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Review Article

Energy intake misreporting among children and adolescents: a literature review

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Abstract

While adults' energy intake misreporting is a well-documented phenomenon, relatively little is known about the nature and extent of misreporting among children and adolescents. Children's and adolescents' dietary reporting patterns are likely to be distinct because of their ongoing cognitive and social development. These developmental differences present unique challenges to aspects of dietary reporting, such as food knowledge, portion size estimation and response editing. This review of 28 articles describes energy intake misreporting among children and adolescents. Like adults, children and adolescents tended to underreport energy, with the largest biases observed with food records. Even when mean reported energy intake was close to its expected value, approximately half of all individuals were classified as misreporters, and overreporting appeared to be more common than it is among adults. Associations between numerous characteristics and misreporting were explored in the literature, with the most consistent findings for age and adiposity. Two predictors for adults, gender and social desirability, were not consistent factors among children and adolescents. The review concludes by highlighting knowledge gaps and recommendations for future research and practice.

Keywords: child, adolescent, energy intake, misreporting, underreporting, dietary assessment.

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Introduction

Dietary assessment encompasses a variety of methods, including direct observation or plate waste analysis, but feasibility and cost prohibit using many techniques to study habitual intake in the general population. Most dietary studies employ one of several self-report methods, primarily food records, dietary recalls or food frequency questionnaires (FFQ) (Rutishauser 2005). One commonality among self-report methods is relying upon respondents to provide accurate information, yet misreporting is pervasive (Rutishauser 2005). Misreporting includes both underreporting and overreporting, with the former being more common. It can consist of food or beverage additions, omissions or substitutions, or may arise through inaccurate portion size estimation. The term *misreporting* can be misleading, however. Misreporting often cannot be distinguished from deviations from habitual eating patterns (with accurate reporting of the altered intake), making it difficult to identify the cognitive, behavioural or reporting processes resulting in biased data. Because of this ambiguity, some studies use terminology such as *low energy reporters* to designate participants with implausibly low values, although *misreporting*, *underreporting* and *overreporting* predominate; the terms will be used throughout this review.

The nature of energy intake (EI) misreporting is not well understood, and patterns vary with the population being surveyed. Compared with adults, less is known about misreporting among children and adolescents, yet it is likely that their response patterns differ. Both cognitive abilities and dietary habits distinguish children from adults (Livingstone & Robson 2000). Depending on their cognitive developmental stage, children may have greater difficulty recalling items eaten, estimating portion size or carrying out abstract reasoning tasks. Children and adolescents may lack sufficient knowledge of foods or preparation methods. Additionally, adolescents' eating patterns are less structured than adults', with meals eaten at unusual times or outside the home, which may particularly affect data quality if recording is perceived as too burdensome (Livingstone & Robson 2000). Given these differences, the factors contributing to misreporting among younger respondents are likely to be distinct from those for adults.

EI misreporting among children and adolescents is a problem of great relevance to public health. Misreporting is significant for three broad reasons related to how dietary intake data are used: (1) to establish diet–disease associations; (2) to set and evaluate nutrition policy and food-based dietary guidelines; and (3) to inform programme planning.

First, dietary data are used to study diet–disease associations, such as with obesity. Since the 1970s, overweight prevalence has more than quadrupled among children ages 6 to 11 and tripled among adolescents in the USA (National Center for Health Statistics 2009). In 2007–2008, 19% of all children and adolescents were overweight, with an additional 35% at risk, although the trend may now be levelling off (Ogden *et al*. 2010). While some studies have documented increases in EI that parallel rising obesity prevalence (Centers for Disease Control and Prevention 2004), others have reported no changes (Nicklas *et al*. 2001). Such inconsistencies may be attributed at least in part to misreporting and contribute to persistent uncertainty regarding the role of diet in many diseases.

Second, practitioners and policy-makers use dietary data to set nutrition standards and evaluate progress towards them (Muñoz *et al*. 1997; Wright *et al*. 2007). Several *Healthy People 2010* objectives for children and adolescents address the consumption of specific nutrients, and progress towards meeting the objectives is measured with the National Health and Nutrition Examination Survey (NHANES) data (United States Department of Health and Human Services 2000). Misreporting may lead to erroneous conclusions about population-wide nutrient intakes, which can affect food policy, priority-setting for interventions and establishing dietary guidelines (Becker & Welten 2001).

Third, similar to the consequences of biased data at the population level, misreporting may adversely affect local programme planning. Dietary data collected through community assessment may be used to determine the prevalence of certain nutrition risks and guide local priority setting. If children and adolescents selectively underreport their consumption of energy-dense snacks, for example, then the need for interventions to help them make better food choices may not be apparent. Conversely, underreporting may cause some nutrient intakes to appear below recommended levels when intake is, in fact, adequate. In either case, planning decisions based on biased information may lead to inefficient resource allocation.

The purpose of this literature review is to describe what is known about EI misreporting among children and adolescents, namely the magnitude of the problem, its prevalence and the individual character-

Key messages

- Like adults, children and adolescents underreport energy intake, although overreporting is also common. Bias may be less severe with dietary recalls and food frequency questionnaires than with food records.
- Plausibility cut-offs based on predicted energy requirements should be incorporated into future dietary studies to quantify children's and adolescents' misreporting.
- More work is needed to tailor dietary assessment methods to children's and adolescents' cognitive and social developmental needs.

istics that are associated with it. The paper concludes by identifying knowledge gaps and recommending subjects for future work in this area.

