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Tracking of childhood overweight into adulthood: a systematic review of the literature

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Summary

Overweight and obesity in youth are important public health concerns and are of particular interest because of possible long-term associations with adult weight status and morbidity. The aim of this study was to systematically review the literature and update evidence concerning persistence of childhood overweight. A computerized bibliographical search – restricted to studies with a prospective or retrospective longitudinal design – was conducted. Two authors independently extracted data and assessed the methodological quality of the included studies in four dimensions (i) study population and participation rate; (ii) study attrition; (iii) data collection and (iv) data analysis. Conclusions were based on a rating system of three levels of evidence. A total of 25 publications were selected for inclusion in this review. According to a methodological quality assessment, 13 studies were considered to be of high quality. The majority of these high-quality studies were published after 2001, indicating that recently published data, in particular, provide us with reliable information. All included studies consistently report an increased risk of overweight and obese youth becoming overweight adults, suggesting that the likelihood of persistence of overweight into adulthood is moderate for overweight and obese youth. However, predictive values varied considerably. Limiting aspects with respect to generalizability and methodological issues are discussed.

Keywords: Adulthood, childhood, overweight, systematic review, tracking.

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Introduction

Child and adolescent obesity is associated with major health risks, both in the short (1) and the long term (2–4). Not only the alarming prevalence rates of overweight among youth, but also the difficulties in treatment of adult obesity (5) have led to its consideration as a public health priority requiring successful preventive strategies. The epidemic proportions of overweight among adults support the idea of population-based preventive approaches. Existing literature suggests that overweight youth are at increased risk of remaining overweight (1,6). Although the magnitude of overweight persistence from childhood and adolescence into adulthood is indistinct, targeting preventive efforts at overweight youth seems a sensible alternative.

There is growing interest in studying the persistence of risk factors and health conditions over the lifespan (7), as evidence is growing for long-term associations with adult disease. In the epidemiological literature, the concept of persistence or relative stability of overweight over time is often referred to as 'tracking' (8). In general, the two concepts are used to describe tracking (i) the relationship (correlation) between early measurements and measurements later in life, or the maintenance of a relative position within a distribution of values in the observed population over time and (ii) the predictability of future values by early measurements (7,9).

Now that an increasing number of studies report results on this subject, it is important to provide a detailed overview of the evidence all studies have provided so far.

Therefore, we conducted a systematic review concerning persistence of childhood and adolescent overweight taking into account the methodological quality of the included studies.

Methods

Definition children/childhood, adolescents/adolescence

In the following, children are referred to as subjects being age ≤ 12 years (childhood); adolescents as subjects being ≥13 age ≤18 years (adolescence). Youth covers both children and adolescents.

Identification and selection of the literature

The best evidence for persistence of childhood and adolescent overweight into adulthood is provided by longitudinal studies. Relevant literature reporting results of this kind of studies was identified by means of a computerized search of multiple electronic bibliographic databases (MEDLINE, EMBASE and CINAHL) from the year of their inception up to February 2007. Using the terms appropriate to each database, the search strategy consisted of four elements (i) research design of the studies (e.g. 'longitudinal studies', 'tracking', 'follow-up studies'); (ii) measurement during childhood/adolescence (e.g. 'childhood', 'infant', 'adolescent', 'adolescence'); (iii) follow-up measurement during adulthood (e.g. 'adulthood', 'adult') and (iv) body composition (e.g. 'overweight', 'obesity', 'adiposity', 'BMI', 'skin fold thickness'). These terms were used as MESH-headings and as free text words. If possible, the search was restricted by excluding 'cross-sectional studies', 'randomized controlled trials' and 'intervention studies'.

Two reviewers (AS, CM) independently screened the eligibility of the articles first on the title and the abstract, and if necessary on the full text. In cases where the reviewers' opinions were initially different, consensus was reached. Additionally, the reference lists of all selected articles and published reviews on this topic (1,4,6,10,11) were screened for potentially relevant publications.

Inclusion and exclusion criteria

Studies had to meet the following inclusion criteria:

- the study had a prospective or retrospective longitudinal design;
- the study described at least one anthropometric measurement during youth (≤18 years) and one anthropometric measurement during adulthood (≥19 years), using body mass index (BMI), skin fold thickness or waist circumference to define body weight status;
- information was provided concerning risk estimate [odds ratio (OR) or relative risk (RR)] of overweight youth to become overweight adults or proportions of overweight youth that become overweight adults comparing overweight youth with non-overweight youth;
- study results had to be written in English.

Studies were excluded if:

- the subjects were participants in an obesity-related intervention or health promotion/education programme;
- the subjects belonged to a selected group (e.g. children born preterm), as this limits the generalizability of the results.

Two reviewers (CM, AS) independently extracted data of the selected studies on sample size, age at measurement during childhood/adolescence and adulthood, definition of overweight/obesity used and main findings. When possible, measures of association as main finding(s) were abstracted. If necessary and if data were available, RRs from the data presented in the articles were calculated.

