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REVIEW

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The effect of discretionary snack consumption on overall energy intake, weight status, and diet quality: A systematic review

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Summary

The consumption frequency and portion size of discretionary snacks are thought to contribute to a greater food intake and risk of overweight or obesity in the developed world but evidence from epidemiological studies is inconclusive. To investigate this, we systematically evaluated evidence on the effects of discretionary snack consumption on weight status, energy intake, and diet quality. Articles involving discretionary snacks reported against the outcome measures of any primary, peer-reviewed study using human participants from free-living conditions for all age groups were included. A total of 14,780 titles were identified and 40 eligible publications were identified. Three key outcomes were reported: weight status ($n = 35$), energy intake ($n = 11$), and diet quality ($n = 3$). Increased discretionary snack consumption may contribute modestly to energy intake, however, there is a lack of consistent associations with increased weight/BMI. Although cross-sectional analyses offered conflicting findings, longitudinal studies in adults showed a consistent positive relationship between discretionary snack intake and increasing weight or body mass index. Given that experimental findings suggest reducing the size of discretionary snacks could lead to decreased consumption and subsequent energy intake, food policy makers and manufacturers may find it valuable to consider altering the portion and/or packaging size of discretionary snacks.

KEYWORDS

diet quality, discretionary snacks, energy intake, weight status

1 | INTRODUCTION

In 2016, 39% of the world's population were classified as living with excess weight and 13% with obesity.[1] More recently, a report from the WHO[2] has outlined an increasing prevalence of individuals living with overweight or obesity among higher-income countries in Europe. Indeed, studies from European countries have indicated a rise in the prevalence of individuals living with overweight and obesity, and/or

Abbreviations: %BF, Percentage body fat; BMI, Body mass index; CI, Confidence interval; CVD, Cardiovascular disease; DM, Diabetes mellitus; DQ, Diet quality; DS, Discretionary snack; EI, Energy intake; FPS, Food portion size; g, grams; kcal, Kilocalories; kg, Kilograms; NHANES, National Health and Nutrition Examination Survey; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO, International Prospective Register of Systematic Reviews; QA, Quality assessment; SSB, Sugar-sweetened beverage; USD, United States dollars; WHO, World Health Organization.

mean BMI, during the COVID-19 pandemic in both adults[3] and children.[4] Accordingly, the increase in individuals living with overweight and obesity has coincided with an increase in obesity-related comorbidities such as cardiovascular disease (CVD), type 2 diabetes mellitus (DM), and cancer[5] as well as overall reduced quality of life[6] and more recently poorer outcomes following COVID-19 infection.[7] On top of the human health cost, the financial burden of obesity, in terms of health care expenditure, has been calculated to amount to USD 190 billion in the United States alone in 2012,[8] with further costs associated with lost productivity/absenteeism due to excess weight.[8]

Although the development of excess weight is often oversimplified to result from an energy imbalance, derived from excess calorie intake in relation to insufficient calorie expenditure, the reality of its development is more complex. It is an interplay of biological, psychological, environmental, and socioeconomic factors that predisposes societies to reduced physical activity and increased food consumption.[9–13] Increased food portion size (FPS) and frequency of consumption are factors that are believed to play a role in this increased propensity to consume excess calories,[14] which may result in increases in weight status. Additionally, so is the increased availability of, readily available and hyperpalatable snack foods.[11] Furthermore, diets that contain a large proportion of such nutrient-poor snack foods may reduce overall diet quality (DQ) and contribute to poorer health status.[15]

The greater frequency of consumption and larger portions of snack foods may partly contribute to increased overall food intake and risk of individuals becoming classified as living with overweight or obesity,[16–18] although this effect may vary depending on the population studied and it is noteworthy that results from observational research are inconsistent.[17,19] These inconsistent results may be influenced by variations in the definition of snacks used in research. Such variation in definition is potentially a major obstacle to the standardization of research relating to the effects of snack intake on diet- or weight-related outcomes.[20,21] Depending on the specific study, the definition of snack can vary from being based on calorie content[22] to time of day consumed (i.e., items usually consumed apart from main meals)[22,23] and even foods self-defined by study participants as snacks.[24]

Toumpakari et al[25] proposed defining foods as core (formed of the five food groups of fruit, vegetables, cereals, meat and alternatives, and milk and alternatives) and non-core (all other foods) in relation to their desirability within a diet. Nutrient cut-offs (e.g., high in sugar or fat) may also be used to classify foods; however, this does not distinguish between core and non-core foods. For example, almonds (30 g) which are associated with health benefits[26,27] contain approximately 50% more fat than a packet of crisps (30 g).[28] Therefore foods defined as discretionary snacks (DS), can be considered as non-core foods usually consumed outside of main meals, that typical dietary guidance (for example the UK Eatwell Guide[29]), does not recommend for regular consumption (e.g., crisps, chocolate, cakes, and confectionery).[25] The inclusion of sugar-sweetened beverages (SSBs) in the definition of discretionary snacks may lead to considerable differences in outcomes compared with definitions that focus solely on solid foods. The reasoning for this is that SSBs alone are known to be the largest single dietary source of added sugars in countries such as the United States[30] and their consumption may disproportionately relate to body mass gain due to reduced satiety and an incomplete compensatory reduction in energy intake (EI) compared to solid foods.[31] Therefore, within this systematic review, SSBs were not included in the definition of DSs.

The objective of this systematic review was to assess the effects of DS consumption, on weight status, EI, and DQ, defining DS as non-core foods that typical dietary guidance does not recommend for regular consumption and that are usually consumed outside of main meals.

2 | METHOD

2.1 | Search strategy

The review followed the PRISMA[32] guidelines (Supplement 1) and was registered in the PROSPERO database (ID CRD42021295446). A systematic search was conducted using six scientific databases: PubMed, Psych Info, Cochrane, ERIC, CINAHL, and Medline in December 2021. Keywords used in the search were drawn from previous relevant literature. The search strategy was organized around DS, defined as non-core foods that typical dietary guidance does not recommend for regular consumption and that are usually consumed outside of main meals (adapted from Gage et al[33]) and three outcomes: dietary EI (any measure), weight status (any measure e.g., BMI, percentage body fat [%BF] or waist circumference), and DQ (measured via validated indices). Limits were set to include only journal articles published in the English language. Further titles were identified by cross-referencing from these sources.

2.2 | Eligibility criteria

Articles involving DS reported against the outcome measures of any primary, peer-reviewed study using human participants within non-institutionalized living conditions for all age groups were included. Studies that did not report a relevant outcome or were validation papers were excluded. Likewise, studies focused on participants with health conditions or using drugs or supplements that may affect appetite, and participants living in countries with a human development index of <0.8, as published in the latest Human Development Report,[34] were also excluded. After the removal of duplicates, articles were screened independently by three reviewers (H.G., D.M., and R.K.) against the eligibility criteria, using the online tool Covidence.[35]

2.3 | Data extraction

Data were extracted from each publication by two of three reviewers (H.G., D.M., and R.K.) and consensus agreed with the third author. Information was extracted on study characteristics, methods, population, interventions, and comparisons as well as all available records matching our a priori selected outcome measures. Corresponding authors were contacted for missing or additional information when necessary.

2.4 | Quality assessment (QA)

Eligible papers underwent a QA using either the checklist for quality assessment of controlled intervention studies or the checklist for quality assessment for observational cohort and cross-sectional studies, as appropriate.[36] These QA tools were designed by the US National Heart Lung and Blood Institute to assist reviewers in focusing on factors essential for critical appraisal of the internal validity of a study. The tools include items to evaluate potential flaws in study methods or implementation. QA was completed for each publication by two of three reviewers (H.G., D.M., and R.K.) with any discrepancies discussed until a consensus was reached (Supplements 2 and 3).

2.5 | Data synthesis

Due to the heterogeneity in exposure metrics and methodologies used across eligible studies, a meta-analysis was not possible. Data are presented in a narrative format, using the Synthesis Without Meta-analysis (SWiM) guidelines.[37]

3 | RESULTS

A total of 14,780 titles were identified. After removing duplicates, 7875 records were retained. Of these, 7483 studies were excluded after reviewing titles and abstracts and 392 full-text articles were assessed for eligibility, resulting in a final sample of 31 eligible publications. A manual review of the references of these publications led to the addition of a further nine articles, and a final sample of 40 publications (Supplement 1).

3.1 | Study characteristics

The characteristics of the included studies are presented in Table 1, with data from studies outlined in Tables 2, 3, 4, 5, and 6. The included studies were mainly cross-sectional in nature ($n = 27$).[15,18,38–62] Additional studies were longitudinal ($n = 7$)[63–69] or had an experimental design ($n = 6$).[70–75] Both male and female participants of varying cultural and socioeconomic backgrounds, were included. Child or adolescent (hereafter referred to as children) populations were reported in 16 studies,[38,39,41,43–45,51–53,55,57,60,61,67,69,71] whereas 23 studies reported on adult populations.[15,18,40,42,46–50,54,56,57,59,62–66,70,72–75] One study, O'Neil et al[68] tracked behavior from childhood through to adulthood. Most studies ($n = 19$) were conducted in the United States.[15,41,44,46,47,49,54,56–58,63–65,68–70,73–75] Sixteen studies reported on participants living in European countries,[18,38–40,45,48,50–53,59,62,66,67,71,72] whereas two studies were reported in Australia,[60,61] two in Canada,[42,55] and one in Saudi Arabia.[43] Different studies reported data using a range of different foods as a measure of DS (Supplement 4). Using the QA tools,[36] the quality ratings for all 40 studies were fair to good, although substantial heterogeneity was observed. Strengths of the studies included clearly identified research questions, description and definition of study populations, and clear definition and measurement of relevant variables. Weaknesses in some studies included failure to assess the impact of DS intake over a timeframe sufficient to reasonably assess an association. Furthermore, some studies did not examine different levels of DS intake as related to the outcome. The results from the QA are presented in Supplements 5 and 6.

3.2 | Outcome measures

Three key outcomes reported within the included literature were (1) weight status ($n = 35$), (2) EI ($n = 11$), and (3) DQ ($n = 3$). Studies are presented below according to themes based on similar research designs.

