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Determinants of the prevalence and incidence of overweight in children and adolescents

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Abstract

Objective: To systematically analyse determinants of overweight prevalence and incidence in children and adolescents, as a basis of treatment and prevention.
Design: Cross-sectional and longitudinal data of the Kiel Obesity Prevention Study (KOPS).
Setting: Schools in Kiel, Germany.
Subjects: Cross-sectional data from 6249 students aged 5–16 years and 4-year longitudinal data from 1087 children aged 5–11 years. Weight status of students was assessed and familial factors (weight status of parents and siblings, smoking habits), social factors (socio-economic status, nationality, single parenting), birth weight as well as lifestyle variables (physical activity, media time, nutrition) were considered as independent variables in multivariate logistic regression analyses to predict the likelihood of the student being overweight.
Results: The cross-sectional data revealed the prevalence of overweight as 18·3 % in boys and 19·2 % in girls. In both sexes determinants of overweight prevalence were overweight and obese parents, overweight siblings, parental smoking, single parenthood and non-German nationality. High birth weight and low physical activity additionally increased the risk in boys. High media time and low parental education were significant determinants in girls. Effect of media time was mediated by maternal weight status in boys as well as by socio-economic status and age in girls. From the longitudinal data, the 4-year cumulative incidence of overweight was 10·0 % in boys and 8·2 % in girls. Parental obesity, parental smoking and low physical activity were determinants of overweight incidence in boys, whereas paternal obesity increased the risk in girls.
Conclusions: Treatment and prevention should address family and social determinants with a focus on physical activity and media use.

Keywords
Determinants
Overweight
Children
Prevalence
Incidence

Childhood obesity is a major public health challenge. At present there is a lack of convincing evidence about suitable and effective strategies for the prevention of childhood overweight. Recently, an obesity prevention evidence framework has been proposed[1]. Key policies include: (i) building a case for action on obesity; (ii) identifying contributing factors and points of intervention; (iii) defining opportunities for action; (iv) evaluating potential interventions; and (v) selecting a portfolio of specific policies, programmes and actions. Therefore, a systematic analysis of determinants of overweight in the micro- as well as the macro-environment is necessary to provide a sound basis for developing strategies against overweight. The systematic analysis should include an analysis of the determinants of overweight prevalence as well as overweight incidence, separately. Childhood overweight (and not only obesity) is predictive for adult morbidity and mortality[2]. In addition, the life-long persistence and health consequences of overweight and obesity in many children suggest a strong need for the prevention of overweight[2]. Primary prevention strategies address the whole population, in particular normal-weight subjects, and are aimed at preventing the incidence of overweight. Therefore, it is important to analyse determinants of incidence. In addition, determinants of the prevalence of overweight need to be addressed by strategies of secondary or tertiary prevention (i.e. treatment of overweight and/or obesity). To our knowledge, determinants of the incidence and prevalence of childhood overweight have not been compared systematically.

Most of our present knowledge is based on cross-sectional data. These studies have investigated the influence of lifestyle determinants on childhood overweight (e.g. lifestyle factors[3–9]), but only few studies have addressed

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familial, social and lifestyle factors together[10–17]. In these cross-sectional studies, parental obesity, low socio-economic status (SES), high weight gain during infancy and television (TV) viewing were found as main determinants of prevalence. Contrary to cross-sectional data, there are only very few longitudinal studies investigating the development of overweight[14,18–21]. In these studies parental overweight was found as the main determinant. In addition, rapid weight gain in early life was found as a significant predictor in two studies[19,20], as was SES[19,21]. In two studies high TV viewing[20] and high energy intake[18] were significantly associated with the development of overweight.

Although the complexity of childhood overweight is generally known, interactions between determinants have been considered in only three cross-sectional studies[11,15,16]. Here we present a study where we systematically analysed cross-sectional as well as longitudinal data of the Kiel Obesity Prevention Study (KOPS) to characterise individual and ecological determinants of the prevalence as well as the incidence of overweight in children aged 5 to 16 years. The analysis should provide a sound basis to develop strategies for primary prevention as well as treatment of overweight.

Methods

Study populations

Study design and recruitment procedures of KOPS have been described previously[22]. Briefly, participants were obtained from three groups participating in KOPS. Group 1 was a representative group of 4997 children aged 5–7 years which was recruited as part of the school entry examination in Kiel, Germany between 1996 and 2001. Group 2 consisted of 4487 children aged 9–11 years who were examined during a school examination between 2000 and 2005. Group 3 consisted of 3237 adolescents aged 13–16 years examined in schools between 2004 and 2006. Participation was voluntary and there were no eligibility criteria except willingness to participate. Signed informed consent was obtained and the study protocol was approved by the local ethical committee.

Questionnaires addressing determinants of overweight (answered by the parents for groups 1 and 2, by the adolescents themselves for group 3) were available for 1837 children aged 5–7 years, 2303 children aged 9–11 years and 2109 adolescents. Thus, the total data of 6249 children and adolescents were used to analyse the determinants of prevalence.

Since all three groups belonged to the same total population (=all children participating in the school entry examination between 1996 and 2001 in Kiel), a subgroup of children was identified who had been examined twice within a 4-year follow-up period: (i) subgroup A comprising 1683 children examined at age 5–7 as well as 9–11 years (*n* 1683); and (ii) subgroup B comprising 9- to 11-year-old children re-examined at age 13–16 years, *n* 918). For the analysis of incidence, only persistent normal-weight and incident overweight children were considered; 183 and 103 persistent overweight as well as forty-three and fifty-six remitted (e.g. who normalised weight status) children of subgroup A and B, respectively, were excluded from analysis. In our longitudinal analysis complete data sets were available for 1087 children and adolescents (687 and 400 of subgroup A and B, respectively). For analysis of cross-sectional data all children who were investigated twice were considered at one age only. Data of the first examination were used unless the questionnaire of lifestyle habits was missing at the first measuring time but available at the second. Then data of the second measurement were used.

Tanner stages (pubic hair stages for both sexes; breast stages for girls, genitalia stages for boys) were self-estimated by the adolescents using standard pictures[23] on scales from 2 to 5. This procedure has been validated by Duke *et al.*[24] in forty-three females aged 9–17 years and twenty-three males aged 11–18 years.