Methodological quality assessment and data abstraction

The methodological quality of the selected studies was scored independently by two reviewers (AS, CM) on the basis of a criteria list adapted from quality criteria lists for observational longitudinal studies (12) and for prognosis studies in systematic reviews (13). AS, CM and MC selected and adapted 15 relevant criteria from the two lists (Table 1), assessing the methodological quality in four dimensions (i) study population and participation rate; (ii) study attrition; (iii) data collection and (iv) data analysis. The reviewers rated each criterion as '+' (positive), '–' (negative) or '?' (not or insufficiently described) on the basis of information provided in the article. Disagreement between the reviewers was discussed until a consensus was reached. A quality score (the percentage of all positive ratings) was assigned to each study, resulting in a possible score of 0–100%. A study was considered to be of high quality if the methodological score was >50%.

Level of scientific evidence

To synthesize the quality scores, a rating system that takes into account the number, the quality and the outcome of the studies was applied. The conclusions were drawn based on three levels of scientific evidence:

- strong evidence: provided by generally consistent findings in multiple (>2) high-quality studies;
- moderate evidence: provided by generally consistent findings in one high-quality study and one or more low-quality studies, or in multiple low-quality studies;

Table 1 Criteria List for Assessment of the Methodologic Quality of Prospective and Historical Cohort Studies [based on Tooth *et al.* (12) and Hayden *et al.* (13)]

Criteria (rating of criteria: + = yes, – = no, ? = not or insufficiently described)	I, V/P
Study population and participation (baseline): the study sample represents the population of interest on key characteristics	
1. Adequate description of source population	I
2. Adequate description of sampling frame, recruitment methods, period of recruitment and place of recruitment (setting and geographical location)	I
3. Participation rate at baseline at least 80%, or if the non-response was not selective (show that baseline study sample does not significantly differ from population of eligible subjects)	I
4. Adequate description of baseline study sample (i.e. individuals entering the study) for key characteristics (number of participants, age, gender, body composition)	I
Study attrition: loss to follow-up is not associated with key characteristics (i.e. the study data adequately represent the sample)	
5. Provision of the exact number of participants at each follow-up measurement	I
6. Provision of exact information on follow-up duration	I
7. Presentation of data proving not selective non-response during follow-up measurement(s)	V/P
Data collection	
8. Adequate description of methods of data collection (i.e. tools and processes)	I
9. Adequate measurement of body composition: all measurements of body composition done by trained personnel (no self-reported data) by means of standardized protocol(s) (self-report = –, no/insufficient information = ?)	V/P
10. Clear description of cut-off points to define overweight/obesity in the study population (studies received after 2001 must report the use of Cole *et al.* cut-off points or other population-based cut-off points)	V/P
Data analyses	
11. Adequate description of analysed sample (in- and exclusion criteria)	I
12. The analysed sample consists of ≥500 participants	I
13. Age- and gender-specific presentation of anthropometric data at baseline and follow-up	V/P
14. Presentation of the measures of association including confidence intervals	I
15. No selective reporting of results	V/P

I, criterion on informativeness; V/P, criterion on validity/precision.

• insufficient evidence: only one study available or inconsistent findings in multiple (>2) studies.

Results

Identification and selection of the literature

The literature search in the various databases yielded 330 potentially relevant publications. After the titles and abstract of theses publications were screened, 37 references were identified as potentially relevant and retrieved in full text. Reference checking revealed another 16 potentially relevant publications, of which nine were retrieved in full text. Twenty-one publications identified from the search were excluded from our review, because (i) only a correlation coefficient between weight in childhood and weight in adulthood was presented ($n = 13$); (ii) the subjects had participated in an intervention ($n = 4$); (iii) the OR for children to become overweight adults was based on parental weight status instead of children's weight status ($n = 1$); (iv) the OR for children to become overweight was based on maturational timing ($n = 1$); (v) proportions of adults who were overweight as children were presented instead of proportions of children that became overweight adults ($n = 1$) and (vi) insufficient information was provided on sample selection ($n = 1$).

Finally, a total of 18 studies, described in 25 articles, that provided information on the longitudinal development of childhood overweight were selected for inclusion in this review (14–38). Table 2 gives a detailed description of the sample sizes, age at baseline and follow-up measurement(s), cut-off points used to define overweight/obesity and the main findings of the studies included in this review. Most of the included studies ($n = 16$) were published after 2000 (15–22,25–30,37,38), seven studies were published between 1990 and 2000 (14,24,31,33–36) and two studies were published before 1990 (23,32).

Methodological quality assessment

The methodological quality of the included studies is presented in Table 3. The scoring of the 25 publications led to an overall initial disagreement between the reviewers of 30% (114/375). Most disagreements were on the item 'participation rate at baseline' (criterion 3) and resulted from incomplete description or interpreting errors. The two reviewers reached consensus on all initial disagreements. The quality score of the publications ranged from 13% to 73%. Thirteen (52%) out of 25 publications had a score of more than 50% (15,16,20–22,28–31,33,34,36,37) and were thus considered to be of high methodological quality.

