range = 8-21 (n = 13 were 18+) Mean age = 12.8, 12.7, and 14.2	Cross-national survey, self-report questionnaire, weekly food intake, height and weight, self-control and social affluence	Self-report exposure to TV adverts for healthy and unhealthy foods	Healthy and unhealthy food consumption	Advertisements exposure was associated with higher intake of fast foods, snacks and soft drinks	Low
Hennessy et al[52] United States	N = 371 Age range = 3-16 Mean age = 9.4	Cross-sectional representative telephone survey, sugar-sweetened beverage consumption	Exposure to TV adverts sugar-sweetened beverage	Sugar-sweetened beverage intake	Exposure to sugar-sweetened beverages in adults was associated with sugar-sweetened beverage intake in children	Low

(Continues)

TABLE 2 (Continued)

Author, Country	Participants	Design	Advertising Intervention	Outcome	Main Results	Risk of Bias
Klepp et al[53] EU	N = 13 305 Age range = 8.8-13.8 Mean age = 11.4	Cross-sectional self-report questionnaire, fruit and vegetable intake, attitudes towards and liking of fruits and vegetables, exposure to TV viewing	Self-report questionnaire exposure to TV commercials	Healthy food consumption	Healthy food advertisements were associated with higher intake of fruits and vegetables	Low
Lwin et al[54] Indonesia	N = 394 Age range = 8-10 Mean age = 9.4	Guided in-class survey (children), paper questionnaire (mothers), self-report measures for fast food consumption and parental mediation	Advertising exposure estimated from self-report TV, online/phone games, print media, and social media time	Fast food consumption	Fast food consumption was positively associated with exposure to TV advertising among metropolitan children, and with online advertising among suburban children	Low
Mi-Hsiu and Chien-Hung[34] China	N = 1043 Age range = 9-12 Mean age = 10.1	Cross-sectional, self-report questionnaire for food frequency and preference	Self-report questionnaire advertising exposure.	Unhealthy snack consumption	Advert exposure was associated with unhealthy snack preference and consumption	Unknown
Scully et al[55] Australia	N = 12 188 Age range = 12-17 Mean age = not stated	Web-based, cross-sectional, self-report questionnaire eating behaviour, food choices, commercial TV viewing, print and other marketing sources	Self-report exposure to digital food marketing	Unhealthy food intake frequency (fast food, sugary drinks, sweet snacks, salty snacks)	Cumulative food advertising exposure was positively associated with adolescent food choices and intake	Low
Veerman et al[56] United States	N = not stated Age range = 6-12 Mean age = not stated	Secondary data sources, including body measurements from National Health and Nutrition Examination Survey	Literature relating to advertising exposure	BMI and food consumption	Model estimates that reducing advertising exposure to zero would decrease the prevalence of obesity for boys and girls by 2.6% and 2.4%	Low

age was 9.2 years. For advergame meta-analysis, the age range for the five included studies was 6 to 12 years and the mean age was 8.7 years.

3.3.2 | Interventions

TV food adverts were embedded in cartoons (n = 12), nature shows (n = 2), children's TV shows (n = 2), and a movie (n = 1); three studies did not state the programme used. Total TV time ranged from 10 to 39 minutes, the mean time was 20.1 minutes. For studies included in meta-analysis, where stated (n = 8), advert duration ranged from 45 seconds to 8 minutes, the mean advert duration was 4.4 minutes. Screen food advert interventions were for low-nutrient, high-energy foods, including fast food products, savoury/potato snacks, cheese, sweets/candies/chocolate, cookies/muffins, ice cream/desserts, breakfast cereals, or high sugar drinks. Specifically, branded food products were used in adverts if integral to the research objectives for the particular study.[27]

3.3.3 | Outcomes

Food items for ad libitum consumption varied between experimental studies; 13 studies offered only low-nutrient, high-energy foods (five peanut M&Ms or chocolate, three candy and chocolate, three potato/corn/wheat snacks, one pizza, one ice cream), nine studies offered a selection of healthy and unhealthy snacks,[21] and three studies did not specify but reported a selection of foods. Ad libitum consumption of food was during the intervention in 10 studies and after the intervention in 15 studies. Where consumption took place during the intervention, duration of snacking ranged between six and 39 minutes (mean 21.1 minutes); two studies did not state the duration of the intervention/ad libitum snacking. Where consumption took place after the intervention, duration of snacking was five minutes (n = 3), 15 minutes (n = 4), 20 minutes (n = 1), 30 minutes (n = 1), or an unlimited time (n = 4); two studies did not state the duration of ad libitum snacking.