Materials and methods

Literature search

Published literature on EI misreporting among children and adolescents was identified through three approaches. First, PubMed, Embase and MEDLINE electronic databases were searched using several terms: *validation studies*, *energy intake, diet assessment*, *recall*, *doubly labeled water*, *Goldberg cut-off*, *plausibility*, *underreporting*, *overreporting* and *misreporting*. In PubMed, the former two terms were used as Medical Subject Heading terms in combination with the other keywords. All searches were restricted to English-language, empirical studies published between 1986 [when doubly labelled water (DLW) validation studies began appearing in the literature] and April 2010 on healthy, free-living children and adolescents ages 18 or younger in Westernized countries. Studies from non-Westernized countries were excluded to minimize cultural differences in survey response. Participants must have self-reported their diets, either independently or with some parental assistance, by means of dietary recalls, food records or FFQs. The validation standard must have been either DLW or plausibility cut-offs.

Titles of the 732 retrieved citations were scanned, and potentially relevant citations were retained for further review. Abstracts from the retained citations were examined, and most were subsequently discarded. Most were excluded because the studies were not diet-related, studied only adults or DLW or plausibility cut-offs were not the validation standard. Others were excluded if EI was exclusively proxy-reported, or if younger respondents' data were not reported separately from adults'. For the second approach, additional studies were identified via a descendancy search on selected articles using the ISI Web of Knowledge. Finally, reference lists from all identified articles were analysed for any additional citations.

Altogether, 28 articles were reviewed, with some based on the same study. Seven articles described some degree of parental assistance, particularly for younger children. Parents aided in completing food records or in filling in missing details afterward (Champagne *et al.* 1996, 1998; Sichert-Hellert *et al.* 1998). They helped to complete young respondents' dietary recalls in four articles (Fisher *et al.* 2000; Huang *et al.* 2004; Ventura *et al.* 2006; Savage *et al.* 2008). Few of the studies described the ages receiving help. In three other articles, it was unclear whether parents aided in children's assessment (Sichert-Hellert *et al.* 1994; Fiorito *et al.* 2006; Lanctot *et al.* 2008).

Literature analysis

Information abstracted from the articles included study design, sample characteristics, dietary assessment method, validation standard, estimates of EI and expenditure, and significance testing for EI misreporting. The proportion of participants classified as accurate reporters or misreporters as well as statistical testing for factors associated with misreporting were also abstracted. In reports where weight change over the course of the DLW assay was used to adjust energy expenditure (EE) estimates, the adjusted values were recorded. If an article provided information on subgroups of the sample, such as breakdowns by age, gender or race/ethnicity, then the subgroups were recorded separately.

Several aspects of children's and adolescents' EI misreporting were explored in this review. Two means of quantifying biases in the data were explored in depth. First, self-reported EI was compared with estimated EE. Second, the proportion of children and adolescents who misreported was used to determine the prevalence of misreporting. Finally, individual characteristics explored in relation to overreporting and underreporting were described.

Results

EI misreporting magnitude

Fourteen studies, encompassing 34 subgroups, compared mean self-reported EI and mean EE or predicted energy requirements (Table 1). Ten of the studies used DLW as the validation standard, and four