3.2.1 | Weight status

Cross-sectional

Fourteen adult studies[15,18,40,42,46–50,54,56,57,59,62] and 13 child studies[38,39,41,43–45,51–53,55,58,60,61] reported cross-sectional data considering the relationship between DSs and weight outcomes. Among adult populations, five studies[15,18,46,59,62] reported positive associations between consumption of DSs and weight status. In two studies of American adults, snacking energy from desserts and sweets (including cakes, cookies, pies, candy, sugar, and sweets)[15] or chocolate consumption,[46] was positively associated with BMI. Likewise, in a population of Swedish adults, Bertéus Forslund et al[18] reported a significant trend among participants living with obesity, for greater EI and snacking frequency, from three food groups: cakes/cookies, candies/chocolate, and desserts, compared to a reference group. Similarly, in a large study of English adults, O'Connor et al[62] identified that individuals living with a BMI > 25 kg/m^2 reported consuming statistically significant greater amounts of crisps, chocolate, ice cream, and sweets (g/10 MJ/day) but not cakes and biscuits compared with those living with a BMI < 25 kg/m^2. Rippin et al[59] examined how FPS might vary with BMI in French and UK adults, however, only cakes in the French group had a significant association between FPS and BMI, where FPS increased with each BMI point increase.

Conversely, two studies[47,57] identified a negative association between chocolate intake and weight status. Golomb et al[47] reported that an increased frequency of chocolate consumption was linked to lower BMI, even after multiple adjustment models, despite also being linked with greater calorie and saturated fat intake. Using national data from American adults, O'Neill et al[57] reported that candy consumers had lower weight and waist circumference than non-candy

TABLE 1 Summary of characteristics of articles.

Outcome (*n*)	Study design (*n*)	Age group (*n*)	Country (*n*)	Sample size (*n*)
Weight (35)	Cross-sectional (28)	Adult (15)	Poland (2) USA (8) Sweden (1) Canada (1) UK (2) European (1)	100–199 (2) 200–299 (1) 300–499 (1) 500–999 (1) 1000–2999 (2) 3000–4999 (3) 5000–9999 (2) 10,000–99,999 (3)
		Children (13)	France (1) UK (2) Greece (1) USA (3) Norway (1) Australia (2) Saudi Arabia (1) European (1) Canada (1)	100–199 (1) 300–499 (3) 500–999 (4) 1000–2999 (3) 3000–4999 (1) 10,000–99,999 (1)
	Longitudinal (7)	Adult (4)	USA (3) Holland (1)	100–199 (1) 5000–9999 (1) 10,000–99,999 (1) 100,000 (1)
		Children (3)	Sweden (1) USA (2)	100–199 (1) 300–499 (1) 5000–9999 (1)
EI (11)	Cross-sectional (6)	Adult (4)	Sweden (1) USA (3)	1000–2999 (1) 3000–4999 (1) 10,000–99,999 (2)
		Children (2)	USA (2)	1000–2999 (1) 10,000–99,999 (1)
	Experimental (5)	Adult (4)	Belgium (1) USA (3)	<100 (4)
		Children (1)	Belgium (1)	<100 (1)
DQ (3)	Cross-sectional (3)	Adult (2)	USA (2)	200–299 (1) 10,000–99,999 (1)
		Children (1)	USA (2)	10,000–99,999 (1)

consumers; in addition, total and sugar candy consumers also had a lower mean BMI than non-candy consumers, although a lower mean BMI was not seen in chocolate candy consumers. Further to these two studies, Just and Wansink[49] reported an inverse relationship between BMI and sweet and salty DSs; however, when excluding the most extreme BMI classifications as outliers, no relationship was found. Additionally, although Matsumoto et al[54] reported a significant change in BMI with different chocolate consumption frequencies, the clinical relevance was minimal and the association did not follow a linear pattern.

Further to the findings of Just and Wansink[49] and Matsumoto and colleagues,[54] nine further studies identified no relationship between DS intake and weight status. Anyżewska et al,[40] in a sample of male Polish Army personnel, reported no association between chocolate, chocolate candies, and candy bars; non-chocolate candies; biscuits and cakes; ice cream and pudding; and salty snacks with BMI or a fat mass index. In a population of post-menopausal Polish women, Górna et al,[48] observed that the frequency of consumption of sweet or salty DSs, which ranged from less than twice per month to at least six times a day, was not associated with the development of overweight or obesity. Despite 95% of a study population of Canadian University students consuming DSs, Brunt et al[42] reported no relationship between sweet baked goods, salty snacks, candy, and BMI. Similar findings were reported in the United Kingdom,[50,59] between portion sizes (g) of food groups consumed with BMI status, adjusted for under-reporting, social class and physical activity, and American[56] cohorts, which reported the category of candy consumption, adjusted for sex, age, and race/ethnicity, despite being positively associated with daily EI.[56] Although Barnes et al[15] reported a positive association between desserts and sweets, no association was reported between chips, crackers, ready-to-eat cereals, popcorn, and related products and BMI.

Similar discrepancies were reported in children. Lioret et al[53] investigated the relationship between overweight status and portion size in French children. Although the analysis included multiple DS categories including sugar or chocolate confectioneries, snack bars,

TABLE 2 Cross-sectional studies reporting DSs and EI and/or weight status for children.

Author/aim	Characteristics Sex, Age (years), SEP, ethnicity	Data collection Method: DS	Data collection Method: Weight	DS	Adjustment
Albar et al 2014[38]					Mean (g) (95% CI)
Association between BMI and DS portion size: change in BMI per 10 g	Mixed, 11–18, NI, 88.2% white.	FFQ	UK90 BMI	Age, sex, and misreporting	Sweet spreads, filling, and icing
					Crisps and savory snacks
					Chocolate confectionery
				Biscuits;	
				Buns, cakes and pastries	
				Sugar confectionery	
Andersen et al 2005[39]					
Comparison of sweet intake of those living with overweight (OW) and not overweight (NO)	Mixed, 8–13, NI, NI,	Diet survey	BMI international cut-off	Sweet intake	Adjusted for age
Babajafari et al. 2011[61]					
Associations between frequency of DSs and BMI and living with being overweight	Mixed, 12–15, 92% middle–high income, 91% white	Diet screeners	BMI	Sweets/lollies:	Unadjusted for gender of adolescent, age of mother, BMI of mother, family income, TV watching, sport, fast food, red meat, soft drink, Salad, cooked vegetables, cakes/biscuits, attitude toward eating together, going out to eat, and deciding to buy food.
Association between frequency of DS and living with being overweight				Cakes/biscuits:	Gender, age of mother, BMI of mother, family income, TV watching, sport, food behaviors
Bandini et al 1999[41]					
Comparison of EI from DSs in individuals living with obesity (OB) and not living with obesity (NO).	Mixed, 12–18, NI, NI	Food diary	% body fat	Chips	
				Candy	
				Baked goods	
				Ice cream	
				Total daily EI from chips, candy, soda, baked goods, and ice cream	
Collison et al 2010[43]					

TABLE 2 (Continued)

Author/aim	Characteristics Sex, Age (years), SEP, ethnicity	Data collection Method DS	Weight	DS	Adjustment
Association between BMI and DSs	Mixed, 10–19, NI, NI	FFQ	BMI	Savory snacks	
				Sweet snacks	
	Couch et al 2014[44]				
Association of weight category and DS intake	Mixed, Child-9, Adults 41.4, NI, NI	3*24-h recalls	BMI and BMI *z*-scores	Sweets and savory snacks	Neighborhood type based on physical activity environment and nutrition environment
Cuenca-García et al. 2014[45]					
Association of tertile of chocolate consumption and weight status	Mixed 12.5–17.5, Mixed, Mixed,	24-h recall	BMI, % body fat, waist circumference	Chocolate	Centre, sex, age, sexual maturation, total EI, saturated fat, fruit and vegetable intake
Kerr et al 2009[51]					
Association of portion size of DS with weight status	Mixed 14–16 NI NI	Food diary	BMI	Crisps and savory snacks	
Kosti et al 2007[52]					
Association between DS intake and weight status	Mixed 12–17 NI NI	FFQ	BMI	Sweets, snacks	
Lioret et al. 2009[53]					
Prediction for overweight (including obesity) by Tertile (T) portion sizes of DS	Mixed 3–11 NI NI	Food diary	BMI	Sweet or savory snacks	Age and sex
				Biscuits	
				Sweetened pastries	

TABLE 2 (Continued)

Author/aim	Characteristics Sex, Age (years), SEP, ethnicity	Data collection Method			
		DS	Weight	DS	Adjustment
Mercille et al 2010[55]					
Association of mean DS portion size[a]/ frequency[b] with BMI categories	Mixed 8–13 NI Native American	24-h recall	BMI	Candies/Chocolate	
				Desserts	
				Crackers, popcorn, pretzels	
O'Neil et al 2011[57]					
Comparison of mean daily EI[a] or anthropometric[b] of DS consumers and non-consumers	Mixed, 2–18 Mixed NI	24-h recall	BMI	Total candy	Sex, ethnicity, and age
				Chocolate candy	
				Sugar candy	
Schumacher et al. 2014[60]					
Association of percentage energy from core and energy-dense, nutrient-poor food groups with weight status	Girls, 13.4–13.9 Low-income Mixed	FFQ	BMI	Confectionary	
				Packaged snacks	
				Baked sweet products	

Note: Letters (e.g., [a, b]) indicated cross-referencing within studies for relevant analysis.
Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; FMI, fat mass index; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIEHS, National Institute of Environmental Health; NIH, National Institutes of Health; NW, normal weight; OWOB, overweight/obesity; SD, standard deviation; SEP, socio-economic profile.

TABLE 2 (Continued)

Author/aim	Average snack consumption	Results	*P* value	Funding source
Albar et al 2014[38]		Regression analysis, β (95%CI)		
Association between BMI and DS portion size: change in BMI per 10 g	23.2 (19·3, 27·2)	−0.175 (−0.66; 0.31)	0.47	NI
	30.2 (28·6, 31·6)	0.121 (−0.13; 0.38)	0.35	
	39.3 (35·7, 42·8)	0.025 (−0.09; 0.14)	0.66	
	37.4 (34·6, 40·2)	0.053 (−0.10; 0.21)	0.50	
	64.9 (61·1, 68·8)	−0.049 (−0.18; 0.08)	0.45	
	42.2 (36·7, 47·7)	−0.055 (−0.19; 0.08)	0.41	

TABLE 2 (Continued)