3.3.4 | Comparisons

Unhealthy food advertisements were compared with nonfood advertisements in all studies included in television meta-analysis (n = 11), of which one study also included a comparison with an advert "light" condition.[20] Advergames with integrated food cues were compared with games with nonfood cues in meta-analysis (n = 5), of which three studies also included comparisons with healthy food cues (n = 2), no game controls (n = 2), and food and nonfood cues combined with protective messages (n = 1). Of studies not included in television or advergame meta-analyses, three compared food adverts with healthy/pro/high-nutrition foods, three to television with no adverts and one to a no television condition.

3.3.5 | Settings

Of the experimental studies, 18 used a between-subject design and seven used a within-subject design; all studies allocated participants randomly, except for one study where the experimental procedure

was unclear.[44] Of those using within-subject designs, number of experimental sessions varied between two and six, and washout periods ranged between one day and one month. Experimental studies were conducted in schools (n = 12), laboratories or research trailers (n = 9), holiday camps (n = 2), childcare facilities (n = 1), or community settings (n = 1). Experiments were conducted in the United States (n = 7), the Netherlands (n = 7), the United Kingdom (n = 5), Australia (n = 2), Canada (n = 2), Spain (n = 1), Georgia (n = 1), and Mexico (n = 1); one study contained separate samples in Spain and Netherlands, which were included as separate studies in meta-analysis.[24]

3.4 | Meta-analysis

Meta-analysis revealed that for television and advergames combined, food advertising, compared with nonfood advertising increased dietary intake among children/adolescents in experimental conditions (Figure 2); mean difference 57.7 kcal ($P < 0.01$; 95% CI, 36.61-78.75; $I^2 = 99.7$). The effect size point estimate for television food advertising was 60.0 kcal ($P < 0.05$; 95% CI, 3.06-116.94; $I^2 = 99.76$). Funnel plots showed some evidence of asymmetry and trim and fill analysis showed evidence of one missing study. Eggers regression analysis revealed low risk of publication bias ($P = 0.696$). The average time children were exposed to television advertising (data available in n = 8 studies) was 4.4 minutes (range 45 seconds to 8 minutes; however, there was no association between length of advert exposure and effect size (n = 9, $r = 0.056$, $P \geq 0.05$). The effect size point estimate for advergames was 53.2 kcal ($P < 0.001$; 95% CI, 31.49-74.85; $I^2 = 99.71$); the mean duration of advergames was five minutes, but it was not considered reasonable to calculate an exposure duration/effect size relationship. Funnel plots showed no evidence of asymmetry and trim and fill analysis showed evidence of no missing studies. Eggers regression analysis revealed low risk of publication bias ($P = 0.511$).

Regression analyses were conducted to explore whether within- or between-subject study design and ad libitum eating duration had a significant effect on the variability of the effect size between studies. Study design was not found to be a significant predictor and there was no significant difference in dietary intake for within- or between-subject studies ($P > 0.05$). Eating duration period was found to be a significant predictor of effect size; studies that gave children 15 minutes or less to eat during and/or post advertising exposure reported significantly lower effect sizes (N = 19, coef = 1.50, SE = 0.69, CI, 0.04-2.97, $I^2 = 99.69$, $R^2 = 17.17\%$).