Table 2 Description of the studies reporting results on the tracking of childhood overweight into adulthood structured by methodological quality (highest quality first)

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Persistence of overweight/obesity (according to BMI)				
Power *et al.* 1997 (31)	Prospective longitudinal $n = 11\,212$ Born in 1958	(1) 7, 11, and 16 years (2) 23 years (self-reported), 33 years FUD: no information provided	(1) Obesity: BMI ≥ 98th percentile (52) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2}	Children obese at 7 years (males/females): 20%/21% = normal weight, 37%/18% = overweight, 43%/60% = obese at age 33. Children obese at 11 years (males/females): 12%/9% = normal weight, 34%/34% = overweight, 54%/57% = obese at age 33. Adolescents obese at 16 years (males/females): 4%/4% = normal weight, 32%/24% = overweight, 64%/72% = obese at age 33.
Valdez *et al.* 1996 (34)	Prospective longitudinal $n = 835$†	(1) 10–15 years (2) 19–32 years FUD: 15 years	(1) Overweight: no information provided (2) Overweight: BMI ≥ 27 kg m^{-2}	OR (95% CI) (age and race adjusted) for one unit difference in BMI (males/females) in adulthood: 1.7 (1.5; 1.8)/1.6 (1.4; 1.7)
Laitinen *et al.* 2001 (28)	Prospective longitudinal $n = 6280$ Born 1965–1967	(1) Birth, 1 years, and 14 years (2) 31 years FUD: 31 years	(1) Overweight/obesity (self-report): BMI ≥ 85th percentile/BMI ≥ 95th percentile (36) (2) Overweight/obesity (30% self-report): BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2} (41)	• Normal weight youth (males/females): 38%/18% became overweight and 4%/4% became obese in adulthood • Overweight youth (males/females): 56%/42% became overweight and 25%/22% became obese in adulthood • Obese youth (males/females): 41%/27% became overweight and 47%/55% became obese in adulthood
Williams 2001 (37)	Prospective longitudinal $n = 1037$ Born 1972–1973	(1) 3, 5, 7, 9, 11, 13, 15 and 18 years (2) 21 years FUD: 3–18 years	(1) Overweight/obesity: BMI ≥ 85th percentile, BMI ≥ 95th percentile (41) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2} (41)	RR (95% CI) for being overweight in adulthood (youth with BMI > 75th percentile vs. youth with BMI < 50th percentile) (males/females): 7 years: 4.0 (3.0; 4.9)/3.2 (2.3; 4.0) 11 years: 4.1 (3.2; 4.9)/4.7 (3.4; 5.9) 15 years: 9.8 (7.7; 11.4)/6.8 (5.1; 8.3)
Deshmukh-Taskar *et al.* 2005 (15)	Prospective longitudinal $n = 841$†	(1) 9–11 years (2) 19–35 years FUD: no information provided	(1) Overweight: BMI ≥ 85th percentile (40) (2) Overweight (incl. obesity): BMI ≥ 25 kg m^{-2} (40)	RR‡ for being overweight in adulthood (overweight children vs. normal weight children) = 1.9

Table 2 *Continued*

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Freedman *et al*. 2005 (21)	Prospective longitudinal $n = 2392^{\dagger}$	(1) 5–14 years (2) ≥18 years FUD: 17 years (age 5–8 years) 14 years (age 9–11 years) 13 years (age 12–14 years)	(1) Overweight/obesity: BMI 85th–94th percentile/ BMI ≥ 95th percentile (53) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2} (53)	OR[§] for being overweight in adulthood (youth with BMI < 85th percentile vs. youth with BMI between 85th and 94th percentile): 7.0 (4.5–10.9) OR[§] for being obese in adulthood (youth with BMI < 85th percentile vs. youth with BMI ≥ 95th percentile): 19.9 (13.6–29.9)
Freedman *et al*. 2001 (20)	Prospective longitudinal $n = 2617^{\dagger}$	(1) 2–17 years (2) 18–37 years FUD: mean 17 years	(1) Overweight: BMI ≥ 95th percentile (53) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2} (53)	RR[‡] for being overweight in adulthood (overweight vs. normal weight youth) = 3.2 RR[‡] for being obese in adulthood (overweight vs. normal weight youth) = 10.1
Engeland *et al*. 2004 (16)	Retrospective longitudinal $n = 128\,121$ Born 1943–1959	(1) 14–19 years (2) 24–54 years FUD: mean 23 years	(1) Overweight: BMI ≥ 85th percentile (40) (2) Obesity: BMI ≥ 30 kg m^{-2} (40)	OR (95% CI) for being obese in adulthood • Adolescents with BMI between 75th–84th percentile vs. adolescents with BMI between 25th–74th percentile: Males: 5.1 (4.7; 5.5) Females 4.0 (3.7; 4.3) • Adolescents with BMI ≥ 85th percentile vs. adolescents with BMI between 25th–74th percentile: Males: 15 (14; 17) Females: 12 (11; 13)
Freedman *et al*. 2005 (22)	Prospective longitudinal $n = 2610^{\dagger}$	(1) 2.5–17 years (2) 18–37 years FUD: mean 18 years	(1) Overweight: BMI ≥ 95th percentile (53) (2) Obesity: BMI ≥ 30 kg m^{-2}	Proportion of overweight youth that became obese in adulthood: 2–5 years (males and females combined): 83% 9–11 years (males/females): 76%/78% 15–17 years (males/females): 86%/90%
Srinivasan *et al*. 1996 (33)	Retrospective longitudinal $n = 783^{\dagger}$	(1) 13–17 years (2) 25–31 years FUD: 12–14 years	(1) and (2) overweight: BMI ≥ 75th percentile	58% of those overweight during adolescence became overweight in adulthood 10% of those lean during adolescence became overweight in adulthood

