Simple anthropometric measures to predict insulin resistance in children

Jessica Roser, Alison Jeffery

Article points

1. Insulin resistance is the process believed to underpin the onset of type 2 diabetes and premature CVD.
2. This report examines whether or not simple measures (BMI, waist circumference and skin fold thickness) can predict which children are at risk of high insulin resistance.
3. The simple measures of body size investigated here are all equally good at predicting the development of insulin resistance.

Key words

- Insulin resistance
- Children
- EarlyBird Diabetes Study

At the time of writing, Jessica Roser was a Research Assistant and Alison Jeffery a Research Nurse at Peninsula Medical School, Plymouth.

The incidence of both types of diabetes is rising (International Diabetes Federation [IDF], 2006). Although type 1 diabetes is more common in childhood than type 2 diabetes, the latter is increasingly presenting in adolescents (Pinhas-Hamiel et al, 1996) and has now been diagnosed in UK children as young as 9 years of age (Ehtisham et al, 2000). This article will look at how measurements that can be taken by DSNs can predict the onset of insulin resistance, a forerunner to type 2 diabetes, in young children.

Type 2 diabetes is the outcome of a process known as insulin resistance (IR), where the body's tissues become increasingly resistant to the effects of insulin. It is likely that this process germinates over years, or even decades, before the onset of diabetes, possibly during childhood. It is therefore important to determine which factors during childhood may lead to IR and whether or not it is possible to predict its development. *Box 1* details a number of factors known to be associated with the development of IR.

There is a need to identify children at risk from developing IR because it may be possible to delay or prevent the progression to type 2 diabetes. Lindström et al (2006) found that in adults with impaired glucose tolerance, those who made intensive lifestyle modifications to diet and physical activity were able to delay progression to type 2 diabetes.

DSNs see individuals who are already diagnosed with diabetes. While paediatric DSNs see children with mostly type 1 diabetes, DSNs who work with adults often see those with type 2 and are, therefore, very well placed to educate and advise other family members also at risk. In this respect, DSNs need valid, up-to-date information regarding the development of IR to aid their decision making.

Aim

In this paper the authors explore the use of simple body measurements, including BMI, waist circumferences (WC) and the sum of five skin folds (SSF) to:

- identify trends in body composition during early childhood
- describe their associations with IR
- assess the most useful predictor of IR in children.

Methods

The EarlyBird Diabetes Study is a non-intervention, longitudinal cohort study of 307 (170 Boys, 137 Girls; 98 % Caucasian) healthy children, focusing on the evolution of IR. It aims to explain why some children will develop metabolic syndrome and type 2 diabetes, while others will not. The study began in 2000 when the children had a mean age of 4.9 years and will continue until they reach an age of 16 years. Specific details have been published previously (see: Voss et al, 2003) and Local Research Ethics Committee approval was obtained in 1999. To summarise, the children were recruited from randomly-selected schools of different socio-economic status in Plymouth. Of the 307 children initially recruited, 223 (127 Boys, 96 Girls) provided a full data set, including all measures of adiposity and metabolic variables at every age up to age 9 years.

Box 1. Factors associated with the development of insulin resistance.

- Increased weight. In adults, there is a well-established link between obesity and insulin resistance (Reaven, 1988). This association has been increasingly observed in children (Rosenberg et al, 2005).
- Family history (Rodriguez-Moran and Guerrero-Romero, 2006).
- Certain racial minority groups (South East Asians, Native Americans, Pacific Islanders, African Americans [Arslanian, 1998]).
- Low birth weight. Historical cohorts have shown this association (Phipps et al, 1993), however it no longer seems to be apparent in contemporary children (Wilkin et al, 2002).

Annual fasting measures

- Insulin.
- Glucose.
- IR was measured by the HOMA-IR equation derived from measures of fasting glucose and insulin (Matthews et al, 1985). HOMA-IR has been validated in children by Gungor et al (2004).
- Triglycerides (TG) and HDL-c.

Anthropometric measures

- Height to the nearest millimetre.
- Weight to the nearest 200 g.
- WC to the nearest millimetre.
- Subcutaneous body fat as the sum of five skin-fold measurements including biceps, triceps, subscapular, suprailiac and paraumbilical, all measured via skin fold callipers.
- Dual energy X-ray absorptiometry (DEXA) to validate SSF as a measure of body fat at age 7 years.