3.4.1 | Effects of BMI

Planned subgroup analyses were conducted on the effect size by BMI; four studies provided appropriate data. Analyses revealed that the effect size of television food advert exposure on dietary intake was greater for children with overweight or obesity (mean difference 125.5 kcal, 95% CI, 18.80-232.25), compared with children with healthy weight (mean difference 79.9 kcal, 95% CI, 19.89-179.66), independent of experimental condition (Figure 3). Compared with nonfood adverts, children with overweight or obesity consumed an average 45.6 kcal more than children with healthy weight following exposure to food adverts. Subgroup analysis revealed the
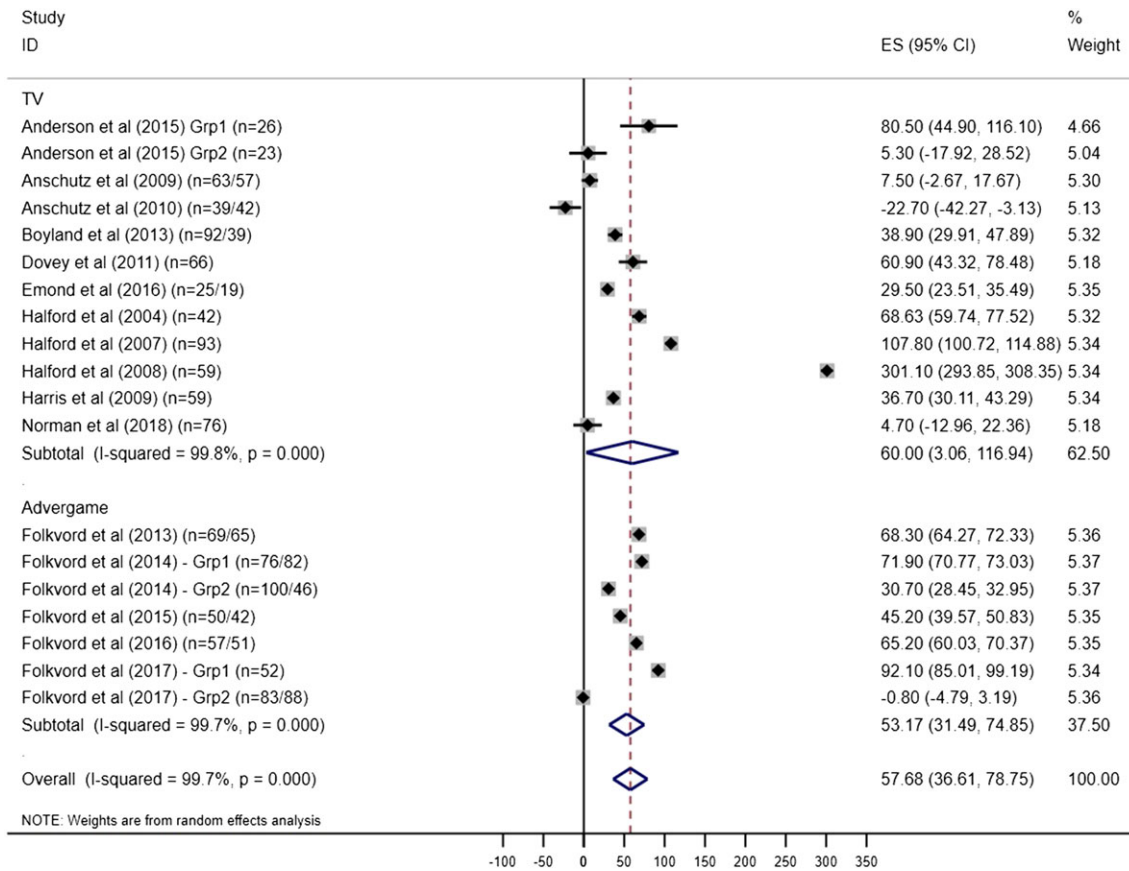
FIGURE 2 Forest plot showing mean difference (kcals) in dietary intake between television (TV) and advergame food advertising and nonfood advertising; 95% CIs and study weights are indicated. The overall effect size was generated by a random effects model [Colour figure can be viewed at wileyonlinelibrary.com]
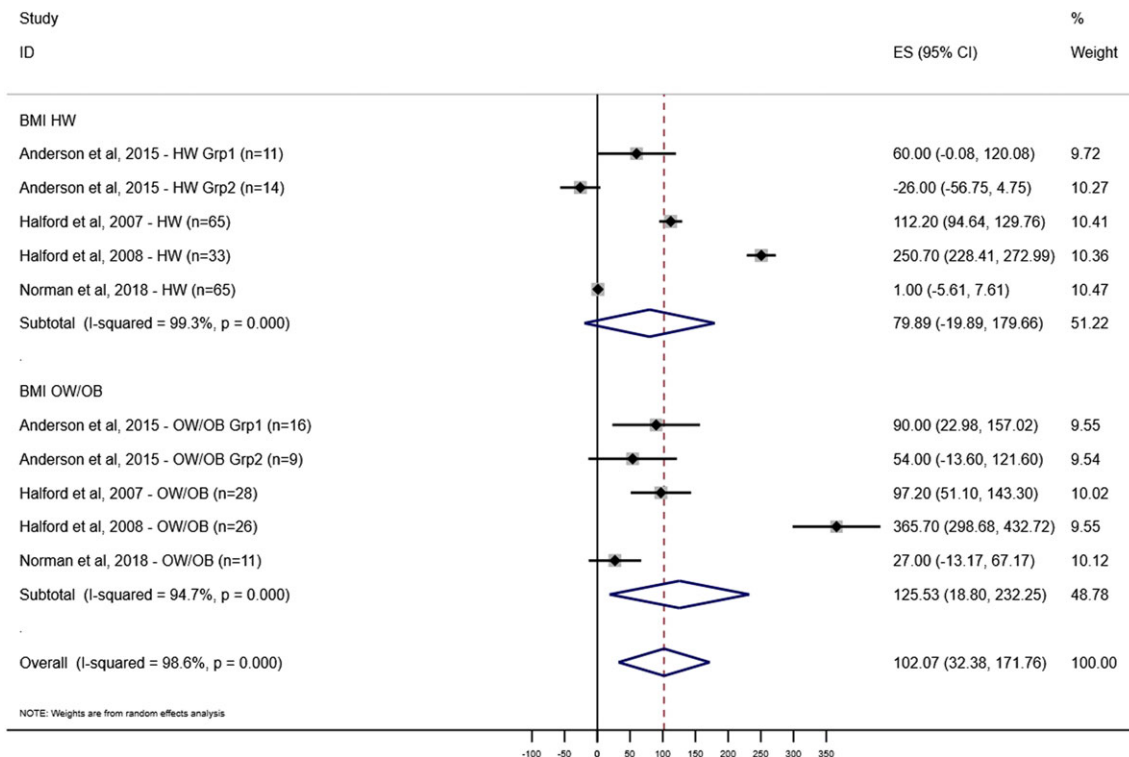
FIGURE 3 Forest plot showing mean difference (kcals) in dietary intake between television food advertising and nonfood advertising by BMI group (HW = healthy weight, OW/OB = overweight/obese); 95% CIs and study weights are indicated. The overall effect size was generated by a random effects model [Colour figure can be viewed at wileyonlinelibrary.com]