Definition of overweight

Height and weight were measured and BMI was calculated[25]. International BMI cut-offs for child overweight (including obesity) were applied using the International Obesity Taskforce standards[26]. In addition, waist circumference was measured midway between the lowest rib and the top of the iliac crest at the end of gentle expiration. Fat mass was calculated from tetrapolar bioelectrical impedance analysis measurements using a population-specific algorithm[25]. Children were characterised as ‘overwaist’ and ‘overfat’ according to British reference values[27,28] due to missing international and German standards.

Determinants of overweight

Potential risk factors for overweight were assessed using a questionnaire that addressed the following determinants.

Family factors

Parental weight and height were self-reported and parents were classified as ‘normal weight’ (BMI < 25 kg/m^2), ‘overweight’ (BMI ≥ 25 kg/m^2) or ‘obese’ (BMI ≥ 30 kg/m^2). Weight and height of siblings were also self-reported by parents and classified in categories according to international BMI reference percentiles[26,29]. Occurrence of nutrition-related diseases (hypertension, diabetes mellitus, hypercholesterolaemia, stroke, myocardial infarction) was asked and classified in categories of ‘no’, ‘in grandparents only’ or ‘already in parents’. Parental smoking habits were classified in categories of 0 (‘no’), 1–15 (‘middle’) and >15 cigarettes/d (‘heavy’).

Social factors

SES was determined according to parental education, i.e. highest level attained by either parent: ‘low’ = 9 school years, ‘middle’ = 10 school years, ‘high’ = 12 school years and more. Single parenthood ('yes', 'no') as well as nationality ('German' and 'non-German') were dichotomised.

Early life determinant

Birth weight was adopted from the well-baby check-up book and classified into categories ('low', 'middle', 'high') using German reference percentiles[30] taking into account gender and duration of pregnancy.

Lifestyle factors

Physical activity and media time were categorised using age- and sex-specific cut-offs (determined from distribution and recommendations). Regular physical activity was assessed as membership in a sports club and training hours per week (4-week test–retest correlation in 14-year-old adolescents was $r = 0{\cdot}50$, $P < 0{\cdot}01$ for duration of physical activity[31]). Physical activity was categorised as 'very low' (0 h/week for all age groups), 'low' (5–7-year-olds: >0–≤1 h/week; 9–11-year-olds: >0–≤2 h/week; 13–16-year-old boys: >0–≤3·5 h/week; 13–16-year-old girls: >0–≤2·5 h/week), 'middle' (5–7-year-olds: >1–≤2 h/week; 9–11-year-olds: >2–≤4 h/week; 13–16-year-old boys: >3·5–≤6 h/week; 13–16-year-old girls: >2·5–≤4·5 h/week) and 'high' (5–7-year-olds: >2 h/week; 9–11-year-olds: >4 h/week; 13–16-year-old boys: >6 h/week; 13–16-year-old girls: >4·5 h/week).

Self-reported media time was assessed as hours per day spent in TV viewing and computer use on a typical weekday (4-week test–retest correlation in 14-year-old adolescents was $r = 0{\cdot}68$, $P < 0{\cdot}01$[31]). In a previous study on 5- to 11-year-old children[32], TV viewing had been compared with (i) energy expenditure as assessed by the combined use of indirect calorimetry and 24 h heart-rate monitoring (time > FLEX heart rate) and (ii) aerobic fitness (submaximal oxygen consumption, O_2-pulse). However, there were no significant differences in either energy expenditure or fitness between groups of children watching TV for ≤1 h/d *v.* >1 h/d. Daily time spent for media use was categorised as 'low' (5–7-year-olds: 0 h/d; 9–11-year-olds: 0–<1 h/d; 13–16-year-old boys: 0–<2 h/d; 13–16-year-old girls: 0–<1·5 h/d), 'middle' (5–7-year-olds: >0–≤1 h/d; 9–11-year-olds: ≥1–<2 h/d; 13–16-year-old boys: ≥2–<2·5 h/d; 13–16-year-old girls: ≥1·5–<2 h/d), 'high' (5–7-year-olds: >1–≤2 h/d; 9–11-year-olds: ≥2–<3 h/d; 13–16-year-old boys: ≥2·5–<3·5 h/d; 13–16-year-old girls: ≥2–<3 h/d) and 'very high' (5–7-year-olds: ≥2 h/d; 9–11-year-olds: ≥3 h/d; 13–16-year-old boys: ≥3·5 h/d; 13–16-year-old girls: ≥3 h/d).

Nutrition was assessed using a twenty-six-item FFQ based on the WHO MONICA FFQ adapted to children[33]. An index of dietary pattern was calculated[31]. Consumption of ≥3 'healthy' foods (wholemeal bread, fruit, vegetables, fish, cheese) and <3 'risk-related' foods (white bread, sausage, soft drinks, fast food, sweets/chips) at least 3–5 times/week were summarized to a 'healthy dietary pattern'. Consumption of ≥3 'risk-related' foods and <3 'healthy' foods at least 3–5 times/week corresponded to a 'risk-related dietary pattern'. Other combinations were mentioned as 'mixed dietary pattern'. The FFQ was validated against a 7 d diet record in children aged 5–7 years (*n* 24) and 9–11 years (*n* 61)[34]. Additionally, differences in the dietary pattern index were analysed when either parents or children completed the FFQ. There were non-systematic differences in several food items when compared with parental reports, i.e. healthy as well as unhealthy foods were over- and underestimated by children. Four-week test–retest percentage agreement (reliability) of dietary pattern in 14-year-old adolescents was 67·6 %.

Statistics

The statistical analyses were performed with the SPSS 15·0 for Windows (SPSS Inc., Chicago, IL, USA) and STATA 11 (Stata Corp., College Station, TX, USA) statistical software packages. Results are presented as median and interquartile range.

Multilevel logistic regression analyses were performed to identify independent risk factors for prevalence and incidence of overweight. A multilevel approach was used to account for the hierarchical data structure (level 1: students; level 2: schools) and thus to control for clustering of participants in schools. It was performed with STATA 11 (XTMELOGIT command). Schools were used as random effect, risk factors of overweight were considered as fixed effects. Categorical determinants were converted in dichotomous dummy variables. Reference categories are marked in Table 2. In the first model all potential determinants were considered. In a second model interaction terms between lifestyle factors and age, parental weight status and parental education were considered additionally. Level of significance was set at $P < 0{\cdot}05$ (two-sided). Missing values were considered as separate covariates but their estimated values are not presented. Due to small selection biases with respect to the total population (data on BMI provided by school physicians), data were weighted on the distribution of the total population with regard to weight status of the children (in cross-sectional data analyses) and SES (in longitudinal data analyses)[35,36]. Students who were under-represented in the study population get a higher weight factor for data analysis and vice versa. All analyses were stratified for sex. Age and pubertal stages were considered as confounders.