Author/aim	Average snack consumption	Results	*P* value	Funding source
Andersen et al 2005[39]		Regression analysis, OR (95% CI)	Trend	
Comparison of sweet intake of those living with overweight (OW) and not overweight (NO)	Quartile 1 (2 g/day) Quartile 2 (16 g/day) Quartile 3 (35 g/day) Quartile 4 (89 g/day)	(1.00) 0.71 (0.47, 1.03) 0.78 (0.49, 1.23) 0.48 (0.29, 0.81)	0.02	Norwegian Research Council and the Norwegian Directorate for Health and Social Affairs
Babajafari et al. 2011[61]		Regression analysis β (95%CI)	Trend	
Associations between frequency of DSs and BMI and living with being overweight	NI on portion size. Rarely/never	1.00,		National Health and Medical Research Council of Australia
	2 or 3 times a week	1.00 (0.85, 1.16),		
	Once or more a day/most days	0.91 (0.70, 1.18).	0.87	
Association between frequency of DS and living with being overweight	Rarely/never 2 or 3 times a week Once or more a day/most days	1.00, 0.83 (0.69,1.02), 0.71 (0.56,0.90).	<0.05	
Bandini et al 1999[41]	kcal/day (mean ± SD)	*t*-test analysis		
Comparison of EI from DSs in individuals living with obesity (OB) and not living with obesity (NO).	Non-Obese = 72 ± 78 Obese = 72 ± 111	$P > 0.05$	ns	National Centre for Research Resources, and the NIH
	Non-Obese = 113 ± 110 Obese = 31 ± 36	$P < 0.01$	<0.01	
	Non-Obese = 208 ± 156 Obese = 112 ± 65	$P > 0.05$	$P < 0.01$	
	Non-Obese = 97 ± 82 Obese = 37 ± 32	$P < 0.01$	$P < 0.01$	
	Non-Obese = 617 ± 356 Obese = 362 ± 223	$P < 0.01$	$P < 0.01$	
Collison et al 2010[43]	Mean (SD)	Pearson's (or Spearman's) correlation (*R*)		
Association between BMI and DSs	4.93 (3.49)	Female: −0.08 Male: −0.11	0.01 0.01	King Faisal Specialist Hospital & Research Centre, Research Advisory Council project
	2.94 (3.06)	Female: −0.04 Male: −0.07	NS 0.01	
Couch et al 2014[44]		Regression analysis Normal weight reference; Estimate (95%CI)		
Association of weight category and DS intake	NI	Overweight; −0.10 (−0.43, 0.23), Obese; −0.07 (−0.47, 0.33),	>0.05	NIH/NIEHS and USDA Grant

TABLE 2 (Continued)

Author/aim	Average snack consumption	Results	*P* value	Funding source
Cuenca-García et al. 2014[45]	Grams/day	Regression analysis β (95% CI)		
Association of tertile of chocolate consumption and weight status	Highest tertile median - 42.6 Mid tertile - NI Lowest tertile median - 4.7	BMI (kg/m2) = −0.005 (−0.0114; 0.0023) Body fat (%) (skinfold) -0.008 (−0.0256; 0.0086) Body fat (%) (BIA) - 0.012 (−0.0265; 0.0034)	0.003 0.002 0.009	European Community Sixth RTD Framework Programme and grants from the Spanish Ministry of Science and Innovation
Kerr et al 2009[51]	g/eating occasion (IQR)	Median (IQR)		
Association of portion size of DS with weight status	NDNS 1997 27 (25, 30) NI 2005 31 (25,35)	NDNS 1997: Normal weight 28 (25, 30), Overweight/obese 27 (25, 30) NI 2005: Normal weight; 31 (27, 36), Overweight/obese; 28 (22, 35)	0.853 0.503	Food Standards Agency
Kosti et al 2007[52]		Regression analysis β (95% CI) per 1 serving/ week		
Association between DS intake and weight status	NI	Boys: 0.99 (0.97–1.00) Girls: 0.99 (0.97–1.01)	0.06 0.26	Departmental sources
Lioret et al. 2009[53]	g per portion	Regression analysis β (95% CI)	Trend	
Prediction for overweight (including obesity) by Tertile (T) portion sizes of DS	3–6 years 25.8 ± 17.3 7–11 years 32.8 ± 19.2	T1 = 1.00, T2 = 0.49 (0.23–1.05), T3 = 0.99 (0.50–1.98) T1 = 1.00, T2 = 1.03 (0.55–1.93), T3 = 0.07 (0.37–1.34)	0.9101 0.2835	NI
	3–6 years 49.5 ± 30.4 7–11 years 57.2 ± 36.6	T1 = 1.00, T2 = 1.47 (0.68–3.17), T3 = 2.20 (1.03–4.68) T1 = 1.00, T2 = 1.20 (0.63–2.29), T3 = 1.24 (0.65–2.38)	0.0392 0.5188	
	3–6 years 116.1 ± 73.8 7–11 years 134.5 ± 89.2	T1 = 1.00, T2 = 1.41 (0.61–3.27) T3 = 3.06 (1.43–6.56) T1 = 1.00, T2 = 1.84 (0.95–3.58) T3 = 1.66 (0.85–3.25)	0.0027 0.1530	
Mercille et al 2010[55]	[a] Mean g ± SD [b] Frequency %	ANOVA[a] g/mean ± SD Chi-squared[b] % ± SD		
Association of mean DS portion size[a]/ frequency[b] with BMI categories	Normal weight 43 ± 48 At risk of being overweight 70 ± 85 Overweight 28 ± 27	[a]Normal weight 43 ± 48, Risk of overweight; 70 ± 85, Overweight; 28 ± 27	0.08[1]	National Health Research and Development Program, Health Canada, and the Canadian Institutes of Health Research
	Normal weight 26.7 At risk of being overweight 30.7 Overweight 16.5	[b]Normal weight 26.7%, Risk of overweight 30.7%, Overweight 16.5%	0.06[2]	
	Normal weight 21.4 At risk of being overweight 13.3 Overweight 11.6	[b]Normal weight 21.4%, Risk of overweight 13.3%, Overweight 11.6%	0.05[2]	

TABLE 2 (Continued)

Author/aim	Average snack consumption	Results	*P* value	Funding source
O'Neil et al 2011[57]	Consumers mean ± SE	Regression analysis kcal (mean ± SE)[a] BMIz-score β (95%CI)[b] (reference non-consumers)		
Comparison of mean daily EI[a] or anthropometric[b] of DS consumers and non-consumers	2–13 years 35.2 ± 1.4 4–18 years 46.2 ± 2.2	Consumers 2248.9 ± 2 6.8, Non-consumers 1993.1 ± 15.1[a] Consumers with overweight/obesity; = 0.78 (0.68–0.90) [b] Consumers with obesity; = 0.74 (0.66–0.82)[b]	<0.0001[a] <0.0001[b] <0.0001[b]	USDA Agricultural Research Service, USDA Hatch Project, National Confectioners Association.
	2–13 years 35.8 ± 1.7 4–18 years 48.4 ± 2.0	Consumers = 2333.8 ± 52.2, Non-consumers 2031.2 ± 13.3[a] Consumers with overweight/obesity = 0.83 (0.66–1.03)[b] Consumers with obesity = 0.85 (0.62–1.17)[b]	<0.0001[a] 0.0876[b] 0.3166[b]	
	2–13 years 29.0 ± 1.3 4–18 years 36.1 ± 3.2	Consumers = 2254.3 ± 29.4, Non-consumers 2024.4 ± 13.4[a] Consumers with overweight/obesity 0.79 (0.69–0.91)[b] Consumers with obesity = 0.80 (0.66–0.95)[b]	<0.0001[a] 0.0015[b] 0.0150[b]	
Schumacher et al. 2014[60]		Kruskal–Wallis equality of populations rank test Median (IQR)		
Association of percentage energy from core and energy-dense, nutrient-poor food groups with weight status	NI	Underweight: 10.0 (9.4–16.1), Healthy: 6.7 (4.2–11.5), Overweight: 6.7 (4.2–11.5), Obese: 7.8 (5.6–14.5), All: 7.0 (4.1–10.9)	0.07	Australian Research Council Discovery Project Grant. Australian Postgraduate Award Scholarship. Australian National Health and Medical Research Council Career Development Fellowship.
	NI	Underweight: 7.4 (5.7–15.4), Healthy: 6.9 (4.2–11.2), Overweight: 6.6 (4.2–11.2), Obese: 6.3 (3.2–9.8), All: 6.8 (4.0–10.7)	0.48	
	NI	Underweight: 5.1 (3.5–11.0), Healthy: 4.9 (3.0–8.3), Overweight: 5.4 (3.1–8.2), Obese: 4.8 (3.1–7.8), All: 5.0 (3.1–8.3)	0.84	

Note: Letters (e.g., [a], [b]) indicated cross-referencing within studies for relevant analysis.
Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; FMI, fat mass index; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIEHS, National Institute of Environmental Health; NIH, National Institutes of Health; NW, normal weight; OWOB, overweight/obesity; SD, standard deviation; SEP, socio-economic profile.

TABLE 3 Cross-sectional studies reporting DSs and EI and/or weight status for adults.

Author/aim	Characteristics Sex, Age (years), Sep, Ethnicity	Data collection method: DS	Data collection method: Weight	DS	Adjustment
Anyżewska et al. 2020[40]					
Relationship between the foods eaten and BMI and FMI	Male, 20–41, NI, NI	FFQ	BMI and FMI	Chocolate, chocolate candies and candy bars	
				Non-Chocolate candies	
				Biscuits and cakes	
				Ice cream and pudding	
				Salty snacks	
Barnes et al 2015[15]					
Association of total daily EI with BMI	Mixed, 18–60, Mixed, Mixed	24-h recall	BMI	Savory DS	Age, sex, race/ethnicity, education, job type, income, partner, physical activity
				Desserts and sweets	
Berteus Forslund et al 2005[18]					
Association between EI and snacking frequency between participants living with obesity and reference groups	Mixed, 43–50, NI, NI	Diet questionnaire	BMI	Cakes/cookies	
				Candies/chocolate	
				Desserts	
Brunt et al 2008[42]					
Contribution of DSs to dietary variety by weight category	Mixed, 21.3 ± 4.85, NI, NI	Diet variety questionnaire	BMI	Ice cream or milk dessert	
				Sweet baked goods	
				Salty snacks	
				Candy	
				Sweets	
Djoussé et al 2011[46]					
Association of frequency of DS intake with EI[a] and BMI[b]	Mixed, 52 ± 13.7, Mixed, NI	FFQ	BMI	Chocolate	
Golomb et al. 2012[47]					
Association of frequency of DS intake with BMI	Mixed, 57 ± 12, NI, NI	FFQ	BMI	Chocolate	Age, sex, activity, sat fat, fruit and vegetable, CES-D, and calories

TABLE 3 (Continued)

Górna et al. 2019[48]					
Influence of frequency of DSs on risk of development of overweight and obesity	Women, 60.1 +/− 9.0, Mixed, NI	FFQ	BMI	Sweets	Age, place of residence, education, occupation, subjective state of health, lifestyle, postmenopausal period, used hormone replacement
				Salty snacks	
Just and Wansink 2015[49]					
Instances of consumption of DSs with BMI	Mixed, 18+, NI, NI	24-h recall BMI		Desserts	
				Sweet snacks	
				Salty snacks	
Kelly et al. 2009[50]					
Association of DS portion size with BMI category	Mixed, 19–64, Mixed, NI	7-day weighed diary	BMI	Biscuits, cakes and pastries	Age, physical activity level, social class, and for percentage of under-reporting
				Creams, ice creams and desserts	
				Confectionery:	
				Savory snacks	
Matsumoto et al 2015[54]					
Association of frequency of DS consumption with total EI[a] and BMI[b]	Male, 40–84, NI, NI	FFQ	BMI	Chocolate	
Murphy et al 2013[56]					
Association of frequency of DS consumption with EI[a] and adiposity status[c]	Mixed, >19, Mixed, Mixed	FFQ	BMI	Candy	Sex, age, race/ethnicity, education, PIR, smoking (Y/N), physical activity, and time watching TV/videos[b]