difference between children with healthy weight and children with overweight/obesity to be statistically significant (I^2 = 98.6%, $P < 0.01$).

3.4.2 | Other findings

The effect of advertising was reported by some studies to vary by sex; however, the nature of the effect was inconsistent with some research finding the effect size to be greater among girls,[28] while others reported the effect size to be greater among boys.[36] The effect size was reported to be greater for children with low neophobia compared with high,[21] highly impulsive compared with less impulsive children,[29] and children with a relatively higher gaze duration or "attentional bias".[39] Combined media (eg, a combination of exposure to television food advertising and advergames) was reported to have a stronger effect on children's dietary intake than television advertising alone;[25] the same study reported that the increase in dietary intake following advertising exposure was not compensated for at subsequent meals. Food adverts for particular foods were reported to increase consumption of those foods,[40] when given the option, children were more likely to consume low nutrient foods following television advertising,[22,37] and consumption of food type was found to vary by BMI group.[8] Children were reported to quickly recognise brand names and recall the content of food advertisements[41] and were found to be responsive to characters and make healthier choices if popular characters were associated with healthier products.[47] Celebrity endorsers were found to be effective at increasing consumption of endorsed food, and the effect was found to extend into nonfood contexts.[27] Healthy food adverts were not found to increase children's consumption of fruit or vegetables.[21] Parental behaviour, such as perceived encouragement to be thin or controlling feeding practices, was reported to affect susceptibility to the effects of television advertising on dietary intake.[20,46] Two studies conducted in Georgia and Mexico found no association between television advertising and energy intake.[42,45]

