Body fat related to daily physical activity and insulin concentrations in non-diabetic children

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Summary

This study explored the associations between body fat versus daily physical activity and insulin concentrations in non-diabetic young children in a Cross-sectional study of 172 children (93 boys and 79 girls) aged 8 to 11 years. Blood samples were analysed for serum insulin and daily physical activity was measured by accelerometers. Time spent performing vigorous activity was estimated from accelerometer data by using established cut off points. Dual-energy x-ray absorptiometry (DXA) was used to quantify abdominal fat mass (AFM) and total body fat (TBF), also calculated as percentage of body weight (BF%). Body fat distribution was calculated as AFM/TBF. Body fat distribution was independently linked to both insulin concentrations and physical activity. In contrast, TBF, AFM and BF% were linked to physical activity only and not to insulin concentrations. In conclusion in this population of non-diabetic children, body fat distribution was independently associated with increased concentrations of insulin and deceased amount of vigorous activity per day. Also, AFM, TBF, and BF% were independently related to minutes of vigorous activity per day.

Introduction

Several reports in recent years highlight the increasing prevalence of obesity and type 2 diabetes (Mokdad et al., 2003; Hotu et al., 2004; Dietz, 2004; Slyper, 2004; Söderberg et al., 2005). An important underlying mechanism of type 2 diabetes is development of insulin resistance, which is characterized by high insulin concentrations (Ten & Maclaren, 2004). Adiposity has also been linked to markers for insulin resistance, even at a young age (Gutin et al., 1994; Owens et al., 2000; Goran et al., 2001; Johnson et al., 2001; Bunt et al., 2003; Krekoukia et al., 2007), and to reduced physical activity (Ekelund et al., 2004; Abbott & Davies, 2004). In contrast, the role of body fat distribution has not been established in this context in children. Another factor in the development of insulin resistance might be low physical activity level. Indeed, some previous studies in children and adolescents (Raitakari et al., 1997; Ku et al., 2000; Schmitz et al., 2002; Bunt et al., 2003; Brage et al., 2004) have demonstrated a negative relationship between daily physical activity and various markers for insulin resistance independently of adiposity. In previously mentioned studies of habitual physical activity and markers for insulin resistance, self-report methods were mainly used to assess physical activity. These methods are known to have limited accuracy in assessing the level of physical activity in subjects of all ages and are considered inappropriate in children under the age of ten (Kohl et al., 2000). Accelerometers, on the other hand, have the capacity to measure the frequency, intensity and duration of physical activity and can be used, by children, over a relatively long period of time (Trost, 2001). They therefore have the potential to overcome the limitations of self-report methods. In addition, many previous studies have used anthropometric methods to assess body fat instead of direct measurement by for example DXA, a method that has been shown to provide accurate and precise measurements of total fat mass (Lohman et al., 2000), including abdominal fat mass (Glickman et al., 2004).

This study investigated the associations between body fat, including body fat distribution, with insulin concentrations and objectively measured physical activity in a population of young non-diabetic children.

Materials and Methods

Subjects and anthropometric measures

Recruitment of the study cohort has been presented previously (Dencker et al., 2006a, b, c; Dencker et al., 2007). In brief, 477 children (259 boys and 218 girls) received an invitation to participate in the study, whereas 248 (140 boys and 108 girls) accepted the invitation. Of those, 172 children (93 boys and 79 girls), admitted collection of blood samples. None of these children were on medication for diabetes. Standard height and body mass were measured in the laboratory with the child dressed in light clothing. Height was measured to the nearest 1.0 cm and body mass was measured to the nearest kg. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared (kg/m^2). Puberty status was assessed by self-evaluation according to Tanner (Duke et al., 1980). The institutional ethics committee of Lund University, Sweden, approved the study. Written informed consent was obtained from the parents of all participating children.