TABLE 3 (Continued)

O'Connor et al 2015[62]					
Association of frequency of DS intake with BMI status	Mixed, 47.36 ± 7.22 NI NI	FFQ	BMI	Crisps	
				Cakes and biscuits	
				Chocolate	
				Ice-creams	
				Sweets	
O'Neil et al 2011[57]					
Comparison of mean daily EI[a] and BMI[b] of candy consumers and non-consumers	Mixed 45.6 ± 0.47 Mixed NI	24-h recall	BMI	Total candy	Sex, ethnicity, and age[a]
				Chocolate candy	Sex, ethnicity, age, and food energy[b]
				Sugar candy	
Rippin et al 2019[59]					
Association of mean DS portion size with BMI status[d,e]	A: Mixed B: 19–64 years C: NI D: 88–91% white	A: 7-day diary[d]; 4-day diary[e] B: BMI		Cakes[d,e]	Age and sex after excluding under-reporters.
				Biscuits and crisps[d]	
				Biscuits[e]	
				Crisps[e]	
				Chocolate[d,e]	
Association of DS consumption frequency with BMI[e]				Cakes[e]	
				Biscuits[e]	
				Crisps[e]	
				Chocolate[e]	

Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; FMI, fat mass index; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIH, National Institutes of Health; NW, normal weight; OWOB, overweight/obesity; SD, standard deviation; SEP, socio-economic profile.

[a]Energy intake.

[b]BMI.

[c]Adiposity status.

[d]French INCA2.

[e]UK NDNS.

TABLE 3 (Continued)

Author/aim	Average snack consumption	Results	*P* value	Funding source
Anyżewska et al. 2020[40]		Pearson's (or Spearman's) *R*		
Relationship between the foods eaten and BMI and FMI	NI	BMI: $r = -0.07$ FMI: $r = -0.04$	0.486 0.687	None
	NI	BMI: $r = 0.03$ FMI: $r = 0.03$	0.789 0.738	
	NI	BMI: $r = -0.17$ FMI: $r = -0.10$	0.103 0.327	
	NI	BMI: $r = 0.00$ FMI: $r = -0.05$	0.990 0.595	
	NI	BMI: $r = -0.08$, FMI: $r = -0.02$	0.460 0.853	
Barnes et al 2015[15]	% of Snacking Energy Intake from Food Groups, mean ± SD	Linear regression analysis β (SE)		
Association of total daily EI with BMI	16.5 ± 22.6	0.002 (0.03)	0.892	NIH/NIDDK
	20.8 ± 22.9	0.04 (0.02)	0.017	
Berteus Forslund et al 2005[18]		Regression analysis—no numerical data	Trend	
Association between EI and snacking frequency between participants living with obesity and reference groups	NI		<0.01	The Swedish Research Council and F Hoffmann–La Roche.
	NI		<0.05	
	NI		<0.01	
Brunt et al 2008[42]		ANOVA—dietary variety (%)		
Contribution of DSs to dietary variety by weight category	NI	Underweight: No:16 Yes:27, Healthy Weight: No:50.5 Yes:49.5, Overweight: No:56.8 Yes:43.2 Obese: No:51.1 Yes: 48.9	NS	NI
	NI	Underweight: No:32.6, Yes:67.4, Healthy Weight: No:40.5, Yes: 59.5 Overweight: No:45.9, Yes:54.1, Obese: No:31.1, Yes:68.9,	NS	
	NI	Underweight: No:34.9, Yes: 65.1, Healthy Weight: No:36.1, Yes:63.9, Overweight: No:43.9, Yes:56.1, Obese: No:33.3, Yes:66.7	NS	
	NI	Underweight: No:55.8, Yes: 44.2, Healthy Weight: No:49.2, Yes: 50.8, Overweight: No:52.0, Yes:48.0 Obese: No:42.2, Yes: 57.8	NS	

TABLE 3 (Continued)

	NI	Underweight: No:0, Yes: 100, Healthy Weight: No:0.6, Yes:99.4, Overweight: No:1.4, Yes:98.6, Obese: No:2.2, Yes: 97.8	NS	
Djoussé et al 2011[46]		Univariate analysis kcal/day[a] kg/m[2b]	Trend	
Association of frequency of DS intake with EI[a] and BMI[b]	NI	<1 per month: 1562 ± 659; 1–3 per month: 1661 ± 716; 1–4 per week: 1809 ± 685; 5 + per week: 2274 ± 984[a] <1per month: 27.3 ± 5.5; 1–3 per month: 27.6 ± 5.4; 1–4 per week: 27.7 ± 5.6; 5 + per week: 28.1 ± 5.9[b]	<0.001[a] 0.0013[b]	NHLBI
Golomb et al. 2012[47]		Regression analysis β (SE)		
Association of frequency of DS intake with BMI	NI	−0.208 (0.060) EI—Chocolate consumption frequency was linked to greater calorie and saturated fat intake	0.001 All <0.001	NHLBI
Górna et al. 2019[48]		Regression analysis β (95%CI)		
Influence of frequency of DSs on risk of development of overweight and obesity	NI NI	0.79 (0.61; 1.03) 0 (0; 5.34)	0.08 0.12	NI
Just and Wansink 2015[49]		ANOVA Mean BMI ± SD		
Instances of consumption of DSs with BMI	NI	Underweight; 0.5 ± 0.7, Normal[1]; 0.5 ± 0.8, Normal[2]; 0.6 ± 0.9, Overweight 0.6 ± 1.0, Obese[1]; 0.6 ± 0.9, Obese[2]; 0.5 ± 0.9, Morbidly obese[1] 0.6 ± 0.9, Morbidly obese[2]; 0.6 ± 0.8	t 0.4946	None
	NI	Underweight; 1.4 ± 1.5, Normal[1]; 1.3 ± 1.4 Normal[2]; 1.3 ± 1.5 Overweight; 1.2 ± 1.4 Obese[1]; 1.1 ± 1.2 Obese[2]; 1.0 ± 1.2 Morbidly obese[1]; 1.1 ± 1.2 Morbidly obese[2]; 0.8; ±1.1	<0.001	

TABLE 3 (Continued)

	NI	Underweight; 1.4 ± 1.3 Normal[1]/m^2; 1.1 ± 1.2 Normal[2]; 1.1 ± 1.2 Overweight; 0.9 ± 1.1 Obese[1]; 1.0 ± 1.1 Obese[2]; 0.9 ± 1.0 Morbidly obese[1]; 0.9 ± 1.1; Morbidly obese[2]; 1.0 ± 1.1	<0.001	
Kelly et al. 2009[50]	Median (IQR)	Regression analysis—no numerical data		
Association of DS portion size with BMI category	Male 33.4 (16·6, 66·3)		Males 0.595 Females 0.137	Food Standards Agency
	Female 28.8 (14, 50)		Males; 0·481 Females 0·123	
	Male 14.2 (7·6, 35.6) Female 12.3 (6.1, 22.8)		Males; NS Females 0.444	
	Male 11.6 (5.5, 19.6) Female 8.3 (4.6, 14.3)		Males; 0·358 Females; 0·789	
Matsumoto et al 2015[54]		Generalized linear regression analysis kcal/d[a] (mean ± SD) BMI kg/m^2 [b] (mean ± SD),		
Association of frequency of DS consumption with total EI[a] and BMI[b]	NI	None = 1528 ± 462, 1–3 serving/month = 1617 ± 471, 1 serving/week = 1695 ± 481, >2 serving/week = 1863 ± 518[a] None = 25.5 ± 3.2, 1–3 serving/month = 25.8 ± 3.3, 1 serving/week = 25.7 ± 3.1, >2 Serving/week = 25.6 ± 3.2[b]	<0.05 <0.05	NHLBI
Murphy et al 2013[56]		Ordered logistic regression[a] kcal/day (mean +/− SD) Regression analysis[b] OR (95%CI) Infrequent consumption: reference		
Association of frequency of DS consumption with EI[a] and adiposity status[c]	NI	Infrequent; 2101 ± 17.1, Moderate; 2192 ± 24.0, Frequent; 2311 ± 27.8[a] Obese: Moderate: 1.02 (0.83,1.24) Frequent: 1.01 (0.81, 1.27)[c] Overweight/obese: Moderate 1.00 (0.84,1.18) Frequent: 0.89 (0.75, 1.05)[c]	0.0005 Trend 0.855 0.262	National Confectioners Association
O'Connor et al 2015[62]		Mann–Whitney *U*-test Median (IQR) (g/10 MJ/day):		
Association of frequency of DS intake with BMI status	NI	BMI < 25 = 2.6 (0.6, 10.3) BMI > 25 = 3.3 (1.2, 12.4	<0.001	Wellcome Trust and the Medical Research Council

TABLE 3 (Continued)

	NI	BMI < 25 = 17 (7.0, 37.0) BMI > 25 = 16.0 (6.0, 37.0)	0.200	
	NI	BMI < 25 = 4.0 (0.8, 10.9) BMI > 25 = 4.5 (1.0, 15.9)	0.001	
	NI	BMI < 25 = 3.8 (0.0, 6.5) BMI > 25 = 4.2 (0.0, 7.4)	<0.001	
	Ni	BMI < 25 = 1.3 (0.0, 3.4) BMI > 25 = 1.4 (0.0, 3.9)	<0.001	
O'Neil et al 2011[57]	Mean (±SD) daily per capita intake (g)	Regression analysis Food energy, kcal[a] (mean ± SE) BMI kg/m^{2}[b] mean ± SE		
Comparison of mean daily EI[a] and BMI[b] of candy consumers and non-consumers	9.0 ± 0.3	consumers = 2,383 ± 22 Non consumers 2,156 ± 12[a] consumers = 27.7 ± 0.15 Non consumers = 28.2 ± 0.12[b]	<0.001[a] 0.0092[b]	National Confectioners Association and USDA–Agricultural Research Service through a specific cooperative agreement. Partial support was received from the USDA Hatch Project.
	5.7 ± 0.2	consumers = 2,403 ± 26 Non consumers 2,176 ± 12[a] consumers = 27.7 ± 0.21 Non consumers 28.1 ± 0.11[b]	0.001[a] 0.0735[b]	
	3.3 ± 0.2	consumers = 2,373 ± 30 Non consumers 2,187 ± 11[a] consumers = 27.6 ± 0.21 Non consumers 28.1 ± 0.11[b]	<0.001[a] 0.029[b]	
Rippin et al 2019[59]	Mean (g) (99%CI)[d,e]			
Association of mean DS portion size with BMI status[d,e]	NW; 117 (111–124)[d] OWOB; 133 (125–141)[d] NW; 69 (64–75)[e] OWOB; 68 (64–73)[e]		<0.01[d] NS[e]	WHO Regional Office for Europe
	NW; 37 (33–42)[d] OWOB; 35 (30–40)[d] NW; 32 (29–34)[e] OWOB; 33 (31–34)[b]		NS[d] NS[e]	
	NW; 32 (29–35)[e], OWOB; 30 (29–32)[e]		NS[e]	
	NW; 27 (24–31)[d], OWOB; 25 (22–29)[d] NW; 37 (34–40)[e], OWOB; 39 (36–43)[e]		NS[d] NS[e]	
		Regression difference in consumption frequency (99%CI)[e]		
		−0.004 (−0.01–0.001)	0.05	