Table 2 *Continued*

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Whitaker *et al.* 1997 (36)	Retrospective longitudinal $n = 854$ Born 1965–1971	(1) 1–2 years, 3–5 years, 6–9 years, 10–14 years, 15–17 years (2) 21–29 years FUD: no information provided	(1) obesity: BMI ≥ 85th percentile (54) (2) obesity: Males: BMI ≥ 27.8 kg m^{-2} Females: BMI ≥ 27.3 kg m^{-2} (55)	OR (95% CI) for being obese in adulthood (obese youth vs. non-obese youth) Age 1–2 years: 1.3 (0.6; 3.0) Age 3–5 years: 4.7 (2.5; 8.8) Age 6–9 years: 8.8 (4.7; 16.5) Age 10–14 years: 22.3 (10.5; 47.1) Age 15–17 years: 17.5 (7.7; 39.5)
Magarey *et al.* 2003 (30)	Prospective longitudinal $n = 155$ Born 1975–1976	(1) 2, 4, 6, 8, 11, 13 and 15 years (2) 20 years FUD: no information provided	(1) Overweight: Cole *et al.* (IOTF) (39) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2}	RR (95% CI) for being overweight at 20 years (overweight youth vs. normal weight youth): 2 years: 2.7 (1.8; 4.1) 8 years: 3.5 (2.4; 5.0) 11 years: 3.6 (2.4; 5.2) 15 years: 4.3 (3.0; 6.1)
Clarke *et al.* 1993 (14)	Prospective longitudinal $n = 2631$ selected 1971–1981	(1) 9–18 years (2) 23, 28 and 33 years FUD: 5–20 years	(1) Overweight: no information provided (2) Overweight: no information provided	48–75% of males (for different age intervals) and 50–88% of females (for different age intervals) who were in the upper quintile (≥81 percentile) of BMI as youth remained in the upper quintile of BMI as adults
Wright *et al.* 2001 (38)	Prospective longitudinal $n = 412$ Born in 1947	(1) 9 years, 13 years (2) 50 years FUD: no information provided	(1) Overweight: BMI > 90th percentile (2) Overweight/obesity (small proportion through self-report): BMI > 24 kg m^{-2}/BMI > 30 kg m^{-2}	RR‡ for being overweight/obese in adulthood [overweight children (age 9) compared with normal weight children] = 1.0/2.3 RR‡ for being overweight/obese in adulthood [overweight adolescents (age 13) compared with normal weight adolescents] = 1.4/3.4
Eriksson *et al.* 2003 (18)	Retrospective longitudinal $n = 4515$ Born 1934–1944	(1) Birth, 1, 3, 5, 7, 9 and 11 years (2) Individuals still living in 2000 FUD: no information provided	(1) Overweight: no information provided (2) Obesity (self-report): BMI ≥ 30 kg m^{-2}	RR ‡ for being obese according to BMI at age 11 (reference category: >18.5 kg m^{-2}): Males: 1.6–3.9 Females: 1.6–2.7

Table 2 *Continued*

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Juonala *et al.* 2005 (27)	Prospective longitudinal $n = 2260$ selected in 1980	(1) 3, 6, 9, 12, 15 and 18 years (2) 24–39 years FUD: 21 years	(1) Overweight/obesity: BMI ≥ 80th percentile/BMI ≥ 90th percentile (2) obesity: BMI ≥ 30 kg m^{-2}	• Age group 3–9 years: 21% of overweight children and 34% of obese children became obese adults vs. 3.6% in lean children. • Age group 12–18 years: 27% of overweight youth and 64% of obese youth became obese adults vs. 5.2% in lean youth.
Guo *et al.* 1994 (24)	Prospective longitudinal $n = 555$ Born 1929–1960	(1) 1–18 years (2) 20, 30 and 39 years FUD: no information provided	(1) Overweight: no information (2) Overweight: Males: BMI > 28 kg m^{-2} Females: BMI > 26 kg m^{-2}	OR (95% CI) for being obese in adulthood (35 years) • Youth BMI > 75th percentile vs. < 50th percentile (males/females) 3 years: 1.5 (1.0; 2.2)/1.5 (1.0; 2.4) 8 years: 2.4 (1.5; 3.9)/3.1 (1.7; 5.5) 13 years: 3.3 (2.0; 5.2)/2.4 (1.5; 3.9) 18 years: 9.5 (4.0; 22.5)/5.8 (2.9; 11.6) • Youth with BMI > 95th percentile vs. <50th percentile (males/females): 3 years: 2.0 (1.0; 4.2)/2.2 (1.0; 4.6) 8 years: 4.9 (2.1; 11.7)/7.5 (2.6; 21.2) 13 years: 8.4 (2.0; 5.2)/5.0 (2.2; 11.5) 18 years: 57.5 (12.2; 271.8)/23.7 (6.8; 82.8)
Eriksson *et al.* 2001 (17)	Retrospective longitudinal $n = 3659$ Born 1924–1933	(1) 6–16 years (2) Individuals still living in 1997 FUD: No information provided	(1) Overweight: no information provided (2) Obesity (self-report): BMI ≥ 30 kg m^{-2}	OR (95% CI) for being obese in adulthood (youth with a BMI > 16 vs. children youth a BMI < 14.5): Males: 3.0 (2.2; 4.2) Females: 3.0 (2.3; 3.9)
Hulens *et al.* 2001 (26)	Prospective longitudinal $n = 161$ boys selected 1969–1974	(1) 12–18 years (2) 30, 35 and 40 years FUD: No information provided	(1) Overweight/obesity: BMI ≥ 85th percentile/BMI ≥ 95th percentile (2) Overweight: BMI ≥ 27.8 kg m^{-2} (36)	OR (95% CI) for being overweight in adulthood (40 years) • Overweight adolescents vs. normal weight adolescents: 13 years: 6.9 (2.3; 18.1) 15 years: 5.0 (1.9; 13.0) 17 years: 6.8 (2.5; 18.6)