Table 1. Accuracy of children's and adolescents' self-reported EI

Reference	Design	Assessment	Subjects[†]	EI (MJ day^{-1} ± SD)	EE (MJ day^{-1} ± SD)	EI/EE[†] 100% ± SD	P[‡]
Bandini *et al*. (1990)	C	14-day estimated record, 14-day DLW	14 M, 14 F, non-obese, mean age 14	9.00 ± 2.49	11.53 ± 2.51	80.2 ± 22.6	<0.0001
			14 M, 13 F, obese, mean age 15	7.26 ± 3.96	14.18 ± 2.56	54.2 ± 31.6	<0.0001
			28 M, age 12–18	NR	NR	73.5 ± 25.5	NR
			27 F, age 12–18	NR	NR	65.6 ± 21.4	NR
Bandini *et al*. (1997)	C	7-day estimated record, 14-day DLW	109 F, non-obese, age 8–12	7.00 ± 1.67	8.03 ± 1.28	88.3 ± 21.0	<0.0001
Bandini *et al*. (2003)	L	7-day estimated record, 14-day DLW	26 F, age 10	7.10 ± 1.26	8.13 ± 1.14	82.0 ± 17.0	NR
			26 F, age 12	7.03 ± 1.41	9.34 ± 1.33	71.0 ± 24.0	NR
			21 F, age 15	6.82 ± 1.51	10.27 ± 1.54	66.0 ± 20.0	NR
Bratteby *et al*. (1998)	C	7-day weighed/estimated record, 14-day DLW	25 M, age 15	11.40 ± 2.71	13.82 ± 1.90	81.9 ± 17.9	NR
			25 F, age 15	8.28 ± 1.88	10.70 ± 1.59	78.3 ± 16.4	NR
Champagne *et al*. (1996)	C	8-day estimated record, 8-day DLW	6 M, 5 F, AA, mean age 11	NR	NR	63.0	0.0002
			6 M, 6 F, W, mean age 11.5	NR	NR	87.0	0.0626
Champagne *et al*. (1998)	C	8-day estimated record, 8-day DLW	56 AA, age 9–12	7.02 ± 0.22	9.82 ± 0.21	73.1 ± 2.3	NR
			62 W, age 9–12	7.99 ± 0.23	10.21 ± 0.23	79.7 ± 2.6	NR
			58 F, age 9–12	6.83 ± 0.23	9.34 ± 0.22	75.0 ± 2.5	NR
			60 M, age 9–12	8.17 ± 0.22	10.69 ± 0.21	77.8 ± 2.4	NR
			7 children, age 9	7.61 ± 0.51	9.33 ± 0.49	80.7 ± 5.5	NR
			81 children, age 10	7.40 ± 0.15	9.55 ± 0.14	77.9 ± 1.6	NR
			21 children, age 11	7.90 ± 0.29	10.15 ± 0.28	79.7 ± 3.2	NR
			9 children, age 12	7.10 ± 0.45	11.04 ± 0.43	67.2 ± 4.9	NR
Livingstone *et al*. (1992)	C	7-day weighed record, 10–14-day DLW	6 M, 6 F, age 12	9.36 ± 1.54	10.51 ± 1.10	88.7 ± 11.7	<0.01
			6 M, 6 F, age 15	9.08 ± 2.92	11.71 ± 2.77	78.1 ± 18.4	<0.01
			5 M, 5 F, age 18	9.28 ± 2.00	13.50 ± 4.11	72.7 ± 24.9	<0.01
Rennie *et al*. (2005)	T	7-day weighed record, cut-offs	2127 children, age 4–17	NR	NR	M: 80.0	NR
						F: 79.0	NR
Singh *et al*. (2009)	C	9-day estimated record, two 14-day DLW	20 overweight F, age 12–15	7.91 ± 2.94	11.86 ± 1.41	66.0 ± 22.0	<0.0001
			14 overweight M, age 12–14	8.76 ± 2.36	13.94 ± 1.31	63.0 ± 18.0	<0.0001
Fiorito *et al*. (2006)	C	Three 24hDR, cut-offs	172 W F, mean age 11.3	NR	NR	95.6	NR
Fisher *et al*. (2000)	C	Three 24hDR, 14-day DLW	76 M, 73 F (99 W, 50 AA), age 4–11	7.87 ± 1.97	7.13 ± 1.33	110.0 ± 31.0	<0.01
Garriguet (2008)	C	One 24hDR, cut-offs	M, age 12–13	NR	NR	100.9	NR
			F, age 12–13	NR	NR	99.2	NR
			M, age 14–18	NR	NR	97.7	NR
			F, age 14–18	NR	NR	94.9	NR
Huang *et al*. (2004)	C	Two 24hDR, cut-offs	2014 children, age 6–19	NR	NR	109.0 ± 34.0	NR
Perks *et al*. (2000)	C	1-year FFQ, 12-day DLW	23 M, 27 F, age 9–16	10.03 ± 3.12	9.84 ± 1.79	102.0	0.92

SD, standard deviation; 24hDR, 24-hour dietary recall; AA, African American; C, cross-sectional study; EE, energy expenditure; EI, self-reported energy intake; F, female; FFQ, food frequency questionnaire; L, longitudinal study; M, male; MJ, megajoule; NR, not reported; T, trend study; W, white. [†]Subjects may be included in more than one subsample if the authors reported results by different classifications. [‡]Test of difference between EI and EE.

used predicted energy requirements. Two studies included longitudinal analyses (one trend and one panel design).

Food records

Nine studies examined weighed or estimated food records kept for 7 to 14 days (Livingstone *et al*. 1992; Bandini *et al*. 1990, 1997, 2003; Champagne *et al*. 1996, 1998; Bratteby *et al*. 1998; Rennie *et al*. 2005; Singh *et al*. 2009). Eight of the nine used DLW for validation. Self-reported EI ranged from 54% to 89% of EE; this difference was consistently statistically significant among the five studies that conducted tests. The sole exception was a pilot study with 12 white fourth and fifth-grade students for whom EI was 87% of EE ($P = 0.06$) (Champagne *et al*. 1996).

Dietary recalls

In contrast to the consistent underreporting of EI observed with food records, the four studies that validated 24-h dietary recalls found either accurate or slightly overreported intakes (Fisher *et al*. 2000; Huang *et al*. 2004; Fiorito *et al*. 2006; Garriguet 2008). EI was 95% to 110% of its expected value. Fisher and colleagues (2000) was the only group to report statistical significance; participants significantly overreported EI (110% of EE; $P < 0.01$).

FFQs

Only one study validated a FFQ (Perks *et al*. 2000). Responses to the Youth-Adolescent Food Frequency Questionnaire were compared with a 12-day DLW assay among 50 children and adolescents. The questionnaire asked about dietary patterns over a 1-year period. Self-reported EI did not differ from EE (102%; $P = 0.92$).

Secular trends in EI misreporting

Rennie and colleagues (2005) looked for changes in mean EI misreporting by comparing two British national dietary surveys conducted in 1983 and 1997. Weighed food records were compared with predicted energy requirements for children ages 10 to 11 and adolescents ages 14 to 15 in the two surveys. Self-reported EI declined significantly in the 14 years between the surveys, even as body weight and body mass index (BMI) increased. This is the only known study examining secular trends in children's and adolescents' EI misreporting.

EI misreporting prevalence

Quantifying the magnitude of EI misreporting is one approach to understanding biases in dietary data. Another is to determine misreporting prevalence, or the proportion of subjects whose self-reported intakes are implausibly low or high. One possibility is that a small number of individuals are highly inaccurate and skew the mean. Conversely, the problem may be widespread. Recalls and FFQs appear to provide better estimates of EI than food records (Table 1), but the apparent accuracy of mean reported intake may be driven by numerous inaccurate reporters in both tails of the distribution, with overreporters offsetting the underreporters.