TABLE 3 (Continued)

Association of DS consumption frequency with BMI[e]	0.005 (−0.004–0.01)	0.2
	0.004 (−0.002–0.009)	0.07
	−0.008 (−0.01–0.001)	0.003

Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; FMI, fat mass index; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIH, National Institutes of Health; NW, normal weight; OWOB, overweight/obesity; SD, standard deviation; SEP, socio-economic profile.
[a]Energy intake.
[b]BMI.
[c]Adiposity status.
[d]French INCA2.
[e]UK NDNS.

ice cream, chocolate spreads, and all savory appetizers and biscuits, only the portion size of biscuits and sweetened pastries was positively associated with children being classified as living with excess weight. Likewise, Albar et al[38] reported a positive association between intakes of only buns, cakes and pastries, and biscuits with BMI, that is, for each 10 g of biscuits or cakes consumed, BMI increased by 0·28 and 0·19 kg/m^2, respectively. Kosti et al[52] reported that eating sweet snacks was positively associated with overweight/obese status in male, but not female Greek adolescents.

Seven additional studies identified a negative association between snack intake and weight status.[39,41,43,45,55,58,61] Andersen et al[39] reported that in a sample of Norwegian 8–13-year-olds, those consuming the highest quartile of sweet intakes had 50% lower odds of living with excess weight compared with those in the lowest quartile of sweet intake. In an Australian trial, Babajafari et al[61] reported an increase in the consumption of cakes/biscuits was associated with a decrease in the odds of living with excess weight among adolescents, although no association between sweets/lollies and BMI was reported. Similarly, adolescents from Saudi Arabia reported savory snacks were inversely associated with BMI for both males and females, whereas sweet DS were inversely associated with BMI in males.[43]

In a multinational sample of European adolescents (Greece, Germany, Belgium, Crete, France, Hungary, Italy, Sweden, Austria, and Spain), Cuenca-García et al[45] investigated a potential relationship between chocolate consumption and markers of total and central body fat. Adolescents consuming the highest tertile of chocolate consumption had higher energy and saturated fat intake compared with those in the lower tertile but lower levels of central and total fatness, including BMI, regardless of relevant confounders. Using national data from American children ($n = 11{,}181$), O'Neill et al[58] investigated the association between chocolate candy and sugar candy intake and body weight. Despite chocolate candy consumers having higher intakes of energy, total fat, saturated fatty acids, and added sugar, they had lower weight, lower waist circumference, and lower percentile BMI-for-age than non-consumers. Similarly, sugar candy consumers had lower weight, BMI waist circumference, and percentile/z-score for BMI-for-age than non-consumers.

Bandini et al[41] compared the intake of high-calorie, low-nutrient-dense foods among those living with and without obesity. They observed that daily caloric intake from chips was similar between adolescent groups yet, caloric intake from candy, baked goods, and ice cream was significantly higher among adolescents living without obesity. However, after adjustment for under-reporting, only the intake of ice cream remained significantly higher. Mercille et al[55] investigated how the quality, quantity, and frequency of DS consumption differs in different BMI categories. Participants with a healthy weight showed a tendency to consume more DSs such as desserts, popcorn/pretzels/crackers, and candies/chocolate compared with participants living with excess weight.

Four further studies identified no relationship between DS intake and weight status.[44,51,52,60] Couch et al[44] and Kosti et al[52] both reported that child weight status was not significantly associated with

TABLE 4 Longitudinal studies reporting DSs and EI and/or weight status.

Aim (T = time)	Characteristics Sex, Age (years), Sep, Ethnicity	Data collection method: DS	Data collection method: Body mass	DS
Children				
Huus et al. 2009[67]				
Association of DS frequency of consumption(T1) with risk of overweight/obesity (T2 − +2.5 years)	Mixed 5 Mixed NI	FFQ	BMI	Chocolate Candy (non-chocolate) Ice-cream
Phillips et al. 2004[69]				
(T1 vs + 4 years post menarche) Association of % of calories from DS with BMIz-score[a] and % BF[b]	Girls T1 10 ± 0.93, T2 16.9 +/− 1.0 NI NI	FFQ	BMI	Candy Chips Baked goods Ice cream
Children to adult				
O'Neil et al 2015[68]				
Association of DS intake at childhood with weight status at young adult follow-up (mean 23.6 ± 2.6 years)	Mixed T1–10 years; T2–23.6 years C: NI D: Mixed	24-h recall/FFQ	BMI	Candy
Adult				
Greenberg and Buijsee 2013[63]				
Association of DS intake with prospective change in BMI kg/m^2 during 6-year period	Women 45–64 Mixed Mixed	FFQ	BMI	Chocolate
Greenberg et al 2015[64]				
Association of DS intake with 3-year change in body weight	Women, 50–79, Mixed, Mixed	FFQ	Body weight	Chocolate
Harris et al 1994[65]				
Association of sweet consumption with change in BMI for an 18-month period	Mixed, 38.2, Mixed, Mixed	FFQ	BMI	Sweets

TABLE 4 (Continued)

Aim (T = time)	Characteristics Sex, Age (years), Sep, Ethnicity	Data collection method: DS	Data collection method: Body mass	DS
Hendriksen et al. 2014[66]				
Associations of DS consumption with subsequent weight change	Mixed, 43.1 +/− 10.4 Mixed NI	FFQ	BMI	Total EDS food (g/y): Sweets (g/y): Cakes and pastries (g/y) Savory snacks (g/y)
O'Neil et al 2015[68]				
Association of DS intake at childhood with weight status at young adult follow-up (mean 23.6 ± 2.6 years)	Mixed T1–10, T2–23.6, NI Mixed	24-h recall/FFQ	BMI	Candy

[a]BMIz.
[b]% Body fat.
Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIH, National Institutes of Health; SD, standard deviation; SEP, socio-economic profile.

TABLE 4 (Continued)

Aim (T = time)	Adjustment	Average snack consumption	Results	P value	Funding source
Children					
Huus et al. 2009[67]		NI on portion size	Regression analysis OR (95% CI) Reference—1–2 times/week	Trend	
Association of DS frequency of consumption(T1) with risk of overweight/obesity (T2 − +2.5 years)	Mothers' education, fathers' education, mothers' BMI, fathers' BMI, heredity risk for diabetes	<1 time/week: 3–5 times/week Daily	0.97 (0.80–1.17) 1.25 (0.81–1.94) 1.20 (0.21–6.87)	0.725	Supported by JDRF-Wallenberg foundations, The Swedish Medical Research Council, The Swedish Child Diabetes Foundation, The Swedish Diabetes Association, Swedish Diary Association R & D, Novo Nordisk Foundation.
		<1 time/week: 3–5 times/week Daily	1.07 (0.84–1.38), 1.18 (0.80–1.22) 2.13 (0.59–7.68)	0.554	
		<1 time/week: 3–5 times/week Daily	1.05 (0.83–1.33) 0.89 (0.71–1.10) 1.04 (0.64–1.61)	0.611	

TABLE 4 (Continued)

Aim (T = time)	Adjustment	Average snack consumption	Results	P value	Funding source
Phillips et al. 2004[69]		NI	Linear mixed model % of calories (estimate) Quartile/Tertile 1—reference	Trend	
(T1 vs + 4 years post menarche) Association of % of calories from DS with BMIz-score[a] and % BF[b]	Age at menarche, parental overweight, and servings of fruits and vegetables	Quartile 2[a] Quartile 3[a] Quartile 4[a] Tertile 2[b] Tertile 3[b]	0.021[a] 0.005[a] 0.082[a] −0.051[b] 0.066[b]	0.088[a] 0.35[b]	
		Quartile 2[a] Quartile 3[a] Quartile 4[a] Quartile 2[b] Quartile 3[b] Quartile 4[b]	0.032[a] 0.030[a] 0.082[a] −0.054[b] −0.101[b] −0.161[b]	0.24[a] 0.63[b]	
		Quartile 2[a] Quartile 3[a] Quartile 4[a] Tertile 2[b] Tertile 3[b]	−0.029[a] −0.030[a] −0.027[a] −0.103[b] −0.221[b]	0.33[a] 0.23[b]	
		Quartile 2[a] Quartile 3[a] Quartile 4[a] Quartile 2[b] Quartile 3[b] Quartile 4[b]	0.00054[a] 0.0124[a] −0.0092[a] −0.0087[b] 0.40[b] 0.19[b]	0.85[a] 0.89[b]	
Children to adult					
O'Neil et al 2015[68]		Candy consumption (baseline) range (g)	Regression analysis BMI kg/m^2 β (SE) Tertile 1—reference		
Association of DS intake at childhood with weight status at young adult follow-up (mean 23.6 ± 2.6 years)	Baseline measures, total energy, age, ethnicity, sex, sex x race, smoking status, alcohol intake, candy at follow-up, and length of follow-up.	Tertile 1 0.00–19.50 Tertile 2 20.0–54.3 Tertile 3 54.8–281.5	Tertile 2 = 0.81 (0.59) Tertile 3 = −0.74 (0.60)	0.173 0.214	National Institute of Child Health and Human Development; American Heart Association; National Institute on Aging. Additional support for this study was obtained from the National Confectioners Association USDA Hatch Project

(Continues)

TABLE 4 (Continued)