Table 2 *Continued*

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Guo *et al.* 2002 (25)	Prospective longitudinal $n = 347$ Born 1929–1960	(1) 3–18 years (2) 20, 30 and 39 years FUD: no information provided	(1) (Age 18 years) overweight/obesity: BMI ≥ 50th percentile/≥ 72nd percentile (56) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2}	OR (95% CI) for being overweight in adulthood (35 years) • Overweight youth vs. normal weight youth: Males: 12.1 (5.5; 27.3) Females: 7.9 (3.6; 17.4) OR (95% CI) for being obese in adulthood (35 years) • Overweight youth vs. normal weight youth: Males: 19.3 (5.2; 71.4) Females: 15.7 (4.7; 52.5)
Field *et al.* 2005 (19)	Prospective longitudinal $n = 269$ selected 1978–1981	(1) 8–15 years (2) 18–26 years FUD: no information provided	(1) Overweight: BMI ≥ 85th percentile (40) (2) Overweight/obesity: BMI ≥ 25 kg m^{-2}/BMI ≥ 30 kg m^{-2} (57)	OR (95% CI) for being obese in adulthood (adolescent BMI ≥ 85th percentile vs. adolescent BMI < 50th percentile): Males: 13.2 (3.9; 45.0) Females: 48.2 (9.4; 247.7)
Vanhala *et al.* 1998 (35)	Prospective longitudinal $n = 439$ Born in 1947, 1952 and 1957	(1) 7 years (2) middle-age (no detailed information provided) FUD: no information provided	(1) and (2) obesity: sex-specific highest third of the BMI	RR‡ for being obese in adulthood (obese children vs. non-obese children) = 2.1
Rolland-Cachera *et al.* 1987 (25)	Prospective longitudinal $n = 164$ selected in 1953	(1) 0–18 years (2) 19–23 years FUD: no information provided	(1) and (2) fat: BMI ≥ 75 percentile	RR for being fat in adulthood (fat youth vs. non-fat youth, age 1) = 2
Persistence of overfatness (according to skin-fold thickness)				
Freedman *et al.* 2005 (22)	Prospective longitudinal $n = 2610$†	(1) 2.5–17 years (2) 18–37 years FUD: mean 18 years	(1) Overweight: BMI ≥ 95th percentile (53) (2) overfat: mean TSF in gender-specific quartile (males: ≥21 mm; females: ≥30.3 mm)	Proportion of overweight youth that became overfat in adulthood: 2–5 years (males and females combined): 65% 9–11 years (males/females): 67%/67% 15–17 years (males/females): 81%/65%

Table 2 *Continued*

Author(s)	Study design Sample size	Age at measurement during (1) Youth (2) Adulthood FUD	Definition of overweight and obesity (which value was used as cut-off?) (1) Youth (2) Adulthood	Main findings with regard to persistence of overweight from youth into adulthood*
Clarke *et al.* 1993 (14)	Prospective longitudinal $n = 2631$ selected 1971–1981	(1) 9–18 years (2) 23, 28 and 33 years FUD: 5–20 years	(1) overfat: no information provided (2) overfat: no information provided	39–42% of males (for different age intervals) and 25–40% of females (for different age intervals) who were in the upper quintile of triceps skin-fold thickness (TSF) as youth remained in the upper quintile of TSF as adults
Garn *et al.* 1985 (23)	Prospective longitudinal $n = 383$ selected 1959–1960	(1) 0.5–5.5 years (2) 19–26 years FUD: 20 years	(1) and (2) obesity: subscapular skin-fold thickness and TSF ≥ 85th percentile (58)	26%/27% of obese children (triceps/subscapular skin fold ≥85th percentile) became obese in adulthood.
Persistence of overwaist (according to waist circumference)				
Laitinen *et al.* 2004 (29)	Prospective longitudinal $n = 5771$ Born 1965–1967	(1) Birth, 1 years, 14 years (2) 31 years FUD: 31 years	(1) Overweight (self-report): BMI > 85th percentile (2) Overweight/obesity (30% self-report): BMI ≥ 25 kg m^{-2}/BMI > 29.9 kg m^{-2} (41) Abdominal obesity: waist/hip ratio ≥90th percentile	OR (95% CI) for having abdominal obesity in adulthood [overweight adolescents (14 years) that are obese in adulthood vs. overweight adolescents that are normal weight in adulthood]: Males: 11.1 (3.7; 33.4) Females: 46.8 (11.0; 199.6)

*Reported as RR or OR (95% CI).