Additional analyses

Since some studies have found associations between several food items and overweight[5,8], we tested the influence of soft drinks, fast food, sweets, fruit and vegetables instead of the dietary index within the logistic regression analysis.

In our previous analysis of determinants of overweight in 5- to 7-year-old children, different determinants were observed between overweight and obesity[37]. Therefore, we stratified the analysis by overweight and obesity (according to international cut-offs for BMI[26]).

BMI is widely used as a measure of fat mass. However, BMI is only an indirect parameter of total body fat and does not reflect body fat distribution[38]. Thus, 'overwaist' and 'overfat' were used as dependent variables in logistic regression analyses instead of overweight.

In the analyses of determinants of incidence, 4-year changes in determinants were considered. Therefore new categories were created with consistent values as well as inconsistent values (categories of change; with the exception of parental education, birth weight and nationality which were unchangeable variables).

Results

Characterisation of the study populations

The study populations are characterised in Table 1. Overweight prevalence was 18·3 % in boys and 19·2 % in girls. Four-year cumulative incidence rates were 10·1 % in boys and 8·2 % in girls. The distributions of all potential determinants of overweight are shown in Table 2 for the cross-sectional as well as the longitudinal study group at baseline. Within the longitudinal cohort family members more often were normal weight, parents had a better education and lived together more often, compared with the cross-sectional cohort. In addition, the children of the longitudinal cohort were more often German and had more favourable lifestyle behaviours. These differences were due to the fact that the longitudinal cohort consisted of normal-weight children only. In addition a selection bias was obvious and was corrected in multivariate analyses by using weight factors (see Statistics).

Four-year changes in determinants

Within the 4-year follow-up period, 9·9 % and 19·8 % of mothers and fathers became overweight while 13·8 % and 10·9 % of mothers and fathers who were overweight at baseline re-normalised their weight. Among siblings, 16·4 % gained weight and 8·7 % ameliorated their weight status. Some 3·6 % of parents started smoking and 19·9 % of former smokers became non-smokers. Moreover, 17·8 % of children who lived with one parent only at baseline lived with two parents at follow-up and 7·9 % changed from a two- to a one-parent household. Four-year changes in lifestyle variables are presented in Table 3. Overall, 58 %, 68 % and 32 % of the children remained within the same category of physical activity, media time and nutrition, respectively. Children who changed a category more often improved their physical activity and nutrition level but they increased media time consumption.

Determinants of prevalence (cross-sectional data)

Significant determinants of prevalence of overweight were family, social, early life and lifestyle factors (Table 4).

Table 1 Characteristics and weight status of children and adolescents of the cross-sectional as well as the longitudinal cohort, Kiel Obesity Prevention Study

	Cross-sectional data				Longitudinal data*							
					Baseline				4-year follow up			
	Boys (*n* 3117)		Girls (*n* 3132)		Boys (*n* 560)		Girls (*n* 527)		Boys (*n* 560)		Girls (*n* 527)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Age (years)	10·0	6·6, 14·2	10·0	6·6, 14·2	6·6	6·1, 9·9	6·5	6·1, 9·9	10·3	9·9, 14·4	10·4	9·8, 14·3
Height (m)	1·43	1·26, 1·65	1·43	1·25, 1·62	1·24	1·19, 1·40	1·24	1·18, 1·39	1·48	1·42, 1·68	1·48	1·40, 1·63
Weight (kg)	35·3	26·0, 53·4	36·5	25·9, 52·4	24·0	21·5, 32·0	24·0	21·0, 31·0	38·7	32·9, 55·0	38·6	32·1, 51·6
BMI (kg/m^2)	17·3	15·6, 20·1	17·9	15·8, 20·4	15·6	14·9, 16·6	15·7	14·7, 16·7	17·8	16·2, 19·7	17·8	16·3, 19·7
BMI-SDS	0·12	−0·48, 0·80	0·18	−0·44, 0·85	−0·11	−0·59, 0·35	−0·08	−0·66, 0·39	0·01	−0·54, 0·47	−0·03	−0·53, 0·53
WC (cm)	63·5	57·0, 71·0	63·0	56·6, 69·5	57·0	53·5, 61·0	56·0	53·0, 59·0	65·0	61·0, 70·0	63·0	59·0, 67·8
FM† (%)	19·1	14·5, 24·5	23·4	18·5, 28·4	18·9	15·5, 22·5	20·1	15·2, 23·9	17·4	14·0, 22·1	21·5	17·5, 26·4
	%		%		%		%		%		%	
NW‡ (%)	81·7		80·8		100		100		90·0		91·8	
OW‡ (%)	13·6		14·1		0		0		9·8		8·0	
OB‡ (%)	4·7		5·1		0		0		0·2		0·2	

IQR, interquartile range; SDS, standard deviation score; WC, waist circumference; FM, fat mass; NW, normal weight; OW, overweight; OB, obese.
*Incident overweight and persistent normal-weight children only.
†According to bioelectrical impedance analysis.
‡According to international BMI reference percentiles[26].