Aim (T = time)	Adjustment	Average snack consumption	Results	P value	Funding source
Adult					
Greenberg and Buijsee 2013[63]		Frequency of consumption of a 1-oz (∼28 g) serving	Regression analysis Change in BMI kg/m^2, mean (95%CI) < 1 month = Reference		
Association of DS intake with prospective change in BMI kg/m^2 during 6-year period	Age, age squared, race, sex, and baseline covariates: body weight, waist-to-hip ratio, alcohol intake, smoking, education, prevalent illness and caloric intake, energy-adjusted dietary vegetable fruit, and fat levels	1–4 month ≥1 week Daily serving	0.26 (0.08–0.44), 0.39 (0.23–0.55) 0.19 (0.04–0.15)	Linear, =0.014. Quadratic, =0.499	NHLBI
Greenberg et al 2015[64]			Regression analysis Body weight change (kg) (95%CI) < 1/month 0 (reference)	Trend	
Association of DS intake with 3-year change in body weight	Age, time, chocolate-candy intake*time; baseline height squared; ethnicity; WHI study arm (2 groups); smoking status; physical activity; educational level; non-chocolate daily caloric intake (kcal/day); modified alternative health eating index	Participants were asked to specify their usual serving size as small (1/2 oz), medium (1 oz), or large (1 1/2 oz), Total chocolate candy intake, calculated from portion size and frequency of consumption, was used to assess the association between a 1 oz increment in chocolate intake and weight gain during the 3-year period	>1/month to <1/week 0.76 (0.66, 0.85) >1/week to <3/week 0.95 (0.84, 1.06) >3/week 1.40 (1.27, 1.53) An additional 1 oz/day 0.92 (0.80, 1.05)	Linear: <0.0001 Quadratic: <0.0001	NHLBI
Harris et al 1994[65]		Servings/week	ANOVA		
Association of sweet consumption with change in BMI for an 18-month period			Coefficient: 0.2374	0.0169	NHLBI
Hendriksen et al. 2014[66]		Energy intake from DS foods (kcal)	ANOVA coefficients (95% CIs)		
Associations of DS consumption with subsequent weight change	Baseline age, sex, baseline weight, height, duration of follow-up, physical activity, education, smoking status, fruit consumption, vegetable consumption, soda drink	Tertile 1,124 ± 44.5 Tertile 2,256 ± 39.0 Tertile 3502 ± 182.0 Tertile 1 20.2 ± 21.5 Tertile 2 48.0 ± 39.9	Location: Amsterdam and Maastricht 9.1 (1.5, 16.8) Location: Doetinchem −6.0 (−20.8, 8.9) Location: Amsterdam and Maastricht 11.5 (26.2, 29.2)	<0.05 NS NS NS	Supported by the Diet, Obesity, and Genes project (http://www.diogenes-eu.org/), which is supported by the European Community (contract FOOD-CT-2005-513,946)

TABLE 4 (Continued)

Aim (T = time)	Adjustment	Average snack consumption	Results	P value	Funding source
	consumption, and total EI excluding DS foods	Tertile 3118.0 ± 113.2	Location: Doetinchem −4.3 (−45.0, 36.5)		
		Tertile 1 47.1 ± 32.9 Tertile 2 97.7 ± 52.9 Tertile 3168.7 ± 108.7	Location: Amsterdam and Maastricht −11.3 (−29.0, 6.4) Location: Doetinchem −9.6 (−41.3, 22.0)	NS NS	
		Tertile 1 56.8 ± 34.8 Tertile 2110.0 ± 55.9 Tertile 3215.2 ± 144.0	Location: Amsterdam and Maastricht 22.0 (8.5, 35.5) Location: Doetinchem −4.0 (−29.0, 20.9)	NS NS	
O'Neil et al 2015[68]		Candy consumption (baseline) range (g)	Regression analysis BMI kg/m² β (SE) Tertile 1-reference		
Association of DS intake at childhood with weight status at young adult follow-up (mean 23.6 ± 2.6 years)	Baseline measures, total energy, age, ethnicity, sex, sex x race, smoking status, alcohol intake, candy at follow-up, and length of follow-up.	Tertile 1 0.00–19.50 Tertile 2 20.0–54.3 Tertile 3 54.8–281.5	Tertile 2 = 0.81 (0.59) Tertile 3 = −0.74 (0.60)	0.173 0.214	National Institute of Child Health and Human Development; American Heart Association; National Institute on Aging. Additional support for this study was obtained from the National Confectioners Association USDA Hatch Project

[a]BMIz.
[b]% Body fat.
Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; FFQ, food frequency questionnaire; T, time; NHLBI, National Heart Lung and Blood Institute; NI, no information; NIH, National Institutes of Health; SD, standard deviation; SEP, socio-economic profile.

TABLE 5 Experimental studies reporting DSs and EI and/or weight status.

Aim	Characteristics Sex Age (years) SEP Ethnicity	Data collection method for DS	Data collection method for Weight	Time
Children				
Marchiori et al 2012[71]				
Effect of size of DS-on-DS intake[a] and EI[b]	A: Mixed B: 9.2 ± 2.5 C: NI D: NI	NA	BMI	1 eating episode
Adult				
Marchiori et al 2011[72]				
Effect of size of DS-on DS intake[a] and EI[b]	A: Mixed B: 18–27 C: NI D: NI	NA	BMI	1 eating episode
Haire and Raynor 2014[70]				
Association of package unit size with total DS consumed	A: Mixed B: 23.7 +/− 3.3 years C: NI D: 81.3% white	NA	BMI	4 days
Raynor and Wing 2007[73]				
Effects of package unit size on food and EI	Mixed 18–30 NI Mixed	Food diary	BMI	3 days
Stroebele et al 2009[74]				
Association of package size on DS intake	Mixed, 18–65, NI, Mixed	Diet questionnaire	BMI	1 week
Wansink et al 2011[75]				
The effect of package size on EI	Mixed, 20.3 ± 1.1, NI, NI	Remaining crackers	BMI	1 eating episode

aAssociation between DS size and DS intake.
bAssociation between DS size and Energy Intake. Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; SD, standard deviation; SEP, socio-economic profile; NI, no information; NIH, National Institutes of Health.

TABLE 5 (Continued)

Aim	DS	Average snack consumption	Results	*P* value	Funding source
Children					
Marchiori et al 2012[71]			ANOVA Number of cookies consumed (mean ± SD)[a] EI (mean g/kcal)[b]		
Effect of size of DS-on-DS intake[a] and EI[b]	Small cookies Large cookies	126-g portion	14.6 +/− 5.8[a] 51/272[b] 9.2 +/− 3.5[a] 64/342[b]	0.001 <0.04	National Research Fund, Luxembourg.
Adult					
Marchiori et al 2011[72]			ANOVA Number of candies consumed (mean n ± SD)[a] EI (mean kcal ± SD)[b]		
Effect of size of DS-on DS intake[a] and EI[b]	Small candies Large candies	90-g portion	6.2 ± 7.2[a] 49.22 ± 57.2[b] 6.9 ± 4.1[a] 109.04 ± 64.5[b]	>0.7[a] 0.04[b]	Ministère luxembourgeoisde la Culture, de l'Enseignement Supérieur et de la Recherche
Haire and Raynor 2014[70]		Consumption (mean (g) ± SD)	ANOVA,		
Association of package unit size with total DS consumed	Pretzel	Single Serving Packages Normal weight 158.1 ± 104.4 Overweight/obese 107.0 ± 101.9 Standard Packages Normal weight 112.7.4 ± 58.9 Overweight/obese 204.4 ± 144.9	Effect size *d* = 0.78 Effect size *d* = 0.78	<0.05	No funding
Raynor and Wing 2007[73]			ANOVA Food EI, kcal (mean +/− SE)		
Effects of package unit size on food and EI	Total snacks	Small unit condition—single-serving packages (ranging from 28 g to 47.6 g) Large unit condition—foods packaged in units that were at least 5 times the size of the single-serving packages (ranging from 140 g to 263.2).	Small amount = 2782.2 +/− 1174.5 Large amount = 5028.1 +/− 2596.1	<0.01	National Institute of Diabetes and Digestive and Kidney Diseases
	Potato chips	Small unit—1-oz bag Large unit—5-oz bag	Small amount = 408.9 +/− 298.3 kcal Large amount = 1015.2 +/− 557 kcal	<0.01	
	Candy	Small unit—1.7-oz bag Large unit—9.4-oz bag	Small amount = 1087.9 +/− 418.7 kcal Large amount = 1772.7 +/− 948.5 kcal	<0.05	

TABLE 5 (Continued)

Stroebele et al 2009[74]			Repeated measures mixed models Mean (g) ± SD		
Association of package size on DS intake	10 different available snacks (Cool Ranch Doritos, Baked Cheetos, Harvest Cheddar Sunchips, Goldfish, Baked Ritz Chips, Snyder's Pretzels, Cheese Nips, Multigrain Wheat Thins, Cinnamon Teddy Grahams and Lorna Doone shortbread cookies)	Standard size packages (187 g to 368.5 g) vs. 100 kcal packages (19.2 g to 26 g)	Week 1 Standard size packages vs 100 g snacks 675.7 ± 61.5 g vs. 373.3 ± 35.6 g, 95% CI: 443.9 g to 161.1 g. Week 2 Standard size packages vs 100 g snacks 415.3 ± 38.8 g vs.486.7 ± 56.5 g, 95% CI: 207.6 g to 64.8 g, Week 2 vs week 1 373.3 ± 35.6 g vs. 486.7 ± 56.5 g, CI: 210.9 g to 16.1 g.	<0.0001 0.300. 0.023	NIH
Wansink et al 2011[75]			ANOVA Calories consumed Mean (kcal) ± SD		
The effect of package size on EI	Crackers	Four small 100-cal packages One large 400-cal packages	222.92 ± 150.40 g 298.05 ± 120.46 g Normal weight participants Participants living with overweight consumed more calories from crackers in the large package (383.54 ± 158.70 g) compared with small packages (175.97 ± 115.54 g)	0.02 NS 0.001	NI

[a]Association between DS size and DS intake.
[b]Association between DS size and Energy Intake. Abbreviations: BMI, body mass index; DS, discretionary snack; EI, energy intake; SD, standard deviation; SEP, socio-economic profile; NI, no information; NIH, National Institutes of Health.

TABLE 6 Cross-sectional studies reporting DSs and DQ.