Sixteen studies with 29 subsamples described the distributions of underreporters, accurate reporters and overreporters (Table 2) (Livingstone *et al*. 1992; Sichert-Hellert *et al*. 1994, 1998; Frost Andersen *et al*. 1995; Johansson *et al*. 1998; Fisher *et al*. 2000; Perks *et al*. 2000; Lietz *et al*. 2002; Huang *et al*. 2004; Ventura *et al*. 2006; Babio *et al*. 2008; Lanctot *et al*. 2008; Savage *et al*. 2008; Vågstrand *et al*. 2009; Vance *et al*. 2009; Kontogianni *et al*. 2010). Thirteen used plausibility cut-offs to categorize subjects. Eight validated dietary recalls, and four each studied food records or FFQs. All of the studies were cross-sectional.

Misreporting prevalence varied considerably, with a range of 2–85% for underreporters and 3–46% for overreporters. Approximately half of all children and adolescents were classified as accurate or plausible. Few articles provided proportions in all three categories, making it difficult to draw stronger conclusions about prevalence patterns. However, it appears that large portions of children and adolescents are misreporters, and overreporting may occur more frequently among youth than adults (Maurer *et al*. 2006).

Table 2. Proportion of children and adolescents classified as underreporters, plausible reporters and overreporters

Reference	Design	Assessment	Subjects	% UR	% PR	% OVR
Lietz *et al*. (2002)	C	7-day weighed record, cut-offs	18 M, 32 F, mean age 12.3	26	NR	NR
Livingstone *et al*. (1992)	C	7-day weighed record, 10–14d DLW	34 adolescents, age 12–18	85	NR	NR
Sichert-Hellert *et al*. (1994)	C	3-day weighed record, cut-offs	720 children, age 10–18	12	NR	NR
Sichert-Hellert *et al*. (1998)	C	3-day weighed record, cut-offs	96 M, age 6–13	3	NR	NR
			73 M, age 14–18	12	NR	NR
			94 F, age 6–13	2	NR	NR
			161 F, age 14–18	20	NR	NR
Babio *et al*. (2008)	C	Three 24hDR, cut-offs	132 F at risk of eating disorders, mean age 14.5	41	56	3
			151 F, age–matched controls	7	87	6
Fisher *et al*. (2000)	C	Three 24hDR, 14d DLW	76 M, 73 F (99 W, 50 AA), age 4–11	20	34	46
Huang *et al*. (2004)	C	Two 24hDR, cut-offs	678 normal weight M, age 6–19	NR	47	NR
			338 overweight M, age 6–19	NR	40	NR
			715 normal weight F, age 6–19	NR	48	NR
			283 overweight F, age 619	NR	43	NR
Kontogianni *et al*. (2010)	C	One 24hDR, cut-offs	426 normal weight adolescents, age 13–18	30	NR	NR
			75 overweight adolescents, age 13–18	43	NR	NR
			16 obese adolescents, age 13–18	57	NR	NR
Lanctot *et al*. (2008)	C	Three 24hDR, cut-offs	284 AA F, age 8–10	55	NR	NR
Savage *et al*. (2008)	C	Three 24hDR, cut-offs	177 W F, age 9	16	58	25
Vance *et al*. (2009)	C	One 24hDR, cut-offs	1041 F, age 13–16	NR	19	NR
			876 M, age 13–16	NR	32	NR
Ventura *et al*. (2006)	C	Three 24hDR, cut-offs	176 W F, mean age 11.3	34	50	16
Frost Andersen *et al*. (1995)	C	FFQ, cut-offs	710 M, median age 18	9	NR	NR
			854 F, median age 18	20	NR	NR
Johansson *et al*. (1998)	C	FFQ, cut-offs	89 M, age 16–19	16	62	23
			96 F, age 16–19	33	58	9
Perks *et al*. (2000)	C	1-year FFQ, 12-day DLW	23 M, 27 F, age 9–16	NR	50	NR
Vågstrand *et al*. (2009)	C	3-month FFQ, cut-offs	253 F, age 16–18	16	67	17
			188 M, age 16–18	13	68	19

24hDR, 24-hour dietary recall; AA, African American; C, cross-sectional study; F, female; FFQ, food frequency questionnaire; M, male; NR, not reported; OVR, overreporter; PR, plausible reporter; UR, underreporter; W, white.

Factors associated with EI misreporting

The validation studies explored associations between misreporting and numerous individual characteristics. These factors can be broadly described in five categories: anthropometric, socio-demographic, psychosocial, behavioural and parental characteristics. Each category is discussed separately.

Anthropometric characteristics

Several anthropometric measures were discussed in the literature. Higher weight, adiposity and BMI were consistently and significantly associated with underreported EI (Table 3). Although Bandini and associates (1997, 2003) failed to find a relationship between either adiposity or weight and misreporting, the negative findings were likely due to enrolment of only normal-weight children. Godina-Zarfl & Elmadfa (1994) found an association between underreporting and weight, but not BMI, after controlling for gender. Lanctot *et al*. (2008) also found that underreporters were significantly taller than plausible reporters, but the association was likely an artefact of underreporters being significantly older.