†The Bogalusa Heart Study is a biracial (65% white and 35% black) community-based study. Seven cross-sectional studies of schoolchildren were conducted between 1973 and 1974 and 1992–1994. In addition, four studies of adults (ages 18–37 years) who had been examined as children were conducted between 1982 and 1996.

‡The RR has not been reported in the publication, but we were able to calculated the RR from data in the publication.

§The Correspondence provided us with additional information.

FUD, follow-up duration; BMI, body mass index, RR, relative risk; OR, odds ratio, CI, confidence interval; TSF, triceps skin-fold.

Table 3 Overall scores of the methodological quality assessment for the included studies

Author/criteria (1–15)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	Percentage '+'
Power *et al.* 1997 (31)	+	+	+	+	+	–	+	+	–	+	–	+	+	–	+	11	73
Valdez *et al.* 1996 (34)	+	+	–	+	+	+	+	–	?	–	+	+	+	+	+	11	73
Laitinen *et al.* 2001 (28)	+	+	+	+	–	+	–	–	–	+	+	+	+	+	+	11	73
Williams 2001 (37)	+	+	+	–	+	+	–	+	?	+	+	–	+	+	+	11	73
Laitinen *et al.* 2004 (28)	+	+	–	–	+	+	–	+	–	–	+	+	+	+	+	10	67
Deshmukh-Taskar *et al.* 2005 (15)	+	–	?	+	+	–	?	+	+	+	+	+	+	–	+	10	67
Freedman *et al.* 2005 (21)	+	+	–	+	–	+	+	+	?	+	+	+	–	–	+	10	67
Freedman *et al.* 2001 (20)	+	+	–	+	–	+	+	–	?	+	+	+	–	–	+	9	60
Engeland *et al.* 2004 (16)	+	–	?	–	+	+	–	–	?	+	+	+	+	+	+	9	60
Freedman *et al.* 2005 (22)	+	+	–	+	–	+	–	+	?	+	+	+	–	–	+	9	60
Srinivasan *et al.* 1996 (33)	+	+	+	–	+	+	+	–	?	–	–	+	–	–	+	8	53
Whitaker *et al.* 1997 (36)	+	+	–	–	+	–	–	–	?	+	+	+	–	+	+	8	53
Magarey *et al.* 2003 (30)	+	+	–	+	+	–	–	–	?	+	–	–	+	+	+	8	53
Clarke *et al.* 1993 (14)	+	+	–	–	+	+	–	–	+	–	–	+	–	–	+	7	47
Wright *et al.* 2001 (38)	+	+	–	–	+	–	+	–	–	–	+	+	–	–	+	7	47
Eriksson *et al.* 2003 (18)	+	+	–	+	+	–	–	–	–	–	–	+	+	+	–	7	47
Juonala *et al.* 2005 (27)	+	+	+	–	–	+	+	+	?	–	–	+	–	–	–	7	47
Guo *et al.* 1994 (24)	–	–	–	+	–	–	–	–	?	–	+	+	+	+	+	6	40
Eriksson *et al.* 2001 (17)	+	+	–	+	–	–	–	–	–	–	–	+	+	+	–	6	40
Hulens *et al.* 2001 (26)	+	+	–	–	–	–	–	+	+	+	–	–	–	+	–	6	40
Garn *et al.* 1985 (23)	+	–	–	–	–	+	+	–	?	+	–	–	–	–	+	5	33
Guo *et al.* 2002 (25)	–	–	–	+	–	–	–	–	–	+	+	–	+	+	–	5	33
Field *et al.* 2005 (19)	–	–	–	+	+	–	–	–	?	+	+	–	?	+	–	5	33
Vanhala *et al.* 1998 (35)	+	–	–	–	+	–	–	–	?	–	–	–	–	–	+	3	20
Rolland-Cachera *et al.* 1987 (25)	–	–	–	?	–	–	+	–	?	+	–	–	–	–	?	2	13

Four (16%) publications had a score of more than 70% (28,31,34,37).

Only five studies had a participation rate at baseline of at least 80% or were able to report that non-response was not selective (27,28,31,33,37). As most studies did not clearly mention whether or not their protocol prescribed if participants were weighed in light clothing (14,16–20,24,25, 28,30,32–36,38), inadequate or missing information was determined on item 8 ('adequate description of data collection'). Three studies explicitly reported that body weight/body height was measured by trained staff (14,15,26) and seven studies used self-reported measures of body weight/body height (17,18,25,28,29,31,38). According to the criteria list used for the assessment of the methodological quality, studies received for publication after 2001 had to report population-based cut-off points to define overweight/obesity [e.g. international overweight and obesity cut-offs of the International Obesity Task Force (39), Centers for Disease Control and Prevention (CDC) growth charts (40), WHO growth charts (41)]. Seven out of 11 studies that were received for publication after 2001 reported population-based cut-off points (15,16,19,21, 22,25,30). Studies received for publication before 2001 at least had to provide information about the exact definition of overweight/obesity. Eight out of 14 studies that were received for publication before 2001 provided an exact definition of overweight/obesity (20,23,26,28,31,32, 36,37).