Aim	Characteristics Sex, Age (years), SEP, Ethnicity	Data collection method DS	DQ	DS
Children				
O'Neil et al 2011[58]				
Association of DS intake and DQ (HEI)	Mixed, 2–18, Mixed, NI	24-h recall	HEI-2005	Total candy
				Chocolate candy
				Sugar candy
Adults				
Barnes et al 2015[15]				
Association of DS behaviors and DQ (HEI)	Mixed, 18–60, Mixed, Mixed	24-h recall	HEI-10	Chips, crackers, ready-to-eat cereals, popcorn, and related products
				Desserts and sweets
O'Neil et al 2011[57]				
Association of DS intake and DQ (HEI)	Mixed 45.6 ± 0.47 Mixed NI	24-h recall	HEI-2005	Total candy
				Chocolate candy
				Sugar candy

Note: Letters (e.g., [a, b]) indicated cross-referencing within studies for relevant analysis.
Abbreviations: BMI, body mass index; DQ, diet quality; DS, discretionary snack; EI, energy intake; HEI, Healthy Eating Index; NI, no information; NIDDK, National Institute of Diabetes and Digestive and Kidney Diseases; NIH, National Institutes of Health; SD, standard deviation; SEP, socio-economic profile; USDA, United States Department of Agriculture.

TABLE 6 (Continued)

Aim	Adjusted	Average snack consumption	Results	*P* value	Funding source
Children					
O'Neil et al 2011[58]		Consumers mean ± SE	Regression analysis β (95%CI) for HEI		
Association of DS intake and DQ (HEI)	Sex, ethnicity, age, and food energy	2–13 years 35.2 ± 1.4 4–18 years 46.2 ± 2.2	Consumers; 0.87 (0.71–1.08) Non consumers = 1.00	0.1979	USDA Agricultural Research Service USDA Hatch Project National Confectioners Association
		2–13 years 35.8 ± 1.7 4–18 years 48.4 ± 2.0	Consumers; 0.94 (0.71–1.23) Non-consumers; 1.00	0.6377	
		2–13 years 29.0 ± 1.3 4–18 years 36.1 ± 3.2	Consumers = 0.86 (0.70–1.06) Non-consumers; 1.00	0.1456	
Adults					
Barnes et al 2015[15]		% of Snacking Energy Intake from Food Groups, mean ± SD	Regression analysis β (SE)		
Association of DS behaviors and DQ (HEI)	Age, sex, race/ethnicity, education, job type, income, partner, physical activity, and total daily energy intake	16.5 ± 22.6	0.05 (0.03)	0.147	NIH/NIDDK
		20.8 ± 22.9	0.16 (0.03)	<0.001	
O'Neil et al 2011[57]		Mean (±SD) daily per capita intake (g)	Regression analysis HEI (mean +/− SE)		
Association of DS intake and DQ (HEI)	Sex, ethnicity, age, and food energy	9.0 ± 0.3	Consumers; 49.9 ± 0.36 Non consumers; 50.3 ± 0.34	0.165	USDA Agricultural Research Service USDA Hatch Project National Confectioners Association
		5.7 ± 0.2	Consumers = 50.0 ± 0.48 Non consumers 50.3 ± 0.32	0.5707	
		3.3 ± 0.2	Consumers = 49.4 ± 0.45 Non consumers 50.3 ± 0.33	0.0319	

Note: Letters (e.g., [a], [b]) indicated cross-referencing within studies for relevant analysis.

Abbreviations: BMI, body mass index; DQ, diet quality; DS, discretionary snack; EI, energy intake; HEI, Healthy Eating Index; NI, no information; NIDDK, National Institute of Diabetes and Digestive and Kidney Diseases; NIH, National Institutes of Health; SD, standard deviation; SEP, socio-economic profile; USDA, United States Department of Agriculture.

consumption of DSs. Kerr et al[51] reported there was no difference in chocolate confectionery or crisps and savory snack intake between adolescents with a healthy weight or with excess weight or obesity in either a UK or Northern Irish cohort. Furthermore, Schumacher et al[60] reported BMI was not associated with the consumption of packaged snacks, baked sweet products, and confectionery products in female adolescents from low-income communities.

Longitudinal

In total, seven studies reported on the longitudinal association of DS consumption on weight status, four of which were in adults[63–66] and three in children.[67–69] All the adult studies reported a positive association between their chosen DS food and increasing weight or BMI. In a large prospective cohort study of postmenopausal American women, Greenberg et al[64] reported that each 1 oz/day increase in chocolate-candy consumption was associated with a greater weight gain of 0.92 kg (0.80, 1.05), after 3 years. Similarly, in an earlier sample of female participants, Greenberg et al[63] reported more frequent chocolate intake was associated with greater prospective weight gain over 6 years, in a dose–response manner. Hendriksen et al[66] reported that after adjustment for potential confounders, a 100-kcal higher intake of savory DSs was significantly associated with an annual weight gain of 9.9 g/year (95% CI: 2.2, 17.5 g/year) in two of the three towns included in the study over an average follow-up of 8.1 years. In a shorter, weight loss intervention trial, Harris et al[65] reported that a mean decrease of 4.7 servings per week of sweets over 18 months was associated with a decrease in BMI of 0.12 kg/m^2.

Initially, Huus et al[67] reported intake of chocolate was positively associated, whereas sweets were negatively associated with living with overweight/obesity in children at 5 years of age. However, after adjustment for parental BMI, parental education, and heredity risk for DM, only frequency of intake of sweets was negatively associated with being classified as overweight or living with obesity. Phillips et al[69] investigated the relationship between the consumption of energy-dense snack foods and relative weight change over 4 years in 196 adolescent girls living without obesity. There was no statistically significant relationship between total DS (cookies, cakes, pies, brownies, potato chips, corn chips, chocolate, and non-chocolate candy food) consumption, expressed as servings per day or as a percentage of daily calories, with body fat percentage. Over a longer time frame, O'Neil et al[68] reported childhood (aged 10 years) candy consumption was not associated with weight status or body composition in young adulthood (aged 19–28 years).

3.2.2 | Energy intake

Cross-sectional

A positive relationship between DS consumption and EI was reported in cross-sectional studies in both adults ($n = 3$) and children ($n = 2$). Increased chocolate[47,54,57] and sugar candy[57] consumption was associated with greater calorie intake in adults. Golomb et al[47] reported that the frequency of chocolate consumption was linked to greater calorie and saturated fat intake among healthy men and women (20 to 85 years). Cross-sectional analysis from Matsumoto et al[54] examined the association of chocolate consumption and reported EI significantly increased by 335 kcal/day comparing no chocolate consumption to ≥2 servings a week. O'Neill et al[58] reported chocolate candy consumers had higher energy, total fat, saturated fatty acid, and added sugar intakes compared to non-consumers, whereas sugar candy consumers had higher energy and added sugar intakes and lower total fat and saturated fatty acid intakes than non-consumers.

One study reported on cross-sectional EI in children, and the findings replicated those of adults.[58] O'Neill et al[58] used NHANES data from American children ($n = 11{,}181$) and reported chocolate candy consumers had higher intakes of energy, total fat, saturated fatty acids, and added sugar than non-consumers. Sugar candy consumers had higher intakes of energy and added sugar and lower intakes of total fat and saturated fatty acids.

Experimental

Five studies[70,72–75] reported data on the effect of DS consumption on EI in adults, four of which used a randomized control trial (RCT) approach.[70,73–75] Increased consumption of a range of DSs, including cookies, cake, sugar confectionery, chocolate confectionery, and savory snacks were reported to be positively associated with an increase in EI. Four RCT studies[70,73–75] modified the package size of the DSs they provided to assess if this influenced the amount consumed. These studies were conducted over a range of time periods, from a week[74] (consuming three different snack brands chosen out of a possible 10, including crisps, crackers, pretzels, and biscuits) to 3 days[73] (potato chips, cheese crackers, cookies, and candy), and one eating episode[70] (crackers). Although Raynor and Wing[73] reported that doubling the amount of food provided was associated with an 80.7% increase in calories of food consumed there was no effect on package unit size. In contrast, both Stroebele et al[74] and Wansink et al[75] reported a positive association between portion size of packaging and EI, and Marchiori et al[72], reported a positive association between food item size and EI.

In a cross-over study, Stroebele et al[74] reported that participants consumed an average of 186.9 fewer grams of DSs per week when receiving 100 kcal snack packs compared to larger, standard-size packages of snacks. Furthermore, within this study, receiving the 100-kcal snack packs first seemed to reduce the amount eaten from standard-size packages. Similarly, in a randomized trial, Wansink et al[75] provided 37 undergraduate students with either a single 400-cal pack or four, 100-cal packs of crackers while watching a movie. Those consuming the four smaller packages ate 25.2% fewer calories than those consuming the large package; however, this effect was only observed in the group with BMI ≥ 25 kg/m^2. Marchiori et al[72] in a non-randomized between-subjects design, offered participants either normal-sized candies or candies that were cut in half. The same number of candies were consumed between groups leading to the normal-size candy group consuming twice as much in gram weight, resulting in an increase of nearly 60 kcal.

These findings were similarly reported in children, in one study. Marchiori et al[71] used a between-subjects randomized design to examine the influence of changing the size of snack food portions on short-term EI among Belgian children. Participants were offered the same weight of cookies, either full size or cut in two to make the portion size smaller. Decreasing the item size of food led to a decrease of 25% in gram weight intake, or a total of 68 fewer kilocalories consumed.

3.2.3 | DQ

Only three studies investigated the association between DS consumption and DQ[15,57,58] and have reported mixed findings. In adults, an increase in desserts and sweets (including cakes, cookies, pies, candy, sugar, and sweets), was significantly inversely associated with a Healthy Eating Index (HEI) score,[15] whereas sweet candy consumers had a significantly lower HEI score compared with non-consumers.[57] In contrast, an increased intake of savory DSs (chips, crackers, ready-to-eat cereals, and popcorn)[15] and chocolate confectionery had no significant association with HEI scores.[57] In children, chocolate consumers reported a mean lower dietary quality (HEI) compared with non-consumers, although no difference was observed with sugar candy consumption.[58] Regression analysis suggested that neither chocolate nor sugar candy consumption predicted DQ scores.[58]

4 | DISCUSSION

This review examined studies that investigated the association between DS consumption and measures of weight status, EI, or DQ. Consistently, an increased intake of DSs was positively associated with EI. However, there was no consistent association between DS intake with increased weight/BMI. The lack of consistency is likely due to differences in research designs as cross-sectional studies, which are weaker designs not capable of establishing causal relationships, showed mixed findings, whereas longitudinal studies in adults, which provide more robust evidence, showed a positive relationship between DS and weight status. Similarly, research reported mixed results for the association between DS intake and DQ, with two studies reporting that sweets and desserts, but not chocolate, were associated with reduced DQ in adults and only one study, in children, finding that consumption of chocolate but not sweets was associated with decreased DQ.