Table 2 Characterization and distribution of potential determinants of overweight stratified by sex, Kiel Obesity Prevention Study

		Cross-sectional data				Longitudinal data* (baseline)			
		Boys		Girls		Boys		Girls	
		%	*n*	%	*n*	%	*n*	%	*n*
Family factors									
Mother		*n* 3015		*n* 3018		*n* 557		*n* 524	
	NW (REF)	68·1	2053	67·7	2043	76·8	428	74·4	390
	OW	21·6	651	22·0	664	17·1	95	20·6	108
	OB	10·2	311	10·3	311	6·1	34	5·0	26
Father		*n* 2637		*n* 2602		*n* 526		*n* 502	
	NW (REF)	47·6	1255	47·1	1226	58·0	305	50·8	255
	OW	41·6	1097	42·9	1116	35·7	188	44·6	224
	OB	10·8	285	10·0	260	6·3	33	4·6	23
Siblings		*n* 2112		*n* 2103		*n* 372		*n* 360	
	UW	16·1	340	18·0	379	27·4	102	22·8	82
	NW (REF)	64·1	1354	61·6	1295	64·0	238	65·6	236
	OW	19·8	418	20·4	429	8·6	32	11·7	42
Diseases†		*n* 2580		*n* 2567		*n* 404		*n* 360	
	No (REF)	7·9	204	6·5	167	14·9	60	11·4	41
	Grandparents	41·3	1066	40·9	1050	32·2	130	33·1	119
	Parents	50·8	1310	52·6	1350	53·0	214	55·6	200
Parental smoking		*n* 3041		*n* 3064		*n* 551		*n* 521	
	No (REF)	49·7	1511	50·6	1550	56·6	312	52·8	275
	Middle	17·1	520	18·4	564	16·4	90	18·6	97
	Heavy	33·2	1010	31·4	950	25·4	149	27·5	149
Social factors									
Parental education		*n* 3050		*n* 3073		*n* 560		*n* 527	
	High (REF)	45·8	1397	45·5	1398	56·8	318	54·5	287
	Middle	33·1	1010	31·1	956	30·0	168	30·0	158
	Low	21·1	643	23·3	719	13·2	74	15·6	82
Single parenthood		*n* 3081		*n* 3099		*n* 560		*n* 527	
	No (REF)	77·6	2391	73·3	2272	85·9	481	82·0	432
	Yes	22·4	690	26·7	827	14·1	79	18·0	95
Nationality		*n* 3083		*n* 3102		*n* 560		*n* 527	
	German (REF)	91·1	2809	90·8	2817	95·4	534	96·6	509
	Non-German	8·9	274	9·2	285	4·6	26	3·4	18
Early life factor									
Birth weight		*n* 2906		*n* 2960		*n* 554		*n* 522	
	Low	7·7	224	8·9	263	9·7	54	8·4	44
	Middle (REF)	76·6	2226	77·0	2279	74·9	415	78·4	409
	High	15·7	456	14·1	418	15·3	85	13·2	69
Lifestyle factors									
Physical activity		*n* 3092		*n* 3118		*n* 553		*n* 523	
	Very low	33·5	1036	36·0	1122	28·6	158	29·1	152
	Low	21·7	671	26·8	836	23·7	131	33·5	175
	Middle	28·6	884	22·0	686	32·7	181	26·2	137
	High (REF)	16·2	501	15·2	474	15·0	83	11·3	59
Media time		*n* 3078		*n* 3085		*n* 555		*n* 521	
	Low (REF)	13·8	425	17·8	549	4·5	25	4·6	24
	Middle	41·2	1268	36·6	1129	24·0	133	20·3	106
	High	27·8	856	27·6	851	58·9	327	57·4	299
	Very high	17·2	529	18·0	556	12·6	70	17·7	92
Dietary pattern‡		*n* 3117		*n* 3132		*n* 504		*n* 475	
	Risky	11·2	349	7·4	232	9·7	49	6·3	30
	Mixed	66·1	2060	61·2	1917	52·2	263	57·1	271
	Healthy (REF)	22·7	708	31·5	983	38·1	192	36·6	174

NW, normal weight; REF, category which is used as reference in multivariate analyses (Tables 4–7); OW, overweight; OB, obese; UW, underweight.
*Incident overweight and persistent normal-weight children only.
†Hypertension, diabetes mellitus, hypercholesterolaemia, stroke and/or myocardial infarction.
‡Calculated from FFQ concerning frequency of consumption of healthy and risk-related foods[31].

The main determinant with the highest odds ratio was parental obesity (boys: OR = 2·1; 95 % CI 1·5, 3·0; girls: OR = 3·7; 95 % CI 2·7, 5·1). Low physical activity increased the risk of overweight in boys (OR = 1·5; 95 % CI 1·1, 2·0) while high media time was a significant determinant in girls (OR = 1·7; 95 % CI 1·2, 2·4). High birth weight (OR = 1·5; 95 % CI 1·1, 1·9) as well as increasing age (OR = 1·1; 95 % CI 1·1, 1·2) were risk factors of overweight in boys only. Girls of low SES had an increased risk of overweight when compared with girls of high SES (OR = 1·6; 95 % CI 1·2, 2·1). When the model was extended by interaction terms, family and

Table 3 Four-year changes in lifestyle variables of children of the longitudinal cohort stratified by sex, Kiel Obesity Prevention Study

Lifestyle factors		Boys %	Boys *n*	Girls %	Girls *n*
Physical activity		*n* 538		*n* 516	
	Low at T0 and T1	22·5	121	31·2	161
	High at T0 and T1	33·5	180	29·7	153
	Low at T0, high at T1	29·6	159	27·7	143
	High at T0, low at T1	14·5	78	11·4	59
Media time		*n* 507		*n* 469	
	Low at T0 and T1	41·8	212	48·0	225
	High at T0 and T1	26·2	133	19·8	93
	Low at T0, high at T1	21·7	110	21·1	99
	High at T0, low at T1	10·3	52	11·1	52
Dietary pattern		*n* 480		*n* 423	
	Risky at T0 and T1	3·3	16	1·2	5
	Healthy at T0 and T1	8·8	42	12·8	54
	Mixed at T0 and T1	19·0	91	19·9	84
	Improved nutrition	21·0	101	19·9	84
	Deterioration of nutrition	47·9	230	46·3	196

T0, baseline; T1, 4-year follow-up.