Main findings

All studies included in this review reported increased risk for overweight or obese youth to become overweight or obese in adulthood. Several studies presented analyses stratified for different levels of body composition (16,19,24,28). These studies showed that persistence of overweight was greater with increasing level of overweight. Most of the studies that provided more than one measurement during childhood and adolescence showed that persistence of weight status increased with age (14,22,24,25,27,30,31,36–38). Some studies reported stronger persistence for girls than for boys (19,21,29), but contrasting findings are also presented (16,18,24,25,37).

Table 4 replicates the findings of our systematic review with regard to persistence according to BMI. Studies that did not provide information on how overweight or obesity was defined were not included (14,17,18,24,29, 32,34).

Summarizing the results of the high-quality studies, the risk of overweight children to become overweight adults is at least twice as high compared with normal-weight children, with the highest RR of 10 found by Freedman

Table 4 Main findings with regard to persistence of weight status from youth to adulthood

Age group	Weight status youth – adulthood	Study	High-quality studies		Low-quality studies	
			RR/OR	Percentage	RR/OR	Percentage
Children	ow – ow	Deshmukh-Taskar *et al.* 2005 (15)	RR = 1.9			
		Freedman *et al.* 2005 (21)	OR = 7.0			
		Freedman *et al.* 2001 (20)	RR = 3.2			
		Magarey *et al.* 2003 (3)				
		2 years	RR = 2.7			
		8 years	RR = 3.5			
		11 years	RR = 3.6			
		Wright *et al.* 2001 (38)			RR = 1.0	
	ow – ob	Field *et al.* 2005 (19)			OR = 13.2/48.2 (m/f)	
		Freedman *et al.* 2001 (20)	RR = 10.1			
		Freedman *et al.* 2005 (22)				
		2–5 years		83		
		9–11 years		76/78 (m/f)		
		Wright *et al.* 2001 (38)			RR = 2.3	
		Juonala *et al.* 2005 (27)				21
	ob – ow	Power *et al.* 1997 (31)				
		7 years		37/18 (m/f)		
		11 years		34/34 (m/f)		
	ob – ob	Freedman *et al.* 2005 (21)	OR = 19.9			
		Juonala *et al.* 2005 (27)				34
		Power *et al.* 1997 (31)				
		7 years		43/60 (m/f)		
		11 years		54/57 (m/f)		
		Whitaker *et al.* 1997 (36)				
		1–2 years	OR = 1.3			
		3–5 years	OR = 4.7			
		6–9 years	OR = 8.8			
		10–14 years	OR = 22.3			
		Vanhala *et al.* 1998 (35)			RR = 2.1	
	ow/ob – ow	Williams 2001 (37)				
		7 years	RR = 4.0/3.2 (m/f)			
		11 years	RR = 4.1/4.7 (m/f)			
Adolescents	ow – ow	Hulens *et al.* (26)			OR = 6.9	
		13 years			OR = 5.0	
		15 years			OR = 6.8	
		17 years				
		Laitinen *et al.* 2001 (28)		56/42 (m/f)		
		Srinivasan *et al.* 1996 (33)		58		
		Magarey *et al.* 2003 (30)	RR = 4.3			
		Wright *et al.* 2001 (38)			RR = 1.4	
		Guo *et al.* 2002 (25)			OR = 12.1/7.9 (m/f)	
	ow – ob	Laitinen *et al.* 2001 (28)		25/22 (m/f)		
		Engeland *et al.* 2004 (16)	OR = 15.0/12.0 (m/f)			
		Wright *et al.* 2001 (38)			RR = 3.4	
		Juonala *et al.* 2005 (27)				27
		Guo *et al.* 2002 (25)			OR = 19.3/15.7 (m/f)	
	ob – ow	Power *et al.* 1997 (31)		32/24 (m/f)		
		Laitinen 2001 (28)		41/27 (m/f)		
	ob – ob	Power *et al.* 1997 (31)		64/72 (m/f)		
		Laitinen *et al.* 2001 (28)		47/55 (m/f)		
		Freedman *et al.* 2005 (22)		86/90 (m/f)		
		Whitaker *et al.* 1997 (36)				
		10–14 years	OR = 17.5			
		15–17 years	OR = 22.3			
		Juonala *et al.* 2005 (27)				64
	ow/ob – ow	Williams 2001 (37)	RR = 9.8/6.8 (m/f)			

RR, relative risk; OR, odds ratio.

et al. For obese children, the RR or OR were generally higher.

For overweight adolescents, we included only one high-quality study reporting a RR of 4.3 and one high-quality study reporting an OR of 15 and 12 for males and females respectively. The percentage of overweight adolescents becoming overweight adults varied between 22% and 58% in three high-quality studies. Overall, the percentage of obese adolescents becoming overweight/obese adults was higher than for children and varied between 24% and 90%, based on three high-quality studies.

Level of scientific evidence

Strong evidence was found that persistence of overweight is 'moderate' both in overweight and obese children.

Discussion

The aim of this systematic review was to provide an update of the existing evidence concerning persistence of childhood overweight, also taking into account the methodological quality of the studies. Previous reviews on the persistence of childhood overweight included studies that were published before the end of December 2001 (1,4,6,10,11), and only one (1) considered the methodological quality of the included studies. Sixteen out of the 25 studies we included in our review were published after 2000, demonstrating the increased attention that is paid to this topic and the importance of supplying an updated review.