3.5 | Nonexperimental studies

3.5.1 | Participants

Across all studies, participants were aged between 8 months and 18 years; mean age where stated (11 studies) was 10.4.

3.5.2 | Interventions

All studies considered the effect of television food advertising, except one study that considered exposure to digital food marketing. Intervention data were estimated from self-reported surveys/questionnaires of television time or advert exposure (n = 9), from a combination of self-report and secondary data (eg, advertising broadcast data; n = 2), or from secondary data sources only (eg, company/media data; n = 3).

3.5.3 | Outcomes

Reported outcomes included dietary intake (n = 12), BMI, or overweight/obesity (n = 3). Of those reporting dietary intake, seven studies reported unhealthy food consumption, four studies reported healthy and unhealthy food consumption, and one study reported healthy food consumption.

3.5.4 | Settings

Study settings varied, some collected primary data, using parent or child self-report questionnaires (n = 11), others used longitudinal survey data (n = 2), one study used secondary data, and one was experimental with nonmeasured outcomes (within-subject design with random allocation, supplemented with self-report data).

3.5.5 | Meta-analysis—nonexperimental findings

Secondary meta-analysis was conducted for the nonexperimental studies reporting an association between television food advert exposure and dietary intake (n = 5); there was a significant positive association where the pooled mean correlation coefficient was r = 0.30 (95% CI, 0.16-0.45).

3.5.6 | Other findings

Various studies found television food advertising to be associated with dietary intake[32-34,48,50,54] but not necessarily body weight.[48] In one study, the association between advertising exposure and dietary intake was only found for lower income families.[30] Consistent with experimental findings, cumulative media, including television and other sources, was positively linked to adolescent food intake.[55] Various studies also found television food or soft drink advertising exposure to be a significant positive predictor of dietary intake in children after controlling for other factors.[30,33,34,48] Contrary to experimental findings, two studies reported exposure to healthy food adverts was associated with fruit and vegetable consumption;[33,53] the latter study also reported self-control to be independently associated with dietary intake. Two studies reported parental mediation, relating to guidance of food consumption or explaining the purpose of advertising could be effective in mediating the influence of television food advertising and associated dietary intake.[31,54]

4 | DISCUSSION

In this rapid systematic review utilising machine learning including 25 experimental studies and 14 studies with nonmeasured outcomes, we found that food advertising increased dietary intake in children under experimental conditions when compared with exposure to nonfood advertising. Exposure to 4.4 minutes of food advertising would on average increase a child's food consumption by 60.0 kcal, whilst playing an advergame with food cues for 5 minutes would increase consumption by 53.4 kcal on average. The similarity of the estimate across both subcategories suggests that this estimate is meaningful, despite high heterogeneity which is likely to have arisen from the variation in study designs, setting, total intervention time, and period allowed for food intake. We were unable to identify a "dose" relationship between unit of advertising exposure and resulting excess calorie consumption. However, we note that advertising exposure in countries such as the United Kingdom is in excess of the experimental

exposures in our included studies; commercial television in the United Kingdom currently shows up to 12 minutes of advertising per hour[57] and median television-watching during weekdays for U.K. children aged 7 to 15 years is 2 to 3 hours per day. Concerningly, children with overweight or obesity appeared to be more vulnerable to the influence of advertising, consuming an average of 45.6 kcal more than children with healthy weight when exposed to food advertising.