Statistical analysis

Means were compared using paired and independent t-tests. BMI data were converted into age and gender specific national reference ranges (standard deviation scores [SDS]) relating to 1990 standards (Cole et al, 1995). We used effect size estimates calculated by the following equation for mean differences to emphasise the practical significance of the results (Hojat and Xu, 2004).

$$\frac{\text{Mean at 9 years of age} - \text{Mean at 5 years of age}}{\text{SD at 5 years of age}}$$

Results

Mean anthropometric data are shown in *Tables 1* and *2*. *Table 1* represents boys from 5–9 years of age and *Table 2* shows the same data collected from the girls. As expected from growing children, all measures of body size increased between ages 5 and 9 years. There was a statistically significant increase in BMI SDS, indicating that these children had crossed BMI centiles, representing weight gain in excess of normal growth. Effect sizes were calculated to determine whether the changes we observed in BMI SDS, WC, SSF and IR were of clinical importance (as opposed to statistical significance). The majority of the effect sizes indicated changes of at least moderate practical importance (ES ≈ 0.50).

The mean WC of boys and girls were similar, but girls had higher BMI scores and significantly more subcutaneous fat, indicated by higher SSF at all ages (data not shown from independent t-tests; $P \leq 0.001$). IR was also much higher in the girls at each age.

In both boys and girls, insulin and IR fell significantly between the ages of 5–7 years ($P < 0.001$, data not shown from paired t-tests).

Page point

1. The EarlyBird Diabetes Study is a non-intervention, longitudinal cohort study of 307 (170 Boys, 137 Girls; 98 % Caucasian) healthy children, focusing on the evolution of insulin resistance.

IR then significantly increased between 7–9 years of age (P<0.001).

There was little association between measures of body size and IR at 5 and 6 years of age. However, a moderately strong correlation emerged at age 7 years and strengthened significantly as the children got older. This was particularly apparent in the girls, where the association between SSF and IR, for instance, increased from r=0.06 at 5 years of age to r=0.63 at 9 years of age (see *Figures 1* and *2*).

Percentage body fat measured by DEXA at 7 years of age was highly correlated with SSF at the same age (r=0.93, P<0.001), indicating that SSF was an accurate measure of total body fat.

Table 3 shows that, from as early as 5 years of age, children who are heavier are at greater risk of developing IR by the age 9 years. The predictive power of each measurement (BMI, SSF and WC) was similar, with SSF having marginally better predictive values at each age. SSF at 5 years of age in the girls explained 14.6% of the variation in insulin resistance at age 9 years. By age 9 years, however, SSF accounted for 38.5% of the variation in insulin resistance. Again, these predictive values were higher in the girls than the boys.

Table 1. Means of BMI, waist circumference (WC), sum of five skin fold (SSF) and insulin resistance (HOMA-IR) in boys (n=127).

Age (years)	BMI (kg/m²)	BMI SDS	WC (cm)	SSF (cm)	HOMA-IR (arbitrary units)
5	15.9	0.17	51.0	3.71	0.46
6	15.8	0.15	52.4	3.85	0.37
7	16.0	0.20	54.4	4.15	0.33
8	16.4	0.27	56.2	4.60	0.37
9	16.9	0.36	58.5	4.99	0.51
Effect size†	0.64 SD	0.17 SD	1.74 SD	1.05 SD	0.16 SD
P value‡	<0.001	0.004	<0.001	<0.001	0.122

† Effect sizes (ES) for significance: ES≈0.20 small practical significance; ES≈0.50 medium practical significance; ES≈0.80 large practical significance.

‡ *P* value from paired t-tests highlighting any statically significant change from 5–9 years.

Table 2. Means of BMI, waist circumference (WC), sum of five skin fold (SSF) and insulin resistance (HOMA-IR) in girls (n=96).

Age (years)	BMI (kg/m²)	BMI SDS	WC (cm)	SSF (cm)	HOMA-IR (arbitrary units)
5	16.4	0.50	51.0	4.50	0.68
6	16.4	0.50	52.4	4.87	0.53
7	16.8	0.52	55.1	5.34	0.42
8	17.3	0.54	56.8	5.90	0.45
9	18.0	0.64	59.4	6.53	0.72
Effect size†	0.91 SD	0.13 SD	1.91 SD	1.19 SD	0.09 SD
P value‡	<0.001	0.071	<0.001	<0.001	0.521

† Effect sizes (ES) for significance: ES≈0.20 small practical significance; ES≈0.50 medium practical significance; ES≈0.80 large practical significance.

‡ *P* value from paired t-tests highlighting any statically significant change from 5–9 years.

Discussion

Families of people with type 2 diabetes will often ask advice about the risks that other family members run with regard to developing diabetes themselves. In responding, the DSN will use his or her expert knowledge of the predisposing factors, stressing the importance of heritability and acquired body weight. This article has attempted to provide more detailed information about factors in childhood that lead to insulin resistance and, ultimately, to type 2 diabetes.