Table 4 Determinants of prevalence of overweight* stratified by sex derived from multilevel† logistic regression analysis (model 1), Kiel Obesity Prevention Study

Nagelkerke's R^2 (%): 11·8 in boys, 16·4 in girls		Boys OR	Boys 95 % CI	Boys *P*	Girls OR	Girls 95 % CI	Girls *P*
Family factors							
Mother	OW	1·3	1·0, 1·7	0·021	1·5	1·1, 1·9	0·002
	OB	1·9	1·4, 2·6	0·000	2·6	1·9, 3·5	0·000
Father	OW	1·6	1·3, 2·0	0·000	1·7	1·4, 2·1	0·000
	OB	2·1	1·5, 3·0	0·000	3·7	2·7, 5·1	0·000
Siblings	UW	0·6	0·4, 0·9	0·010	0·5	0·3, 0·7	0·000
	OW	1·7	1·3, 2·3	0·000	1·6	1·2, 2·0	0·001
Diseases	Grandparents	1·1	0·8, 1·5	0·434	0·8	0·6, 1·1	0·178
	Parents	1·2	0·9, 1·6	0·211	1·1	0·8, 1·4	0·639
Parental smoking	Middle	1·4	1·1, 1·9	0·010	1·1	0·8, 1·4	0·723
	Heavy	1·6	1·2, 2·0	0·000	1·5	1·2, 1·8	0·001
Social factors							
Parental education	Middle	1·2	0·9, 1·5	0·160	1·2	1·0, 1·6	0·079
	Low	1·2	0·9, 1·6	0·321	1·6	1·2, 2·1	0·001
Single parenthood	Yes	1·6	1·2, 2·0	0·000	1·5	1·2, 1·9	0·001
Nationality	Non-German	1·4	1·0, 1·9	0·030	1·7	1·3, 2·3	0·000
Early life factor							
Birth weight	Low	0·7	0·4, 1·0	0·070	0·9	0·6, 1·3	0·609
	High	1·5	1·1, 1·9	0·005	1·3	1·0, 1·7	0·078
Lifestyle factors							
Physical activity	Very low	1·3	0·9, 1·9	0·115	1·1	0·8, 1·6	0·546
	Low	1·5	1·1, 2·0	0·018	1·1	0·8, 1·6	0·382
	Middle	1·0	0·7, 1·5	0·806	1·0	0·7, 1·4	0·956
Media time	Middle	0·9	0·6, 1·2	0·328	1·2	0·9, 1·7	0·229
	High	1·1	0·8, 1·6	0·479	1·5	1·1, 2·1	0·011
	Very high	1·2	0·8, 1·7	0·453	1·7	1·2, 2·4	0·004
Dietary pattern	Poor	0·5	0·3, 0·8	0·001	0·5	0·3, 0·8	0·004
	Mixed	0·8	0·6, 1·0	0·032	1·0	0·8, 1·2	0·972
Confounder							
Age		1·1	1·1, 1·2	0·000	1·0	0·9, 1·0	0·555
Pubertal stage		0·9	0·7, 1·0	0·099	1·2	1·0, 1·4	0·058

OW, overweight; OB, obese; UW, underweight.
*According to international BMI reference percentiles[26].
†Adjusting for clustering effect in schools; reference categories are given in Table 2. Significance indicated by $P<0·05$.

lifestyle factors lost significance while the interaction term between media time and weight status of mothers became significant in boys (OR = 1·2; 95 % CI 1·1, 1·3) as did interaction terms between media time and age (OR = 1·0; 95 % CI 0·9, 1·0) and parental education (OR = 1·2; 95 % CI 1·0, 1·3) in girls (Table 5). Figure 1 illustrates the

Table 5 Determinants of prevalence of overweight* stratified by sex derived from multilevel† logistic regression analysis (model 2), Kiel Obesity Prevention Study

Nagelkerke's R^2 (%): 15·2 in boys, 18·9 in girls		Boys			Girls		
		OR	95 % CI	*P*	OR	95 % CI	*P*
Family factors							
Mother	OW	0·8	0·5, 1·4	0·388	1·6	1·0, 2·6	0·078
	OB	0·8	0·3, 2·1	0·688	2·9	1·2, 6·8	0·019
Father	OW	2·1	1·2, 3·8	0·014	1·9	1·1, 3·4	0·029
	OB	2·8	0·9, 8·7	0·075	4·1	1·4, 12·2	0·011
Siblings	UW	0·6	0·4, 1·0	0·032	0·4	0·2, 0·7	0·000
	OW	1·8	1·3, 2·4	0·001	1·7	1·2, 2·3	0·001
Diseases	Grandparents	1·0	0·7, 1·4	0·900	0·8	0·6, 1·1	0·187
	Parents	1·0	0·7, 1·4	0·858	0·9	0·7, 1·3	0·623
Parental smoking	Middle	1·5	1·0, 2·0	0·032	1·1	0·8, 1·5	0·729
	Heavy	1·8	1·4, 2·4	0·000	1·4	1·1, 1·8	0·013
Social factors							
Parental education	Middle	0·9	0·5, 1·6	0·723	1·7	1·0, 2·9	0·058
	Low	0·6	0·2, 1·7	0·298	3·0	1·1, 8·1	0·034
Single parenthood	Yes	1·5	1·1, 2·1	0·017	1·4	1·1, 1·9	0·018
Nationality	Non-German	1·2	0·9, 1·8	0·246	1·5	1·0, 2·1	0·031
Early life factor							
Birth weight	Low	0·6	0·3, 1·0	0·040	1·0	0·7, 1·6	0·976
	High	1·5	1·1, 2·0	0·021	1·2	0·9, 1·7	0·266
Lifestyle factors							
Physical activity	Very low	1·5	0·7, 3·1	0·321	1·6	0·8, 3·3	0·159
	Low	1·3	0·7, 2·6	0·380	1·3	0·7, 2·3	0·399
	Middle	1·0	0·6, 1·7	0·895	1·1	0·7, 1·8	0·754
Media time	Middle	0·8	0·5, 1·3	0·327	1·1	0·7, 1·7	0·568
	High	0·9	0·5, 1·6	0·781	1·2	0·7, 2·0	0·520
	Very high	0·9	0·4, 2·0	0·724	1·1	0·5, 2·6	0·809
Dietary pattern	Poor	0·3	0·1, 1·3	0·115	0·5	0·1, 2·0	0·346
	Mixed	1·2	0·3, 4·5	0·771	1·3	0·4, 4·1	0·705
Confounders							
Age		1·3	1·1, 1·5	0·001	1·0	0·9, 1·1	0·885
Pubertal stage		0·8	0·7, 1·1	0·078	1·2	1·0, 1·5	0·085
Interaction terms							
Physical activity × age		1·0	1·0, 1·0	0·472	1·0	1·0, 1·0	0·096
Physical activity × mother's weight status		1·0	0·9, 1·1	0·771	1·1	1·0, 1·1	0·052
Physical activity × father's weight status		1·0	1·0, 1·1	0·415	1·0	1·0, 1·1	0·732
Physical activity × parental education		1·0	0·9, 1·0	0·533	1·0	1·0, 1·1	0·494
Media time × age		1·0	1·0, 1·0	0·145	1·0	0·9, 1·0	0·043
Media time × mother's weight status		1·2	1·1, 1·3	0·003	1·0	0·9, 1·2	0·888
Media time × father's weight status		1·0	0·9, 1·1	0·589	1·1	0·9, 1·2	0·338
Media time × parental education		1·0	0·9, 1·1	0·643	1·2	1·0, 1·3	0·020
Nutrition × age		1·0	0·9, 1·1	0·724	1·0	1·0, 1·1	0·477
Nutrition × mother's weight status		1·1	0·9, 1·4	0·581	1·0	0·7, 1·1	0·389
Nutrition × father's weight status		1·0	0·7, 1·2	0·651	0·9	0·7, 1·3	0·588
Nutrition × parental education		0·9	0·7, 1·2	0·411	1·1	0·8, 1·4	0·682