Socio-demographic characteristics

Seventeen studies examined gender, age, race/ethnicity, health status, household income or house-

Table 3. Anthropometric characteristics explored in relation to children's and adolescents' misreporting

Reference	Characteristic						
	BMI	BMI z-score	BMI percentile	Adiposity	Fat mass	Weight	Height
Babio *et al.* (2008)	S						
Bandini *et al.* (1990)	S			S		S	
Bandini *et al.* (1997)				N		N	
Bandini *et al.* (2003)				N			
Champagne *et al.* (1996)				S			
Champagne *et al.* (1998)	T			S			
Fisher *et al.* (2000)				S		S	
Fiorito *et al.* (2006)	S						
Garriguet (2008)	S						
Godina-Zarfl & Elmadfa (1994)	N					S	
Huang *et al.* (2004)	S						
Johnson-Down *et al.* (1997)			S				
Lanctot *et al.* (2008)	S					S	S
Livingstone *et al.* (1992)	S						
Savage *et al.* (2008)	S	S	S				
Sichert-Hellert *et al.* (1998)	S						
Singh *et al.* (2009)	S						
Vågstrand *et al.* (2009)	S			S			
Vance *et al.* (2009)	S						
Ventura *et al.* (2006)	S	S			S		

BMI, body mass index; N, not significant ($P \geq 0.10$); S, significant ($P < 0.05$); T, trend ($0.05 < P < 0.10$).

hold size (Table 4). Of the 12 studies assessing gender, only two found significant differences, with females more likely to underreport. However, four studies found gender-moderating effects, with heavier or older females more likely to underreport (Livingstone *et al.* 1992; Godina-Zarfl & Elmadfa 1994; Sichert-Hellert *et al.* 1994; Huang *et al.* 2004).

In contrast to gender, an inverse association between age and accurate reporting was generally consistent. The strongest line of evidence for age came from a longitudinal study in which girls' reported EI dropped significantly from 82% of EE at age 10 to 66% by age 15 (Bandini *et al.* 2003). Population-based studies also documented significant age differences. Huang *et al.* (2004) found that overreporting was more likely to occur among younger children who received more parental assistance, whereas adolescents, who reported independently, were more likely to underreport. Rennie and others (2005) found a maximum EI underestimate among adolescents ages 15 to 18.

Three of the four studies examining race/ethnicity found a significant association with misreporting. In both a pilot and large-scale study, African Americans were less accurate than their white peers, although the difference between groups was smaller in the full-scale study (Champagne *et al.* 1996, 1998). 'Other race/ethnicity' was associated with misreporting in a separate study, although the result is difficult to interpret as the group included eight children representing six different ethnic groups (Bandini *et al.* 1997). In contrast, Fisher *et al.* (2000) found no differences in proportions of underreporters, accurate reporters or overreporters between children of European American and African American ancestry.

Four studies assessed family income, with conflicting results. One found different results for male and female adolescents (Garriguet 2008). Among females ages 12 to 17, those in the average/high-income category were more accurate than those in the highest-income category. However, the absolute differences were quite small. There were no differences across income categories for males. Vågstrand *et al.* (2009) found that males in families with the highest incomes were 80% less likely to overreport EI than those in medium-income families. No income-associated differences were found among female adolescents.

Table 4. Sociodemographic characteristics explored in relation to children's and adolescents' misreporting

Reference	Characteristic					
	Gender	Age	Race/ethnicity	Income	Household size	Health status
Bandini *et al*. (1990)	N					
Bandini *et al*. (1997)		S	S	N		
Bandini *et al*. (2003)		S				
Bratteby *et al*. (1998)	N					
Champagne *et al*. (1996)			S			
Champagne *et al*. (1998)	N	T	S			
Fisher *et al*. (2000)	N	N	N			
Garriguet (2008)	N			S		S
Godina-Zarfl & Elmadfa (1994)	S	S				
Huang *et al*. (2004)		S				
Johnson-Down *et al*. (1997)	N	N				
Lanctot *et al*. (2008)		S		N	N	
Perks *et al*. (2000)	N	N				
Rennie *et al*. (2005)	N	S				N
Sichert-Hellert *et al*. (1998)	N	S				N
Vågstrand *et al*. (2009)	N			S	S	
Vance *et al*. (2009)	S					

N, not significant ($P \geq 0.10$); S, significant ($P < 0.05$); T, trend ($0.05 < P < 0.10$).

Neither Bandini *et al*. (1997) nor Lanctot *et al*. (2008) found any significant income-related differences in reporting. It is unclear how income was measured in any of the studies, making it difficult to evaluate any potential relationship between household income and misreporting.

Associations between household size and misreporting are also unclear. One study did not find a significant difference between African American underreporters and plausible reporters (Lanctot *et al*. 2008). Elsewhere, adolescents from one-child families were 3.5 to 8.8 times more likely to be underreporters compared with those with siblings (Vågstrand *et al*. 2009). The authors did not hypothesize why household size may predict misreporting.

Finally, three studies included various measures of health status. Two found that controlling for feeling unwell did not alter the extent of underreporting (Sichert-Hellert *et al*. 1998; Rennie *et al*. 2005). Garriguet (2008) assessed two other health measures for adolescents. Males who said their current health status was poor underreported EI more than those who rated their health as excellent. Health status was not significant for females, nor was having a chronic health condition for either sex.