Measurement of physical activity

Methodology of physical activity assessment has been previously presented in detail (Dencker et al., 2006a, b, c). In brief, MTI model 7164 accelerometer (Manufacturing Technology Inc., Fort Walton Beach, Fl, USA) was worn around the hip for four consecutive days. Epoch time is the timeframe that accelerometer counts are averaged, thus the time resolution of the activity measurement. We choose an epoch time of 10 seconds in order to capture short bursts of activity since younger childrens activity pattern tends to be sporadic and unsustained

(Bailey et al., 1995). Accelerometer counts above 583 count/epoch (corresponding to 3500 counts/min) were considered vigorous activity, such as running (Freedson et al., 1997; Trost et al., 1998). Summing up all segments above this threshold made it possible roughly to estimate the number of minutes per day the child was engaged in such activities. The accelerometer measurement took place within as short timeframe from the DXA measurement and collection of blood sample as possible, usually the same or the adjacent week.

Dual-Energy X-Ray Absorptiometry

Methodology of dual-energy X-ray absorptiometry (DXA) measurements has been previously presented in detail (Dencker et al., 2006c; Dencker et al., 2007). In brief, whole-body composition was measured by DXA (DPX-L version 1.3z, Lunar, Madison, WI, USA). Total body fat (TBF) and abdominal fat mass (AFM) were quantified. Percent body fat was calculated as TBF divided by total body mass times 100 (BF%). Body fat distribution was defined as AFM/TBF. DXA has been shown to provide accurate and precise measurements of fat mass (Lohman et al., 2000), including abdominal fat (Glickman et al., 2004).

Blood samples

A non-fasting blood sample was available from each child, which was collected in conjunction with the DXA measurement. Insulin was determined radioimmunochemically with the use of a guinea pig anti-human insulin antibody, ^{125}I-labelled human insulin as tracer and human insulin as standard (Linco Research, St Charles, MO, USA). Free and bound radioactivity was separated by use of an anti-IgG (goat anti-guinea pig) antibody (Linco). The sensitivity of the assay is 12 pmol/l and the coefficient of variation is less than 3% within assays and less than 5% between assays. Insulin concentrations are reported in pmol/ml.

Statistics

All statistical analyses were performed using Statistica 5.0 (StatSoft Inc., Tulsa, OK, USA). Means and standard deviations (SD) were calculated for all variables. The distribution of BF%, TBF, AFM and insulin were skewed so logarithmic transformation (natural logarithm (ln)) was applied. Univariate relationships between physical activity and fitness variables were assessed with Pearson correlation analysis. Student's t-test between means was used to analyse group differences. A value of $p<0.05$ was regarded as a statistically significant difference. Multiple linear forward regression analysis was performed separately, to evaluate the independent significant factors for BF%, TBF, AFM and AFM/TBF. Activity data (minutes per day above 583 count/epoch) and serum insulin as well as potential confounders such as age, days of activity recording and puberty status were introduced to the model.

Results

DXA measurement was not available in one child. Thirteen children (8%) were excluded for failing to achieve at least three days of valid accelerometer registrations. Complete accelerometer and DXA data were thus evaluated from a final study group consisting of 158 children (82 boys and 76 girls). Three girls were Tanner stage 2, the remaining 155 children were all Tanner stage 1. Summary of age, antropometric, DXA and accelerometry data are displayed in Table 1.

One hundred and thirty-two children (84 %) achieved the full four days of accelerometer recording whereas 26 children (16%) achieved three days. Children who had three days of valid registrations had higher amount of vigorous activity per day compared with those who had four days of registrations with borderline significance (47±19 vs. 40±17, $p=0.05$). There

was no significant difference in the duration of accelerometer recording per day between children with three or four days of recordings (11.7±1.4 vs. 12.0±1.2, p=0.17 ns). There was significant negative univariate correlation between body fat measurements vs. insulin concentrations and vigorous activity per day (table 2). However, in the multiple stepwise linear regression analysis performed for body fat measurements, only body fat distribution was independently linked to both insulin concentrations and vigorous activity, whereas TBF, AFM and BF% were only linked to vigorous activity. Summary of the regression analysis is displayed in table 3.

Discussion

In this population of non-diabetic young children, total body fat mass, percent body fat, abdominal fat mass, and body fat distribution were independently linked to objectively measured minutes of vigorous physical activity per day. In addition, body fat distribution was independently linked to both insulin concentrations and vigorous activity. The main objective of the current study was to explore any coexisting relationship between body fat, physical activity and insulin concentrations. Other aspects that possibly could influence these relationships such as genetics, dietary factors, low birth-weigh or catch-up growth were not investigated. Also, the cross-sectional nature of this study only explores relationships and do not address cause and consequence. In addition, an acceptance rate of 36% of all invited children was low.