OW, overweight; OB, obese; UW, underweight.
*According to international BMI reference percentiles[26].
†Adjusting for clustering effect in schools; reference categories are given in Table 2. Significance indicated by $P < 0·05$.

significant interactions. An increased risk for overweight with increasing media time consumption was obvious for boys of obese mothers (Fig. 1(a)), girls at the age of 5–11 years (Fig. 1(b)) and girls from families of middle and high SES (Fig. 1(c)).

Determinants of incidence (longitudinal data)

Parental obesity (OR = 4·4; 95 % CI 1·5, 13·1), parental smoking habits (OR = 2·5; 95 % CI 1·1, 5·5) as well as low physical activity (OR = 4·1; 95 % CI 1·2, 14·4) were the significant determinants of incidence of overweight in boys (Table 6). In addition, incidence of overweight decreased with increasing age of the boys (OR = 0·8; 95 % CI 0·6, 1·0). Taking into account interaction terms, low physical activity (OR = 27·7; 95 % CI 1·2, 618) remained a significant determinant of incidence (Table 7). In girls, obesity of the father (OR = 6·8; 95 % CI 1·7, 27·9) was the only significant determinant of incidence of overweight (Table 6).

Additional analyses

When including individual food items (soft drinks, fast food, sweets, fruit and vegetables) instead of the nutrition index none of these items reached significance (data not shown).

When stratifying the analyses according to overweight and obesity the same determinants reached significance,

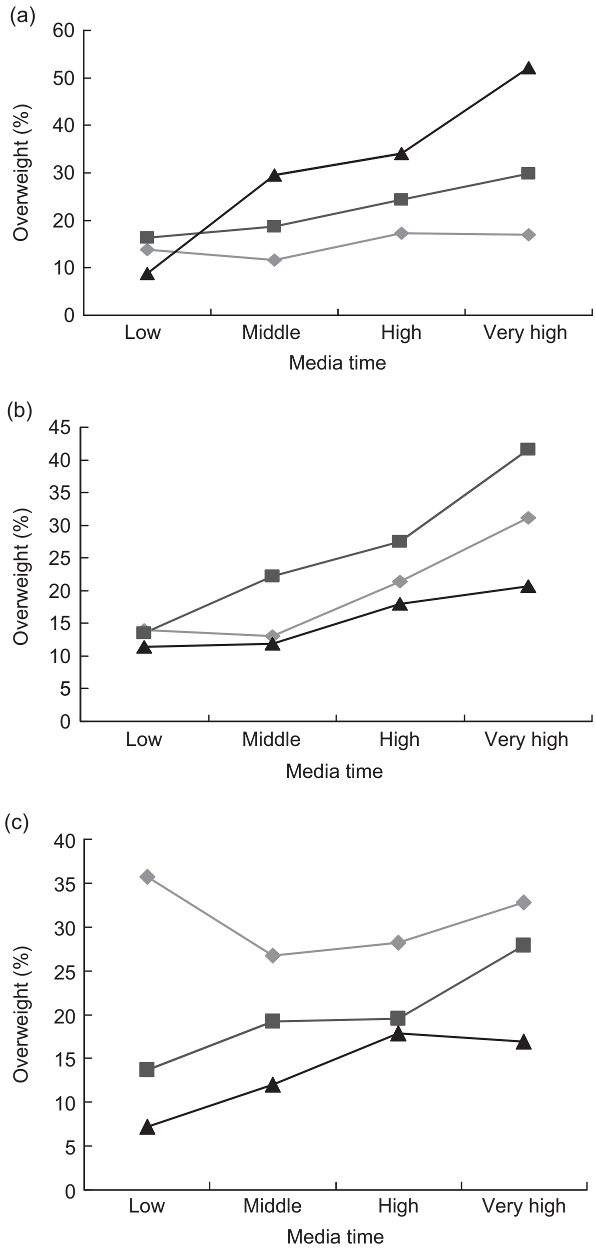

Fig. 1 Prevalence of overweight according to media consumption and stratified by: (a) maternal weight status (–◆–, normal weight; –■–, overweight; –▲–, obese) in boys; (b) child's age (–◆–, 5–7 years; –■–, 9–11 years; –▲–, 13–16 years) in girls; and (c) socio-economic status according to parental education (–◆–, low; –■–, middle; –▲–, high) in girls, Kiel Obesity Prevention Study

whereas the odds ratios were higher for obesity but also had higher 95 % confidence intervals (data not shown).

Explained variance (Nagelkerke's R^2) was 14·3 % for determinants of prevalence (for both sexes combined). Data were re-analysed with overwaist and overfat as dependent variable. Explained variance was 11·3 % and 19·2 % for overwaist and overfat, respectively.

Within the analysis of incidence 4-year changes in determinants did not reach significance.

Discussion

Determinants of prevalence

In KOPS parental overweight and obesity were found as main determinants of overweight risk in German children and adolescents (Table 4), as in other studies[10–14]. By contrast, in the literature the impact of lifestyle factors was not uniform. A high media time increased the risk of overweight[6,9,11]. Nutrition and physical activity were not strongly associated with the risk of overweight in multivariate analyses[6,11,12,14].