Nine of the 13 high-quality studies were published after 2000. This indicates that in particular recently published data provide us with reliable information. Still, the main findings reported in the publications were consistent for high-quality and low-quality studies: all studies reported an increased risk for overweight or obese youth to become overweight or obese adults. Thus, the available literature provides strong evidence that persistence of overweight into adulthood is moderate for overweight and obese youth.

The most common shortcomings we identified in our methodological assessment were (i) the inadequate description of the measurement protocol (e.g. what did participants wear during the measurements?) and (ii) the use of self-reported weight and height. The latter may be important because misreporting of weight is very common (42) and can lead to either under- or overestimation of the persistence of overweight.

Of particular note is that most studies in the present review included subjects who grew up in very different circumstances than today's children. Therefore, current persistence of overweight may differ from previous generations as the longitudinal studies described here are primarily based on cohort studies conducted more than 20 years ago, when prevalence of obesity was lower and the environment was less 'obesogenic' as it is nowadays (43). Generalizability of the findings is also limited by the fact that all studies were conducted in high-income countries. Outcomes may be quite different for populations in developing countries.

Methodological issues

A few considerations should be made when interpreting the findings of the present study.

Although the studies we included in our review consistently conclude that overweight persists from childhood or adolescence into adulthood, combining the results is complicated by the heterogeneity between studies with regard to (i) the analytical methods used to examine the degree of persistence of overweight; (ii) the intervals over which persistence is studied and (iii) the criteria used to define overweight status.

Most studies used the definition of overweight status in adults based on BMI cut-off points, as defined by the WHO guidelines (41). As BMI is lower in children and adolescents than in adults, the previously mentioned definitions are not suitable for the younger age groups. BMI changes during childhood and adolescence differ between boys and girls, so age- and sex-specific reference data have been developed (39–41). Instead of using these population-based cut-off points, several studies in our review used internally generated BMI percentile cut-off points (e.g. the 85th percentile). As the prevalence of obesity is increasing so is the 85th percentile, leading to different cut-off points for different time periods as well as for different populations. To enhance consistency of reporting measures of overweight and obesity among studies and to improve comparability of study results, we recommend the use of the definition of the International Obesity Task Force (39).

A small number of studies that we included (22,23) used skin folds to define obesity with internally generated cut-off points. It is well known that skin-folds are better in discriminating between lean mass and fat mass in an individual and therefore are a more sensitive alternative for determining body fatness, especially in youth (44,45). Stronger persistence of overweight from childhood into adulthood based on BMI vs. skin-folds might therefore indicate rather persistence of body build (38) instead of body fatness. However, measurement errors contribute significantly to the variability that is associated with skin-fold measurements (46), which might influence the magnitude of persistence reported in those studies.

Most of the studies that provided more than one measurement during childhood and adolescence showed that the persistence of weight status increased with age. However, within increasing age, time intervals between

measurements decreased. The observed increased persistence might therefore be due to the shorter time intervals between measurements.

One potential limitation that we share with many other systematic reviews, can be introduced by the literature search and selection procedure. We tried to minimize selection bias by checking reference lists of both previously published reviews and articles retrieved in the search. Owing to publication bias, positive findings are more likely to be published (47,48) leading to an overestimation of the persistence of overweight. Screening references of identified studies and systematic reviews may have resulted in an overrepresentation of studies with positive results that are more likely to be referred to, leading to reference bias. Both publication and reference bias might be decreased when using a prospective registry for longitudinal studies, comparable with International Standard Randomized Controlled Trial Number Register, which is not existent until now.

In the absence of an evidence-based consensus on which criteria should be used for assessing the methodological quality of longitudinal studies, we used an adapted criteria list (see *Methods* section). Therefore, the choice of the items we selected for our quality assessment is, to some extent, arbitrary. The use of checklists assessing the methodological quality has been well established in randomized controlled trials [e.g. CONSORT statement (49,50)], and has been linked with improved quality of reporting (12). However, much less attention has been paid to the development of similar checklists for observational longitudinal studies.

The authors are aware of the limitations of a synthetic approach, i.e. it can give a false impression of homogeneity across study results. Particularly, the differences in follow-up duration between studies and indistinct information with regard to the follow-up duration complicate accumulation of the results as well as comparability between studies. The use of a standard tool for assessing the quality of longitudinal studies might improve the quality of reporting (51) (e.g. concrete information on follow-up duration).

The main difference between the present review and previous reviews on this topic is the systematic assessment of the strength of the existing evidence. We provide a detailed methodological quality assessment, which enables the reader to gain more insight into the process of rating and makes it possible to repeat the assessment. Furthermore, the increasing number of recently published studies with a follow-up beyond the early adult years enables us to gain insight in the long-term persistence of weight status.

Our systematic review indicates that tracking of childhood weight status into adulthood is moderate for overweight and obese youth. Therefore, interventions during childhood and adolescence should focus on preventive efforts especially among high-risk groups. On the other hand, it must be considered that comparison of youth and adult prevalence rates of overweight indicates that the majority of overweight adults were not overweight during childhood. Therefore, population-based approaches are also important.

Conflict of Interest Statement

No conflict of interest was declared.

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