Increased consumption of a range of DSs has been consistently reported to be positively associated with an increase in EI in both adults[47,54,57,72–75] and children.[58,71] In this review, a wide range of DS measures were identified; however, overall, the results suggested that using portion-controlled packaging can help reduce FPS and energy consumed. These findings support recent systematic reviews that, increased portion size is positively associated with EI in children[76] and adults.[77,78] Reducing portion size, availability, and appeal of larger-sized portions, packages and tableware have the potential to reduce food consumption.[79] A plausible explanation for this is that people may consume DSs when they are neither hungry nor genuinely satiated. The decision about the appropriate amount of food to consume is therefore not a response to a physiological requirement but may be based on food hedonics, that is, liking and wanting.[80] It may be suggested that people interpret that consuming one unit of food is the appropriate amount to consume regardless of the size of the food items.[72]

Although two studies reported higher EIs derived from a measure of DS consumption in individuals living with obesity compared to those without,[18,41] in studies investigating the effects of DS intake, portion size, and frequency, on various aspects of weight status, the results varied considerably. Among adults nine cross-sectional studies,[15,40,42,48–50,56,57,59] indicated there was no relationship between a measure of DS intake and weight status, whereas five studies[15,18,46,59,62] reported a positive relationship, and four studies[47,49,54,57] indicated an inverse association. However, among the latter studies, the result was not maintained when excluding individuals with extreme weight categories[49] and was deemed not to be clinically significant in another.[54] Among children, the findings continue to be inconsistent, with seven studies[39,41,43,45,55,58,61] reporting an inverse association; three studies,[38,52,53] a positive association; and 11 studies,[38,41,43,44,51–53,55,60,61] no relationship between an individual's DS intake and weight status.

These conflicting findings could be at least partially explained by the physical activity levels of the participants as there is strong evidence demonstrating that higher physical activity levels can attenuate body mass gain.[81] In adults, for example, Anyżewska et al[40] reported high physical activity levels which may have attenuated the impact of high DS consumption on BMI. Interestingly, O'Neill et al[58] reported that higher candy consumers had lower BMI levels but stated that physical activity did not influence the main findings but reduced the association with BMI. However, they did not report the adjusted data for physical activity levels, leaving it unclear how much of an attenuation it had on BMI. In contrast, Kelly et al[50] and Murphy et al[56] did adjust for physical activity levels and still observed no association between BMI categories and DS intake. In children, association of DS intake with weight status was not adjusted for physical activity levels in 5 of the studies[38,51,52,55,60] that showed no effect of DS intake. Furthermore, cross-sectional studies only provide a snapshot of dietary intake and weight status making it difficult to determine causal effects.[82] For example, reverse causation could also play a role in cross-sectional studies.[83] It is possible that when data was collected those with higher obesity levels may have reduced DS intake to help reduce their obesity levels. In contrast, longitudinal studies are more robust to these limitations and offer better insights into DS intake and weight status.

All four longitudinal studies in adult populations reported a positive association between DS intake and weight status. Conversely, all three studies in children's populations reported inverse associations between DS consumption with weight status. We are unable to determine the reason for the greater proportion of studies reporting an inverse association in child and adolescent populations, compared with adults, a discrepancy that was most notable in longitudinal research studies. It might be speculated that children, due to their rapid growth and inherently faster metabolic rate, may consume more DS foods without negative impacts on their weight status.[84,85] Furthermore, rapid growth during childhood often includes increases in both weight and height, limiting the use of BMI as a valid measure of adiposity in this age group. It should also be mentioned that BMIz is considered by some to be a poor predictor of both adiposity and changes in adiposity over time, in young children.[86,87] This may be partially due to the greater risk of misclassifying rapidly growing children as living with overweight or obesity, by using age-stratified BMI or BMIz.[88] Although difficult to compare due to differing definitions of snacks, previous systematic reviews have observed similar conflicting findings in adults[89] and children[90] with regards to the role of snacks contributing to obesity levels. Likewise, authors have recognized that the differing methodological approaches to addressing the role of snacks and weight status are a key challenge to producing clear conclusions.

Typically, diets of high quality are associated with a reduced risk of mortality and non-communicable diseases.[5] For example, the risk of all-cause mortality, cardiovascular disease, cancer, type 2 DM and neurodegenerative disorders are reduced by 22%, 22%, 16%, 18%, and 15%, respectively, due to following a high-quality diet.[91] Therefore, diets that are high in nutrient-poor foods may contribute to adverse health outcomes due to low overall DQ. Previous research has indicated that snacking may be positively associated with higher DQ.[92,93] However, specific snack foods may affect DQ differently due to their nutrient composition. For example, Barnes et al[15] observed that consumption of nuts, fruit, and fruit juice was positively associated however, desserts and sweets were negatively associated with DQ.

Further to findings reported by Barnes and colleagues,[15] DQ was reported to be lower in sugar candy consumers compared with non-consumers; however, no difference was observed between chocolate consumers and non-consumers.[58] The nutrient composition of snack foods may be a determinant of how it affects overall DQ. Sugar candies are mainly a source of sugar in crystalline or semisolid form with rarely any addition of products with nutritional properties; in contrast, chocolate candies contain sugar but also a mixture of processed cacao, and cocoa butter, with additional products, including milk, fruit, and nuts, among other ingredients, which may contribute slightly more positively to DQ. For example, dark chocolate is a rich source of phytonutrients and has previously been associated with an improved lipid profile leading to reduced CVD risk.[94,95] However, in children, the trend was equivocal as chocolate consumption, compared to non-consumption, was associated with lower DQ, but sugar candy consumption was not.[58] Despite this, neither chocolate nor sugar candy consumption predicted DQ.[58] Additional research is required to understand how DS foods contribute to DQ in adults and children.

In interpreting these results, consideration should also be given to the type of research employed in each study. Cross-sectional studies are inherently limited in using data from a single point in time and as such may not represent normal or ongoing behaviors or states.[82] Longitudinal and experimental studies provide the advantage of following cohorts, which may differ by eating behavior, and observing changes, which may occur over a time course sufficient for changes in weight status to occur.[82] As such, longitudinal and experimental studies are considered to offer more valid epidemiological insights,[82,96] and in this systematic review, longitudinal data relating to DS intake and weight status may offer more relevant information than similar but cross-sectional research. Likewise, the different analysis techniques used to interpret the data, including what adjustments were included within the statistical model, may go some way to explaining inconsistencies in findings.

4.1 | Strengths and limitations

Within this review, the diversity of studies, including cross-sectional, longitudinal, and experimental, in both adult and child/adolescent populations, allows for both a general and more focused depiction of the current literature related to DS consumption. However, the diversity of individual study designs, exposure and outcome measures, study durations, and so forth adds a great deal of heterogeneity making a meta-analysis less reliable; hence, our decision to not include such an analysis. Indeed, the sheer diversity of definitions of DSs and/or different dietary assessment methods among the included studies and the literature in general was and is an issue of relevance. No generally accepted definition exists of what constitutes a DS, and distinctions between how DS consumption is presented in the literature are often ambiguous. Studies reported DSs in a variety of ways including food not consumed as part of a meal,[15,66] time consumed,[51] eating episodes,[52] or indeed did not provide a specific definition but just a list of relevant foods.[38–43,45–49,54,57–61,63–65,74] Inconsistencies in the definition of DSs make comparisons between studies difficult to interpret. The study definition of DS used herein was chosen to solely focus on foods that add variety to the diet but are not recommended for consumption such as chocolates, crisps, and sweets. As such all studies that specifically focused on these types of DS were included in this review. However, as a result of this definition, some studies may have been excluded that grouped these DS with snacks that are typically recommended for consumption such as nuts, yogurts, and fruits. By excluding such snacks this allowed the study to reveal the association of DS without confounding the results with core foods that are beneficial for consumption.

A further concern of all such nutritional epidemiology research is the reliability of diet intake assessment and the possibility of under-reporting. Recording dietary intake in population-level studies is inherently difficult with participants providing inaccurate records due to poor memory, inability to record food intake near to time of consumption, inaccurate estimation of portion sizes, and confusion regarding the definition of certain food categories, such as DSs.[97] Furthermore, the misreporting and in particular, under-reporting of food intakes (either intentionally or unintentionally) may present considerable limitations to any conclusions drawn from such data, and appropriate adjustment during data analysis is recommended.[98,99] However, such adjustment is not always carried out, as can be seen by the small number of studies included in this review which explicitly mention that the use of an adjustment for under-reporting was made in their analysis.

Finally, it should be emphasized once more that this review has only focussed on a single, albeit diverse, food category, DSs. It is understood that DSs make up only one aspect of a more varied dietary pattern with other foods that may contribute to the development of excess weight, in the wider, multifactorial obesogenic environment.[100] The results discussed in this review should therefore be carefully considered with this in mind.

4.2 | Implications for practice and future research

The purpose of nutritional epidemiology is to provide a better understanding of how foods might affect the health of a particular population and furthermore to give insights into how dietary alterations might affect health outcomes. Although such dietary changes may be made by the individual, they are notoriously difficult to maintain long-term in our current food environment[101]; and therefore, large-scale changes affecting the food environment itself, at a policy level, may be preferable.[102] Extrapolation of the results of this systematic review is best interpreted in terms of specific populations and considering the study designs employed. In adults, while cross-sectional studies provided somewhat inconclusive results related to the effect of DS intake on weight status and food intake, a greater proportion of longitudinal studies highlighted that greater DS portion size and/or frequency of intake was associated with increased EI and weight status over time. Results from experimental studies, however, consistently demonstrate that a larger portion size or packaging size is associated with greater EI. As greater EI over time may contribute to the development of excess weight gain, policies aimed at providing, smaller, individual portions of dietary snacks may play a part in reducing overall EI.

Results in children, however, are far less conclusive and tend to, counterintuitively, suggest that greater DS portion size and/or frequency of intake was associated with reduced weight status. This observation requires further investigation to determine the role DS intake may play in childhood and adolescent obesity.[103] This might take the form of investigations assessing the impact of different-sized DS portions on acute (<24 h) EI and how this may impact behavior and translate to longer term EI, body composition, and DQ. Further large-scale epidemiological studies that explore the influence of DS intake on DQ and how that may cluster with other health behaviors are warranted to promote long-term health.

5 | CONCLUSION

Increased DS consumption may contribute to EI in the diet and contribute to higher body mass levels as shown by experimental and longitudinal data. However, cross-sectional data, which are inadequate to determine clear conclusions, do not show consistent associations between DS intake and increased body mass/BMI. Given that experimental and longitudinal findings suggest that reducing the size of DSs could lead to decreased consumption and subsequent lower EI and body mass, food policymakers and manufacturers may find it valuable to consider altering the portion and/or packaging size of DSs. To support strategies for weight management, such policy changes may help consumers by altering product packaging, for example, providing smaller, individual-sized portions of DSs. Such a strategy may influence the quantity of DSs consumed. Currently, there is a lack of studies that have investigated a potential relationship between DS intake and DQ, which provides scope for further future studies. Furthermore, the negative associations of DS intake with weight status in children and adolescents require further investigation.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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