We found in KOPS that low physical activity as well as high media time increased the risk for overweight (Table 4). However, poor nutrition habits reached no significance as a risk factor but surprisingly entered our analysis as a protective factor. Our finding might suggest a bias in overweight children due to the assessment instrument. However, our FFQ was validated against 7 d food records and a sufficient agreement was found ($r = 0{\cdot}3$–$0{\cdot}4$ for several food items)[33,34]. Under-reporting may affect data quality in overweight children. However, two validation studies could not show that under-reporting was common in overweight children only[39,40]. The inverse effect of nutrition disappeared when interaction terms were taken into account (Table 5). We take this as evidence for a minor effect of nutrition on prevalence of childhood overweight. We found sex differences in determinants of overweight. Low physical activity was significantly associated with overweight in boys whereas high media time increased overweight risk of girls. This is in contrast to the study of Jouret *et al.*[10] in which no sex differences were found in media time consumption but in physical activity: structured physical activity was associated with overweight in girls only. A recent study of Perez-Pastor *et al.*[41] showed that mother's obesity may affect only daughter's obesity whereas father's obesity affected son's obesity only. In KOPS this sex-specific influence could not be confirmed; obesity of both mothers and fathers had an influence on overweight in boys as well as girls (Table 4).

Considering interaction terms (Table 5; Fig. 1) showed that a more complex understanding of childhood obesity is needed. As in the study of Vandewater and Huang[16], we found that TV viewing and weight status of the children was moderated by parental weight status and age of the children. The risk of overweight increased with TV viewing in children with at least one obese parent but not in children with normal-weight parents[16]. In addition, there was a further interaction between media time and parental education. We found that high media time increased the prevalence of overweight in children with higher parental education. Thus, a high parental education did not protect against the negative impact of high media consumption. This finding is in line with the study of Singh *et al.*[15] in which the association between obesity and TV viewing and physical activity was more pronounced in children of higher SES groups.

Table 6 Determinants of incidence of overweight* stratified by sex derived from multilevel† logistic regression analysis (model 1), Kiel Obesity Prevention Study

Nagelkerke's R^2 (%): 16·5 in boys, 23·1 in girls		Boys			Girls		
		OR	95 % CI	*P*	OR	95 % CI	*P*
Family factors							
Mother	OW	1·0	0·4, 2·3	0·910	0·4	0·1, 1·1	0·081
	OB	4·4	1·5, 13·1	0·007	1·5	0·4, 5·8	0·550
Father	OW	1·8	0·9, 3·8	0·098	1·6	0·7, 3·4	0·268
	OB	3·8	1·3, 11·6	0·017	6·8	1·7, 27·9	0·008
Siblings	UW	1·1	0·6, 2·1	0·820	1·3	0·6, 2·8	0·495
	OW	1·3	0·4, 4·6	0·707	0·7	0·1, 2·5	0·540
Diseases	Grandparents	1·4	0·6, 3·2	0·377	0·8	0·3, 2·0	0·649
	Parents	1·6	0·7, 3·9	0·267	1·6	0·6, 3·9	0·337
Parental smoking	Middle	1·4	0·5, 3·5	0·519	1·3	0·5, 3·4	0·644
	Heavy	2·5	1·1, 5·5	0·021	1·6	0·7, 3·6	0·289
Social factors							
Parental education	Middle	0·8	0·4, 1·8	0·638	1·8	0·8, 4·3	0·150
	Low	0·7	0·2, 2·0	0·458	2·1	0·8, 5·7	0·126
Single parenthood	Yes	1·9	0·8, 4·6	0·151	1·1	0·5, 2·6	0·792
Nationality	Non-German	1·8	0·5, 6·8	0·383	–	–	0·985
Early life factor							
Birth weight	Low	0·6	0·2, 1·9	0·391	2·3	0·7, 7·1	0·149
	High	1·8	0·8, 4·0	0·156	1·3	0·4, 4·0	0·605
Lifestyle factors							
Physical activity	Very low	4·1	1·2, 14·4	0·029	3·1	0·8, 11·6	0·097
	Low	3·2	0·9, 12·3	0·085	1·1	0·3, 4·4	0·916
	Middle	3·2	0·9, 11·5	0·072	1·1	0·2, 4·8	0·920
Media time	Middle	1·9	0·4, 8·9	0·423	1·6	0·4, 7·0	0·544
	High	1·7	0·4, 7·8	0·508	0·7	0·2, 3·1	0·648
	Very high	2·2	0·4, 13·5	0·389	0·5	0·1, 3·4	0·521
Dietary pattern	Poor	0·5	0·1, 2·3	0·393	0·7	0·2, 3·2	0·683
	Mixed	1·0	0·5, 2·0	0·944	0·6	0·3, 1·2	0·144
Confounder							
Age		0·8	0·6, 1·0	0·031	0·8	0·7, 1·0	0·102

OW, overweight; OB, obese; UW, underweight.
*According to international BMI reference percentiles[26].
†Adjusting for clustering effect in schools; reference categories are given in Table 2. Significance indicated by $P<0·05$.

Thus, reduction of media time should be a target of obesity treatment programmes in children and adolescents of obese mothers and of families from middle and high social status.

Determinants of incidence

In KOPS parental obesity, parental smoking habits and low physical activity were significant risk factors for incidence of overweight. By contrast, parental overweight had no significant effect on incidence (Table 6). There is evidence that genetic and environmental factors, which are related to parental obesity, have a greater effect before the age of 6 years[42]. An effect is therefore more clearly seen in the cross-sectional analyses of children than in the analysis of longitudinal data.

In our study low physical activity was the only significant lifestyle determinant of incidence of overweight. The effect remained even after controlling for interactions with parental weight status and SES (Table 7). In contrast to the present study, Maffeis *et al.*[14] did not find lifestyle variables to significantly affect the change in relative BMI over a 4-year period when parental obesity was taken into account. Davison and Birch[18], who analysed predictors of change in girls' BMI from age 5 to 7 years, showed that girl's BMI at age 5 years, family risk of overweight, mother's increase in BMI, father's enjoyment of activity, energy intake and girl's percentage fat intake reached significance. Gortmaker *et al.*[4] showed that watching TV for more than 5 h/d increased the 4-year incidence of overweight in US children.