A major strength of our study was the use of DXA in order to precisely quantify body fat. An additional strength of the present study was the use of accelerometers to objectively evaluate physical activity. This represents a considerable improvement compared to self-report methods (Kohl et al., 2000). In our study there was a borderline significant difference in

physical activity for children who had three days of valid measurements compared with those who had four days of valid measurements. The number of monitoring days was introduced to the multiple regression analysis models to compensate for this potential confounder. A strength of our study in the estimation of vigorous activity is the use of a short epoch time of 10 seconds, since the physical activity pattern in children is often sporadic and unsustained (Bailey et al., 1995). The MTI accelerometers therefore underestimate vigorous activity, when using longer epoch time, e.g. one-minute epochs (Nilsson et al., 2002).

It is well known that all measurements of insulin in epidemiological studies are haunted with problems of within-subject variability in relation to between-subject variability. It is likely that differences in this regard could be a factor between our non-fasting blood samples compared with blood-sample taken under more rigorous conditions. However, the insulin response to a glucose load or a meal is prolonged in insulin resistant subjects, and the differences in insulin levels between groups of different physical activity levels or degrees of fatness is likely to reflect differences in insulin sensitivity (Lindegårde & Saltin, 1981).

It is of interest to observe the uniform relationships between various body fat measurements and minutes of vigorous activity measured by accelerometers. In a recent report from the European Youth Heart Study (EYHS), time performing moderate and vigorous activity (measured by accelerometers) correlated weakly with BMI (Ekelund et al., 2004). However, only 0.5% of the variance in BMI could be explained by daily activity. As in our study, the body mass of this population was normally distributed. A plausible explanation for the fact that our study showed a much higher correlation between body fat and activity could be that we measured TBF directly and did not use BMI as a surrogate. Another explanation could be the use of a short epoch time in our study that should result in more accurate estimate of

vigorous activity (Nilsson et al., 2002), in combination with the intensity threshold selection. A report including 47 children aged 5-10 years supports the view that objectively measured vigorous activity is linked to body fat (Abbot & Davies, 2004). In this study, as in ours, activity was assessed by accelerometers and related to objectively measured body fat. Time performing vigorous and hard intensity activity was correlated with percentage body fat ($r=-0.43$ and $r=-0.39$, respectively ($p<0.05$)).

Previous reports on African-American and Caucasian US children (Gutin et al., 1994; Johnson et al., 2001) and in Pima Indian children (Bunt et al., 2003), using the DXA technique, suggest an association between total body fat and various markers for insulin resistance. Also, central fat deposition has been related to insulin resistance (Owens et al., 2000; Goran et al., 2001; Krekoukia et al., 2007). Our results are similar despite possible ethnical differences as well as differences in life styles. Also, the children in the previously mentioned studies had substantially higher mean values of percent body fat (20-40%), compared to the children in the present study. In studies on children with normal weight distribution insulin concentrations was weakly correlated with skinfold thickness (Brage et al., 2004). The EarlyBird Study reported a weak relationship between Log Homeostasis assessment model-insulin resistance (HOMA-IR) and various anthropometric measurements (Murphy et al., 2004). These data support our findings and indicate that there is a positive relation between body fat and insulin concentrations also in a population based cohort of children that are not at high risk of developing type 2 diabetes.

Studies using self-report based evaluation of physical activity, have demonstrated inverse relationships between various measures of insulin resistance and physical activity in populations of young children independent of body fat (Raitakari et al., 1997; Ku et al., 2000;

Schmitz et al., 2002; Bunt et al., 2003), despite the shortcomings of self-report based assessment of physical activity (Kohl et al., 2000). Previous studies using accelerometers in large-scale paediatric populations have given diverging results. In the report from The EarlyBird Study (Murphy et al., 2004), no relation was found between total physical activity and Log HOMA-IR in 307 children with an average age of five. In contrast, Brage and co-workers (Brage et al., 2004) reported in children of the Danish part of EYHS with an average age of 9.7 years, an inverse relationship between activity and insulin concentrations in girls, but not in boys. Despite the large sample size, 310 girls and 279 boys, no relationship between activity and insulin concentrations could be found among boys. Our study fails to detect any consistent relationship between insulin concentrations and activity measurements independent of body fat with one exception. Our methodological shortcoming of not being able to obtain fasting blood-sample because of logistical difficulties could be a factor. However, the existing independent relationship between insulin concentrations, physical activity and central fat deposition (AFM/TBF) is of interest as it has been suggested that visceral adiposity in particular is of importance in risk factor aggregation for insulin resistance (Owens et al., 2000; Goran et al., 2001; Krekoukia et al., 2007).

