Dietary Fat Intake Predicts 1-Year Change in Body Fat in Adolescent Girls With Type 1 Diabetes

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OBJECTIVE — The purpose of this study was to determine whether objectively measured physical activity and dietary macronutrient intake differentially predict body fat in adolescent girls with type 1 diabetes and control girls.

RESEARCH DESIGN AND METHODS — This study comprised 23 girls (12–19 years) with type 1 diabetes and 19 age-matched healthy control girls. At baseline, physical activity and energy intake were assessed for 7 consecutive days by accelerometry and a structured food diary, respectively. Body composition was measured by dual-energy X-ray absorptiometry at baseline and after 1 year.

RESULTS — Fat intake was positively related to a 1-year change in percentage body fat ($P = 0.006$), after adjustment for total energy intake. No significant interaction was observed (case-control group × main exposure), indicating that the association between fat intake and gain in body fat was similar in both groups. Physical activity did not predict gain in body fat; however, total physical activity was positively associated with a gain in lean body mass ($P < 0.01$). Girls treated with six daily dosages of insulin increased their percentage of body fat significantly more than those treated with four daily injections ($P < 0.05$).

CONCLUSIONS — In this prospective case-control study, we found that fat intake predicted gain in percentage of body fat in both adolescent girls with type 1 diabetes and healthy control girls. The number of daily insulin injections seems to influence the accumulation of body fat in girls with type 1 diabetes.

Diabetes Care 29:1227–1230, 2006

Excessive weight gain has frequently been reported in adolescent girls with type 1 diabetes (1–7). It is mainly explained by increased fat mass (6). The underlying cause of this excessive weight gain is unclear, although intensified insulin therapy may contribute, possibly reflecting increased energy intake due to more frequent hypoglycemia (2,8,9).

We have previously observed a tendency toward lower levels of physical activity in adolescent girls with type 1 diabetes compared with healthy control girls, suggesting that the total amount of physical activity may contribute to the development of overweight (10). To our knowledge no study has previously addressed the prospective associations among physical activity, energy intake, and changes in body composition in adolescent girls with type 1 diabetes. In this prospective case-control study we hypothesized that the total amount of physical activity is inversely associated with gain in body fatness and that total energy intake is positively associated with gain in body fatness in adolescent girls with type 1 diabetes. We also hypothesized a differential association between girls with diabetes and control girls.

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Received for publication 29 November 2005 and accepted in revised form 2 March 2006.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.
DOI: 10.2337/dc05-2318

RESEARCH DESIGN AND METHODS

— Twenty-six girls who had type 1 diabetes for at least 2 years were recruited in this study. Twenty-three of these were followed up after 1 year. Among the girls completing the study, two were using insulin pumps at baseline and four at follow-up; 17% were in Tanner stage 2–3 and 83% were in Tanner stage 4–5 at baseline. Four were being treated for celiac disease and one for hypothyroidism. The girls who were lost to follow-up had a mean age of 15.5 years, mean BMI of 25.4 kg/m^2, mean HbA_{1c} (A1C) of 8.5% and mean daily dosage of insulin of 1.0 unit · kg^{-1} · day^{-1} at baseline. The control girls were identified as the females of the same age and from the same residential area appearing next to the diabetic patients in the register of the county taxation authorities. Twenty-three control girls were recruited, 19 of whom agreed to participate in the follow-up. Of the control girls completing the study, 31% were in Tanner stage 2–3 at baseline. Control girls who did not participate in the follow-up measurements had a mean age of 17.6 years and a mean BMI of 23.9 kg/m^2. Clinical characteristics of participants completing the study are presented in Table 1. All subjects and their parents gave informed consent. The study was approved by the Ethics Committee of Örebro County Council.

Pubertal stage

Pubertal stage assessments were made on the basis of a self-estimating manual ("Flickboken"), using schematic drawings of different Tanner stages (11).

Body composition

Dual-energy X-ray absorptiometry (Lunar, Madison, WI) was used to assess body composition. The coefficients of variation of body composition measurement, determined by three measurements on each of three phantoms with a fat content of 10, 20 and 40 kg, were 10.4, 1.7, and 0.3%, respectively.