Comparison of determinants of prevalence and incidence of overweight

Parental obesity and smoking habits as well as low physical activity were significant determinants of prevalence as well as incidence, whereas social factors influenced overweight prevalence only. These data may be taken as evidence for the idea that a societal approach is more important in the treatment of childhood overweight than in primary prevention. In addition, the impact of lifestyle factors may also differ: while high media time added to increased prevalence, low physical activity was the major determinant of incidence. Thus primary prevention programmes should involve the family and focus on increasing physical activity. By contrast, in treatment programmes, family involvement as well as a societal approach is important in combination with a lifestyle approach addressing physical activity and media consumption in children

Table 7 Determinants of incidence of overweight* stratified by sex derived from multilevel† logistic regression analysis (model 2), Kiel Obesity Prevention Study

		Boys			Girls		
Nagelkerke's R^2 (%): 19·3 in boys, 25·8 in girls		OR	95 % CI	P	OR	95 % CI	P
Family factors							
Mother	OW	3·4	0·2, 63·9	0·418	3·6	0·1, 127	0·482
	OB	19·3	0·9, 426	0·061	13·8	0·4, 488	0·148
Father	OW	0·5	0·0, 7·8	0·639	0·0	0·0, 1·0	0·050
	OB	1·0	0·1, 19·7	0·979	0·3	0·0, 8·3	0·492
Siblings	UW	1·1	0·5, 2·3	0·847	1·5	0·6, 3·5	0·371
	OW	1·1	0·2, 4·6	0·941	0·4	0·1, 2·5	0·304
Diseases	Grandparents	1·8	0·7, 4·8	0·214	0·8	0·3, 2·3	0·696
	Parents	2·0	0·7, 5·5	0·188	1·3	0·5, 3·7	0·620
Parental smoking	Middle	1·3	0·4, 3·8	0·656	1·0	0·3, 3·1	0·944
	Heavy	2·0	0·8, 5·1	0·147	1·3	0·5, 3·3	0·632
Social factors							
Parental education	Middle	2·7	0·4, 19·7	0·338	1·1	0·2, 6·5	0·926
	Low	16·4	0·4, 692	0·142	0·4	0·0, 13·0	0·582
Single parenthood	Yes	2·1	0·7, 5·9	0·181	1·1	0·4, 3·0	0·784
Nationality	Non-German	1·8	0·3, 9·2	0·500	–	–	–
Early life factor							
Birth weight	Low	0·7	0·2, 2·4	0·540	3·1	0·9, 10·8	0·072
	High	1·8	0·7, 4·7	0·197	1·2	0·4, 4·3	0·744
Lifestyle factors							
Physical activity	Very low	–	–	–	0·2	0·0, 22·8	0·495
	Low	27·7	1·2, 618	0·036	0·1	0·0, 4·8	0·281
	Middle	22·5	1·7, 292	0·017	0·3	0·0, 3·8	0·377
Media time	Middle	0·9	0·1, 12·6	0·924	18·3	0·6, 597	0·102
	High	0·8	0·0, 30·1	0·915	–	–	–
	Very high	0·4	0·0, 43·8	0·685	–	–	–
Dietary pattern	Poor	–	–	–	–	–	–
	Mixed	–	–	–	–	–	–
Confounder							
Age		1·0	0·4, 2·5	0·949	0·5	0·2, 1·4	0·169
Interaction terms							
Physical activity × age		1·0	0·9, 1·2	0·801	1·0	0·8, 1·2	0·889
Physical activity × mother's weight status		1·1	0·6, 1·8	0·801	0·7	0·3, 1·6	0·364
Physical activity × father's weight status		1·0	0·6, 1·7	0·982	1·4	0·6, 2·9	0·420
Physical activity × parental education		1·1	0·7, 1·6	0·772	0·8	0·5, 1·5	0·492
Media time × age		0·8	0·5, 1·1	0·181	1·0	0·7, 1·5	0·816
Media time × mother's weight status		0·8	0·2, 2·5	0·633	0·5	0·2, 1·9	0·345
Media time × father's weight status		2·4	0·8, 7·4	0·140	3·5	0·9, 13·6	0·068
Media time × parental education		1·2	0·6, 2·4	0·656	0·6	0·3, 1·3	0·214
Nutrition × age		1·0	0·7, 1·6	0·878	1·4	0·9, 2·3	0·108
Nutrition × mother's weight status		0·5	0·1, 2·1	0·337	0·4	0·1, 2·1	0·263
Nutrition × father's weight status		1·4	0·4, 5·5	0·627	3·4	0·7, 15·4	0·109
Nutrition × parental education		2·7	1·0, 7·2	0·054	1·1	0·4, 2·8	0·841

OW, overweight; OB, obese; UW, underweight.
*According to international BMI reference percentiles[26].
†Adjusting for clustering effect in schools; reference categories are given in Table 2. Significance indicated by $P < 0·05$.

and adolescents of obese mothers and from families of middle and high social status.

Age is differently added to prevalence and incidence. The risk of being overweight increased with age while the risk of becoming overweight decreased. Both findings indicate that the older the children are, the more likely they are to be already overweight. Our data thus argue in favour of early treatment and prevention of overweight.

Limitations

Although many individual and ecological factors were considered in the present study, only 14 % of the variance of overweight could be explained (Tables 4–7). Our definition of overweight was based on BMI which might be a poor indicator of fat mass. Therefore, analyses were repeated using waist circumference and percentage body fat mass. However, this did not increase explained variance (see Results). Additional variables which were significant determinants of overweight in other studies like sleep duration[20], infant weight gain[19,20], mother's weight gain[18] and smoking habits during pregnancy[19] were not included in our analyses. Since we have analysed this in a subgroup of the KOPS population we do not assume that they would increase explained variance. Genetic influences were not directly considered but were included in weight status of parents and siblings. If all these determinants explain only less than one-fifth of the variance of overweight, one may question if the approach proposed by Swinburn *et al.*[1] is sufficient to combat the obesity epidemic. Recent studies from our group have shown that weight gain is due to a relatively small positive energy balance[43]. Thus differences in lifestyle factors between overweight and normal-weight subjects are too small to be detected with conventional epidemiological methods. This idea is in line with an alternative strategy to combat the obesity epidemic which was recently published by Hill[44]. Hill promoted small changes in diet and physical activity to prevent further weight gain. However, it could be questioned if this 'easy option' approach is sufficient to solve such a complex phenomenon like overweight.

Conclusions

Treatment of overweight should involve family and social environment and should mainly address high physical activity as well as low media consumption. Measures of primary prevention should also involve family and should preferentially address high physical activity. Beyond these conventional measures, alternative approaches like the small-changes approach should be tested.

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