Psychosocial characteristics

Compared with anthropometric or sociodemographic factors, few measures of psychosocial, behavioural or parental characteristics were examined in more than one study (Table 5). Ventura *et al*. (2006) explored several such measures, particularly psychosocial characteristics. Girls who underreported had significantly higher scores for weight concern and diet restraint, defined as cognitive control over eating. There were no significant differences in social desirability or eating disinhibition (the loss of control over eating). Overreporters were not distinguishable from plausible reporters on any of the measures. These findings mirrored similar observations for diet restraint (Babio *et al*. 2008) and social desirability (Lanctot *et al*. 2008). Lanctot *et al*. (2008) found significant differences between underreporters and plausible reporters in self-efficacy for healthy eating and body image. Underreporters had greater self-efficacy for healthy eating, and a greater discrepancy between self-rated current appearance and ideal appearance.

The lack of findings for social desirability is notable because it differs from what has been found for adults,

Table 5. Psychosocial, behavioural and parental characteristics explored in relation to children's and adolescents' misreporting

Characteristic	Reference								
	Babio *et al.* (2008)	Bandini *et al.* (1997)	Garriguet (2008)	Lanctot *et al.* (2008)	Rennie *et al.* (2005)	Savage *et al.* (2008)	Sichert-Hellert *et al.* (1998)	Vågstrand *et al.* (2009)	Ventura *et al.* (2006)
Psychosocial characteristics									
Weight concern									S
Diet restraint	S								S
Social desirability				N					N
Eating disinhibition									N
SE for healthy eating				S					
Body image				S					
Behavioural characteristics									
>5% weight loss/mo	S								
Unhealthy eating behaviours				S					
Currently dieting					N				
Subject recorded							N		
Normal eating on record days							N		
Weekday recording only							S		
Study influenced intake							S		
No unusual recording days							S		
Ate less than usual							S		
Reported EI/meal							S		
Meals/day							S		
Time between first and last meal							S		
Physical activity			S						
# fruit and vegetable servings			S						
Previous year alcohol consumption			S						
Smoking			S					N	
Parental characteristics									
Maternal feeding practices									N
Maternal EI underreporter								S	
Obesity		N		S		N			
Education			S	N				N	
Age				N					
Marital status								N	
Height				N					
Weight				S					
Maternal smoking								N	
Maternal occupation								N	
Maternal hours worked/wk								S	

N, not significant ($P \geq 0.10$); S, significant ($P < 0.05$); SE, self-efficacy.

among whom underreporting is associated with higher social desirability (Maurer *et al*. 2006). Differences between children and adults may be interpreted two ways. One explanation is that different measures of social desirability produced different results. Most misreporting studies with adults used the Marlowe-Crown Social Desirability Scale, whereas studies of children have used the nine-item 'Lie Scale' from the Revised Children's Manifest Anxiety Scale (Ventura *et al*. 2006; Lanctot *et al*. 2008). The other is that the two studies of children included young respondents, ages 9 and 11. Social desirability concerns come to the fore during adolescence (Borgers *et al*. 2000). Thus, while social desirability may be related to misreporting for older children and adolescents, the 9- or 11-year-olds that have been studied to date are too young.

Behavioural characteristics

Many behavioural characteristics were explored, often with single studies incorporating multiple measures (Table 5). In one, adolescent female underreporters were 2.5 times as likely to have reported a weight loss of more than 5% in a month as plausible reporters (Babio *et al*. 2008). Lanctot and others (2008) found that underreporters had less healthy eating behaviours. Rennie *et al*. (2005) concluded that current dieting did not alter the extent of underreporting. Sichert-Hellert's group (1998) found there was no difference in the proportion of underreporters, compared with plausible reporters, who kept their own food records or described their eating behaviour on recording days as normal. Three additional factors were significant for males but not for females: recorded only on weekdays, claiming the study influenced one's dietary intake and having no unusual recording days. A higher percentage of underreporters reported the former two behaviours, whereas a higher percentage of plausible reporters said that they had no unusual recording days (e.g. attending a party).

In one study, adolescent males and females who reported higher levels of leisure-time physical activity or eating fewer than five daily servings of fruits and vegetables underreported EI significantly more (Garriguet 2008). Males who drank alcohol in the previous year underreported EI slightly more than non-drinkers, and smokers had higher self-reported EI; no significant differences were found for females for either behaviour. Vågstrand *et al*. (2009) likewise did not find differences in the proportions of underreporters, plausible reporters and overreporters among current, former and non-smokers.

Parental characteristics

Eleven parental characteristics were examined in the literature (Table 5). Adolescent females whose mothers were classified as underreporters were 3.4 times as likely to be underreporters themselves; no differences were found for males, or for the likelihood of overreporting in either gender (Vågstrand *et al*. 2009). Two of three studies did not find an association between parental obesity and child misreporting (Bandini *et al*. 1997; Savage *et al*. 2008). However, Lanctot *et al*. (2008) found that underreporting African American girls had parents with higher BMIs and weight compared with plausible reporters. Garriguet (2008) observed that males (but not females) underreported EI significantly more if the highest level of household education was less than a postsecondary degree, although two other studies failed to find an association with parental education (Lanctot *et al*. 2008; Vågstrand *et al*. 2009). Mothers' self-reported feeding practices (Ventura *et al*. 2006), marital status, smoking status, occupation (Vågstrand *et al*. 2009), and parental age and height (Lanctot *et al*. 2008) were not significant. Vågstrand *et al*. (2009) found that adolescent males whose mothers worked 30 to 40 h per week were 90% less likely to underreport than those whose mothers worked 40 h per week. Patterns were reversed for females, with more plausible reporting among those whose mothers worked more hours weekly.