Table 1—*Clinical characteristics of the girls with type 1 diabetes and control girls*

	Baseline		Follow-up	
	Type 1 diabetes	Control	Type 1 diabetes	Control
n	23	19	23	19
Age (years)	15.7 ± 2.1	15.6 ± 1.9	16.8 ± 2.1	16.6 ± 1.9
Height (cm)	163.8 ± 7.9	164.3 ± 6.9	165.0 ± 7.3	165.8 ± 5.7
Weight (kg)*	65.3 (16.0)	57.2 (24.1)	68.2 (16.3)	61.6 (18.6)
BMI (kg/m^2)*	23.6 (2.6)	20.5 (8.0)	24.0 (3.2)	21.3 (6.6)
BMI SDS	0.84 ± 0.8	0.67 ± 1.2	0.99 ± 0.8	0.67 ± 1.1
Fat mass (kg)	20.7 ± 7.6	20.0 ± 10.0	23.2 ± 7.0	21.7 ± 9.3
Percent body fat	32.6 ± 8.3	31.0 ± 9.9	35.0 ± 6.5	32.7 ± 8.4
Fat-free mass (kg)	38.2 ± 3.9	38.1 ± 4.2	39.1 ± 4.2	39.4 ± 4.0
Daily dosage of insulin (units/kg)	1.1 ± 0.3	—	1.2 ± 0.4	—
A1C (%)	7.6 ± 1.4	—	7.5 ± 1.5	—
Duration of diabetes (years)*	6.0 (7.7)	—	—	—

Data are means ± SD. *Skewed variables are presented as median (interquartile range). The groups were compared using Mann-Whitney *U* tests for skewed variables and unpaired *t* tests for normally distributed variables. Changes in body composition variables in each group were examined with paired *t* tests. There were no significant differences between the groups in body composition variables at baseline or follow-up or in 1-year change. SDS, standard deviation score.

Physical activity and food intake

The measurement and analysis of physical activity and food intake have been described in detail previously (10). Physical activity and dietary intake were measured simultaneously over a 7-day period with a uniaxial accelerometer (model WAM 6471; Computer Science and Applications, Schalimar, FL) and a 7-day food diary ("Menyboken," Swedish National Food Administration), respectively.

Laboratory methods

A1C was measured by high-pressure liquid chromatography with the Mono-S standard (12). The reference level for healthy persons is 3.5–5.3%.

Statistical analysis

Differences among the groups for clinical characteristics, body composition, physical activity, and energy intake were assessed by an unpaired *t* test or Mann-Whitney *U* test. Associations between changes in body composition variables (fat mass, percent body fat, and lean body mass) with energy intake and physical activity were assessed by ANCOVA, adjusting for study group. Further adjustments were made for Tanner stage and body composition (fat mass or lean body mass) at baseline. Interactions terms between study group and Tanner group, with energy-adjusted fat intake were included in the models to examine whether case-control group or Tanner stage modified the associations between the main exposures with change in body composition. The results of the ANCOVA are presented as a regression slope (β coefficient). In the diabetic group the associations of daily dosage of insulin and A1C with change in body composition (i.e., fat mass or lean body mass) variables were analyzed by multiple regression analysis, with change in body composition as the dependent variable, adjusting for the body composition variable of interest at baseline. StatView, version 5.0.1, was used for all statistical analyses. The level of statistical significance was set at $P < 0.05$.

RESULTS

Body composition

Data on body composition are presented in Table 1. Lean body mass, total fat mass, and percent body fat increased significantly in both groups. There was no significant difference between girls with diabetes and control girls regarding change in any of the body composition variables.

Physical activity and energy intake

Physical activity did not differ significantly between the groups (type 1 diabetes 463 ± 128 cpm, control girls 541 ± 153 cpm; $P = 0.10$). Neither did we observe any significant difference between the groups in total daily energy intake (type 1 diabetes 8.4 ± 1.8 MJ/day, control girls 9.6 ± 2.8 MJ/day). Energy-adjusted carbohydrate intake was significantly lower in diabetic girls (50 ± 6 vs. 53 ± 5%; $P < 0.05$), whereas energy-adjusted protein intake was significantly higher (16 ± 2 vs. 13 ± 2%; $P < 0.0001$) than in the healthy control girls. No significant difference was observed between groups for energy-adjusted fat (34 ± 6 vs. 33 ± 5%) and fiber intake (20 ± 7 vs. 17 ± 6 g/day).

Associations among physical activity, energy intake, and change of body composition

Changes in percent body fat and body fat mass were positively associated with energy-adjusted fat intake ($P < 0.01$ and $P < 0.05$, respectively) and inversely associated with energy-adjusted carbohydrate intake ($P < 0.01$ and $P < 0.01$, respectively) (Fig. 1). Total physical activity (counts per minute) and total energy intake were not associated with changes in percent body fat or in body fat mass.

Changes in lean body mass were not associated with energy-adjusted carbohydrate or fat intake but were positively associated with the total amount of physical activity (β = 0.006 [kilograms per counts per minute], $P < 0.01$). No significant interactions were observed for any of the analyses.

Associations among insulin therapy, A1C, and change in body composition

There were no significant associations between daily dosage of insulin or A1C and changes in percent body fat or in lean body mass in multivariate models. However, a significant difference was found between the 1-year increase in percent body fat between those treated with four daily dosages of insulin ($n = 9$) compared with those treated with six doses ($n = 6$) (0.8 ± 2.6 and 3.6 ± 2.1%-units body fat, respectively, $P < 0.05$).