In conclusion objectively measured BF%, TBF, AFM, and body fat distribution was in the present study associated with vigorous activity. Insulin concentrations were independently linked to body fat distribution in addition to vigorous activity. These preliminary observations support the view that both vigorous activity and weight control are of importance for metabolic function, already at an early age and not only in overweight children, and this is worth to investigate further. The development and attempts to implement strategies to prevent sedentary behaviour and overweight in children is likely to be of importance if the prevalence of Type 2 diabetes is to be reduced.

Acknowledgement

The authors are grateful to Lilian Bengtsson for expert technical assistance. This study was supported by the Swedish Research Council (Grant 6834), The Swedish Diabetes Foundation, Albert Påhlsson Foundation, Region Skåne, Centrum För Idrottsforskning and the Faculty of Medicine, Lund University.

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Table 1. Summary of age, anthropometric, blood sample, accelerometer, and DXA data for all children with valid measurements. Values are mean ± SD and range.

	Boys n=82	Girls n=76	p-value
Age (years)	9.9±0.6 (8.6-10.8)	9.8±0.6 (8.5-10.9)	0.12 ns
Height (cm)	141±7 (122-162)	141±7 (124-159)	0.94 ns
Body mass (kg)	35.0±7.7 (20-65)	34.8±6.3 (23-51)	0.79 ns
BMI (kg/m^2)	17.4±2.6 (12.8-28.1)	17.4±2.6 (13.5-26.0	0.94 ns
TBF (kg)	6.1±4.6 (1.3-28.3)	8.0±4.4 (1.9-22.8)	0.01
BF%	16±8 (6.2-43.6)	22±9 (7.2-44.7)	<0.001
AFM (kg)	2.4±2.0 (0.4-11.4)	3.1±2.0 (0.6-9.6)	0.01
Insulin (pmol/l)	85±40 (26-239)	117±86 (36-485	0.002
Average number of days recorded	3.8±0.4 (3-4)	3.9±0.3 (3-4)	0.52 ns
Valid recording per day (h)	12.0±1.2 (8.7-16.2)	11.9±1.3 (8.6-16.4)	0.67 ns
Vigorous activity per day (min)	46±20 (5-116)	35±13 (10-70)	<0.001

Table 2. Unadjusted Pearson correlation coefficients between total body fat (TBF), percentage body fat (BF%), abdominal fat mass (AFM), and body fat distribution (AFM/TBF) vs. selected variables for all children with valid measurements (n=158).

Variables	TBF*	BF%*	AFM*	AFM/TBF
Age (years)	0.03 ns	-0.07 ns	-0.04 ns	-0.06 ns
Insulin*	0.17	0.18	0.18	0.21
Vigorous activity per day (min)	-0.36	-0.39	-0.36	-0.23

*Logarithmically transformed values

Table 3. Regression analysis. Dependent variables were TBF, BF%, AFM, and AFM/TBF. Independent variables were gender, minutes of vigorous activity per day, days of monitoring, age, Tanner stage, and Insulin.

Variables	Coefficient	SE	Total r^2	p-value
TBF*				
Vigorous activity	-0.011	0.003	0.13	<0.001
Gender	0.242	0.097	0.17	0.014
BF%*				
Vigorous activity	-0.008	0.002	0.15	<0.001
Gender	0.276	0.071	0.23	<0.001
AFM*				
Vigorous activity	-0.011	0.003	0.13	<0.001
Gender	0.246	0.111	0.16	0.029
AFM/TBF				
Vigorous activity	-0.0005	0.0002	0.05	0.014
Insulin*	0.015	0.006	0.08	0.023

*Logarithmically transformed values