Discussion

Summary of findings

Like adults, children and adolescents tend to underreport EI. Although the studies reflect considerable methodological variability, underreporting of approximately one-fifth of energy requirements is not uncommon, particularly with food records (Table 1). The four studies that validated dietary recalls and the single study validating an FFQ documented mean self-reported EIs up to 10% higher than estimated EEs. These findings suggest that retrospective methods may be preferable to use with younger respondents, which is contrary to the common acceptance of food records as the gold standard for dietary assessment methods.

About half of children and adolescents are plausible reporters (Table 2). As with adults, misreporting prevalence varied considerably, ranging from 2% to 85% classified as underreporters and from 3% to 46% classified as overreporters. The four reports that described both the magnitude and prevalence of EI misreporting (Tables 1,2) suggest that even when mean reported EI is close to 100% of its expected value, large proportions of participants misreported. The higher proportions of accurate reporters in some studies may reflect parental assistance. Differences in the equations used for predicting energy requirements or defining cut-off values may also account for variability in the findings.

Children and adolescents may be more likely to overreport than adults. For example, a large-scale Norwegian study found that only 5% to 7% of adults overreported EI on an FFQ (Johansson *et al*. 1998), compared with 46% of children overreporting on an FFQ (Table 2). More severe bias was revealed in DLW studies, with only 34% of participants in one study and no more than 15% in another reporting accurately. This observation likely reflects DLW's more direct measure of EE, offering greater precision for classification than plausibility cut-offs. Overreported EI may result from children reporting food items they did not actually consume, rather than errors in portion size estimation. In several studies using observation to validate fourth graders' school meal recalls, Baxter and colleagues (2004) have described high rates of intrusions, or items children reported but were not observed eating. In one such study, 54% of foods the children reported eating during the previous day's school breakfast or lunch were intrusions (Baxter *et al*. 2004). However, omissions were also found to be quite high (67%). The extent to which high intrusion rates contribute to energy overreporting is unclear, as foods were not converted to nutrients in these studies. In general, EI underreporting is a more pervasive problem, and it therefore gets more attention; yet, the nature and extent of overreporting among younger respondents clearly merits further exploration.

Numerous individual characteristics were explored in relation to children's and adolescents' misreporting, especially underreporting. Findings generally paralleled those for adults and were especially consistent across several anthropometric measures. Notably, youth differed from adults in the relationships between gender or race/ethnicity and misreporting. Adult females are more likely to underreport than adult males, but gender seemed primarily to serve as a moderator of other relationships rather than a direct contributor among children and adolescents. Two of the three studies that assessed race/ethnicity found white children were more accurate than their African American peers, which is the reverse from what has been documented among young adults who are only slightly older: 18- to 21-year-old African American females underreported EI to a lesser degree than white females ($P = 0.07$) (Kimm *et al*. 2006). Although a large number of psychosocial, behavioural and parental characteristics have been explored in the literature, few of these factors were tested in more than one study, making it difficult to draw any conclusions about the importance of these factors as predictors of EI misreporting.

Differences among children, adolescents and adults should not be surprising. Youths are still developing both cognitively and socially, which can impact any of the tasks in the cognitive response process model: comprehension, retrieval, judgement and response (Tourangeau *et al*. 2000). Depending on the particular method, dietary assessment may require word comprehension, literacy, memory, a concept of time, portion size estimation, abstract reasoning, knowledge of food items and preparation or motivation to record one's diet faithfully. Children younger than 10 typically lack the cognitive skills to complete dietary assessments independently (McPherson *et al*. 2000). The social aspects of dietary assessment become increasingly salient to adolescents, who are more sensitive to context and social norms (Borgers *et al*. 2000). Developmental differences may account for the various discrepancies in aspects of EI misreporting. These differences underscore the need for a conceptual framework to guide future dietary validation studies in younger age groups.

Methodological issues in the literature

Study quality

The quality of the reviewed studies varied considerably. In a few cases, the level of methodological detail was inadequate. More often, studies were limited either in the ability to establish causal relationships between individual characteristics and patterns of misreporting, or the degree to which findings were generalizable.

All but two studies were cross-sectional. While magnitude and prevalence of EI misreporting can be quantified with a single time point, cross-sectional designs cannot be used to measure secular trends and are inappropriate for establishing causality. Only one study quantified trends in EI misreporting (Rennie *et al*. 2005), and another followed the same subjects for several years (Bandini *et al*. 2003). Despite the additional challenges of longitudinal research, future studies must employ such designs in order to better understand the EI misreporting phenomenon among children and adolescents.

Generalizability was limited by the large number of studies that did not use random samples. Ten of the 28 reports included in this review used DLW as the validation standard. DLW studies tend to be small and confined to a single geographic area. Most of these studies relied on convenience samples of volunteers, who may have been motivated to provide higher quality data than could be expected in large-scale, population-based studies. The extent to which findings from DLW studies are generalizable to the entire child and adolescent population is unclear. The application of predicted energy requirements and plausibility cut-offs, proposed by Goldberg *et al*. (1991) and McCrory *et al*. (2002), has allowed researchers to explore EI misreporting in epidemiologic surveys, so findings from national data in the USA (Huang *et al*. 2004), Canada (Garriguet 2008) and the UK (Rennie *et al*. 2005) provide a clearer picture of children's and adolescents' EI misreporting.