CONCLUSIONS — We found that high dietary fat intake adjusted for total energy intake significantly predicted gain in body fat in adolescent girls with type 1 diabetes and in healthy control girls. The total amount of physical activity was not associated with changes in body fat mass, but high levels of physical activity significantly predicted gain in lean body mass. No significant interactions were observed, indicating that these associations did not differ between type 1 diabetic and healthy adolescent girls.

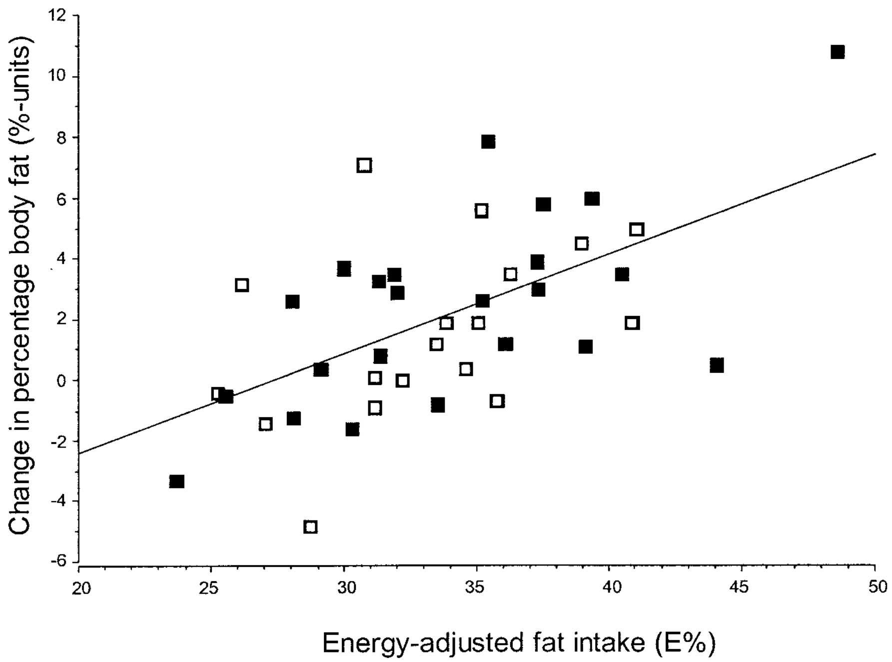

Figure 1— *Association between energy-adjusted fat intake (E%) and 1-year change in percent body fat in adolescent girls with type 1 diabetes (■) and healthy control girls (□). Change in percent body fat = −9 + 0.33 E%;* $R^2 = 0.33$*;* $P < 0.0001$.

The role of dietary fat intake in the development of obesity in childhood is controversial (13–17). However, it is possible that higher intakes of dietary fat contribute to an increase in total energy intake because dietary fat has a weaker effect on satiation compared with carbohydrates (18,19) and is more energy dense. The fact that we did not observe any association between total energy intake and change in percentage body fat may be explained by under-reporting of total dietary intake, which is common in adolescents (20). It is also plausible that dietary fat has a specific role in the accumulation of body fat, because excess energy from dietary fat intake is more easily stored as body fat than is excess energy derived from carbohydrates (21).

Insulin is a potent inhibitor of lipolysis (22) and stimulates lipogenesis (23), which could result in greater fat accumulation in girls with diabetes due to the effect of subcutaneous insulin therapy, resulting in peripheral hyperinsulinemia (24). This may then contribute to the development of overweight often observed in diabetic girls, and it could be hypothesized that the association between fat intake and percent body fat would be steeper in girls with diabetes compared with control girls (interaction). However, our results indicated that higher dietary fat intake predicted a similar increase in percentage body fat in both diabetic girls and control girls.

Our small sample size and relatively short follow-up time may be limiting factors to detect a differential association between fat intake and change in body fat. However, our precise measure of body composition at baseline and follow-up and the detailed characterization of activity patterns and dietary intake suggest that our results are not due to chance or measurement error.

In summary, our results suggest that high dietary fat intake predicts gain in percent body fat similarly in adolescent girls with diabetes and in healthy control girls. Furthermore, physical activity is associated with a gain in lean body mass in adolescent girls. Our findings emphasize the need for dietary advice to decrease fat intake and increase levels of physical activity in adolescent girls with and without type 1 diabetes to avoid unhealthy gains in fat mass.

Acknowledgments— The study was supported financially by the Research Committee of Örebro County Council and the Swedish Child Diabetes Foundation (Barndiabetes fonden).

The authors thank Linda Sjölander and Ingegerd Karlsson for contributing to the data collection and Lolita Mörk for analyzing the food records.

Part of this article were presented in abstract form at the annual meeting of the International Society for Pediatric and Adolescent Diabetes, St. Malo, France, 3–6 September 2003.

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