The point estimates for the effect size of television compared with advergame advertising were highly similar, suggesting similar effects, despite television watching being passive and with interspersed advertising whilst playing advergames is active with advertising embedded throughout. Findings from the experimental studies relate to the immediate effects of acute advertising, whereas children in 'normal life' are exposed to various media in combination and over longer periods of time. However, findings from the nonexperimental studies similarly showed that exposure to television food advertising was predictive of greater calorie intake in children.

4.1 | Comparison with the literature

Our review is consistent with a previous review by Boyland et al;[7] however, findings in that meta-analysis were presented as standardised mean difference, and this review included data from a number of additional studies. A broader review that included any form of marketing by Sadeghirad et al[58] found that 3.8 minutes of food marketing was associated with an additional consumption of 30.4 kcals in children. These analyses included a range of marketing (including games, packaging, and sponsorship), and the effect size was calculated from fewer studies, six compared with 16 in this review. The current review also analysed the impact of screen advertising in "real world" studies' with nonmeasured outcomes, thereby increasing the breadth and reliability of evidence of the effect of screen advertising on dietary intake.

4.2 | TV and advergames

Despite these differences, research has found no differences in the persuasive effect of adverts on television or advergames.[59] There was evidence from experimental data that combined media of television and advergames induces a greater effect on dietary intake.[25]

4.3 | Mechanisms of food advertising

The mechanisms by which advertising affects eating behaviour in children are unclear and are likely to vary by contextual and individual factors. However, recent research using functional magnetic resonance imaging (fMRI) has revealed that the ventromedial prefrontal cortices (vmPFC) in children's brains, functions of which include decision making, reward valuation and self-control, are activated significantly more after watching television food advertisements.[60] The same research reported that following food advert exposure, food decisions by children were made faster and tended to favour taste over health.[60] In addition to situational factors, eating behaviour in adults and children is directed by impulsive and reflective decision making,[61] and these findings suggest that food advertisements may reduce the extent to which children utilise reflective/inhibitory control systems, which are negatively associated with risky eating behaviours, and promote impulsive decision making, which is positively associated with risky eating behaviours.[62,63]

4.4 | Public health implications

There is a substantial burden of illness and disease resulting from childhood overweight or obesity and a clear need for policy makers to address this public health problem. There is clear evidence that acute exposure to television food advertising increases immediate dietary intake, particularly of unhealthy foods. While there is a scarcity of evidence relating to the long-term effects of food advertising, reducing exposure both on television and via advergames is likely to improve children's food choices, reduce intake of unhealthy foods, and improve long-term health outcomes.

4.5 | Limitations

There may have been limitations in the rapid review methodology adopted for this work; potential bias was reduced by utilising independent reviewers for screening on title and abstract but machine learning was used to exclude a large number of articles without screening on title and abstract. Only one reviewer was used for full-text screening, but stringent criteria were thought to assist in reducing potential bias. While justifiable in the context of this review, findings may also have been limited by excluding studies from before 1980 and report publications.

The number of studies included for meta-analyses was relatively small, variability was high and effects due to error cannot be discounted. There were also small sample sizes for subgroup analyses by BMI (subgroup samples ranged from 11 to 28 for groups of children with overweight or obesity). Study heterogeneity was high and CIs were large for television advertising meta-analysis, indicating that caution should be taken with these results overall. There was also a limitation with advergame meta-analysis since studies were all by the same primary author.

5 | CONCLUSIONS

The evidence from this research shows that television and advergame screen advertising for unhealthy foods increases immediate dietary intake in children. There appears to be an effect by BMI where dietary intake of children with overweight or obesity increased to a greater extent than children with healthy weight. Given children and adolescents' changing use of media and unknown levels of advert exposure, the longer-term impacts of these reported effects in the real world are difficult to determine. More research on the effect of advertising duration and dose of exposure would be particularly useful, as would longitudinal work which considers the longer-term outcomes of advertising exposure. While the extrapolation of these findings to real world population is limited, this research is likely to have notable implications for policy and practice.

ORCID

Simon J. Russell 🅾 https://orcid.org/0000-0001-9447-1169

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