Validation standards

An additional consideration with DLW is that the assays are conducted for up to 2 weeks, so they are most frequently used to validate food records, which can be kept over the same time period. DLW studies are less common with other assessment methods because the reference periods do not match. However, dietary recalls are used in some of the largest dietary surveys conducted in the USA, including NHANES. Because DLW studies can provide some of the most accurate information on EI misreporting, more studies of different assessment strategies are needed. To attain greater correspondence in the reference periods, researchers could duplicate the approach used in two studies by administering repeat 24-h recalls over the course of the DLW assay (Fisher *et al*. 2000; Fiorito *et al*. 2006). Alternatively, repeated DLW assays could be conducted with the same subjects over 12 months followed by the administration of an FFQ at the end of the year to cover the same time span (e.g. Paul *et al*. 2005).

Again, plausibility cut-offs present an alternative to address mismatches between reference periods. Eighteen studies in this review used plausibility cut-offs. Although cut-offs are not as sensitive to detecting bias as the DLW assay, they represent the best alternative for large-scale use and for evaluating data that have already been collected.

Limitations

This literature review has several limitations. All reviews are subject to potential publication bias. Misreporting may be underestimated if studies that concluded dietary assessment methods were invalid went unpublished. Second, the review was performed by a single author, so the findings may be biased through errors in identifying the literature and coding the results. Finally, as this review represents the first effort to describe children's and adolescents' misreporting, study quality criteria were not applied in order to include as many reports as possible.

Box 1. Research questions for future energy intake (EI) validation studies of children and adolescents

- What are the reporting patterns of other racial/ethnic groups such as Hispanics, Native Americans and Asian Americans?
- What characteristics are associated with EI overreporting? Are they distinct from those that predict underreporting?
- Are nutrition salience and frequency of school meal consumption related to reporting accuracy?
- Does EI misreporting differ systematically with assessment method?
- What valid measures of physical activity are feasible to incorporate into dietary studies?
- Can tailoring dietary assessment methods to the cognitive and social development of children and adolescents improve their accuracy?

Recommendations for dietary practice and research

Practice recommendations

Given the variability of EI misreporting from study to study, every dietary assessment project should attempt to quantify the bias. A few relatively small additions to study procedures would make it feasible. When preparing to conduct a dietary survey, whether on a local or a national scale, study planners should include measures of height, weight and age so that McCrory *et al.*'s (2002) plausibility cut-offs can be computed and applied. Preferably, valid measures of physical activity should also be incorporated so that physical activity levels can be assigned individually for more precision (Black 2000).

Research recommendations

Although reviewed studies explored numerous factors in relation to EI misreporting (Tables 3–5), the field has progressed without the development of a guiding conceptual framework. Future research should further explore and refine the relationships among both established and less well characterized concepts in order to develop a predictive theory of EI misreporting. Such research should employ more longitudinal rather than cross-sectional designs.

In addition to the need for a guiding conceptual framework, many questions of particular interest to dietary assessment of children and adolescents remain (Box 1). Some of these questions have been touched on previously, so only three specific issues are discussed here.

First, race/ethnicity was explored in just four studies, with mixed results (Table 4). Childhood obesity disproportionately affects minority populations. Mexican American males and African American females are 1.7 to 1.8 times as likely to be at or above the 85th percentile for age- and sex-specific BMI as white children ages 2 to 19 (Ogden *et al.* 2010). Because dietary intake data are central to understanding and addressing the causes of the epidemic, it is essential to study the misreporting patterns of minority children and adolescents.

Second, validation studies should include a more thorough examination of overreporters' characteristics. Although overreporting is less common than underreporting, different characteristics may be associated with the phenomenon. Overreporting is infrequent among adults, and overreporters tend to be younger, leaner, have lower BMIs and are more likely to want to increase their weight compared with accurate reporters (Johansson *et al.* 1998). Because overreporting was more prevalent across studies of children and adolescents compared with findings with adults, it is especially important to examine it more thoroughly in studies of young people.

Finally, other factors that have not previously been explored in DLW or plausibility cut-off validation studies with children and adolescents merit further attention. Tooze *et al.* (2004) hypothesized that individuals who were more attentive to their caloric intake would be able to report more accurately. However, the authors' four-item nutrition salience measure failed to reveal any significant differences between accurate reporters and underreporters in a sample of 484 middle-aged adults. It is possible that improved measures of nutrition salience may yield different findings, and that the factor may play a significant role in predicting children's and adolescents' misreporting.

Domel (1997) described interviewing fourth-grade children to elicit how they remember what they have eaten during school lunch. The most common strategies to aid recall included regular or habitual eating patterns and remembering reading the school lunch menu. It is possible that children and adolescents who eat school meals more frequently may have an easier time recalling their intake, which could improve accuracy. None of the studies reviewed explored this possibility.

This literature review affirms that no self-report dietary assessment method is ideal. The strategy of validating one self-report method against another should no longer be used, particularly when low-cost, easily implemented alternatives like plausibility cut-offs are available. As future EI validation studies are conducted, a conceptual framework describing misreporting should be articulated and tested. Addressing previously unexplored issues may help to expand or refine the framework. In the process, many of the gaps in our understanding of the nature and extent of children's and adolescents' EI misreporting will be addressed, which in turn will ultimately help to improve the data used as the foundation to address pressing child nutrition issues.

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