We observed the expected increases in all measures of body size between the ages of 5 and 9 years. Whether the increases are pathological (excess weight gain) or physiological (expected weight gain associated with normal growth) is difficult to establish with certainty, and for this reason we have used measures of BMI SDS. There was a statistically significant increase in BMI SDS between 5 and 9 years of age, indicating upward centile crossing. This, and the effect sizes, indicates that the observed increases in body weight are pathological.

We conclude that those children who are the heaviest are most at risk. We have compared three measures: BMI and WC, which are relatively simple to measure with a little training; and SSF, which requires more training and is used less often in clinical settings. Skin folds, however, correlate very well with total body fat. We found that all three measures correlated very similarly with IR in these young children and no one measure was superior in its predictive value at each age. Unlike adults, very young children have predominantly subcutaneous fat, and little of the visceral fat which is strongly related to IR in adults. WC in adults, used as a proxy for visceral fat, is now the preferred screening

measure in assessing type 2 diabetes risk (St-Pierre et al, 2007), with high predictive values. In young children, however, our data show that BMI measurements give equally good values. Where adult WC growth charts are based on known metabolic risk, children's are not and are not yet widely available in clinics.

Further risk factors (family history, birth weight and early infant growth, socio-economic markers, physical activity and diet) and their contribution to the development of IR will be addressed in future EarlyBird publications.

The data presented here suggest that, with substantially greater IR, young girls are more at risk of metabolic disease than young boys. This may account for the fact that girls are more likely to be diagnosed with type 2 diabetes than boys in young populations (Murphy et al, 2004).

Conclusion

Raising awareness of the impending epidemic of type 2 diabetes, along with its associated cost to the individual and the health service, should be the responsibility of all health professionals. At present, there is no nationwide screening programme to detect diabetes, let alone impaired glucose tolerance or insulin resistance, in adults or children. DSNs are well placed to help raise awareness of the risk factors for diabetes among apparently healthy relations of the people they see with diabetes and among the general public. They are also well placed to advise on prevention. Indeed, some may see an opportunity here to pursue an educational role, both in schools and in the wider community.

Risk factors for diabetes in children are similar to those in adults, although more research is needed to establish the exact contribution of each risk factor, individually and in combination, to the development of the disease. The progression of disease from insulin resistance to impaired glucose tolerance and, ultimately, to diabetes, has a variable time course, but may be accelerated by the transient insulin resistance of puberty and by the increasing strain put on pancreatic ß cells by increased body fat. If insulin resistance and impaired glucose tolerance are detected early enough, positive lifestyle changes and weight management could delay or even prevent conversion to overt diabetes. Importantly, it would greatly reduce the incidence of serious complications.

In conclusion, children and young people at

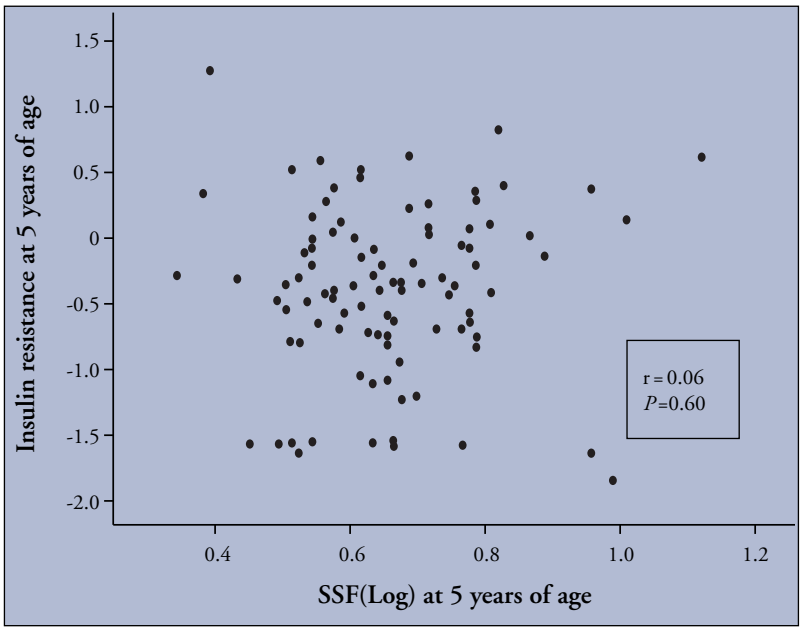

Figure 1. Scatter plot showing insulin resistance and the sum of five skin folds (SSF) at age 5 years in girls.

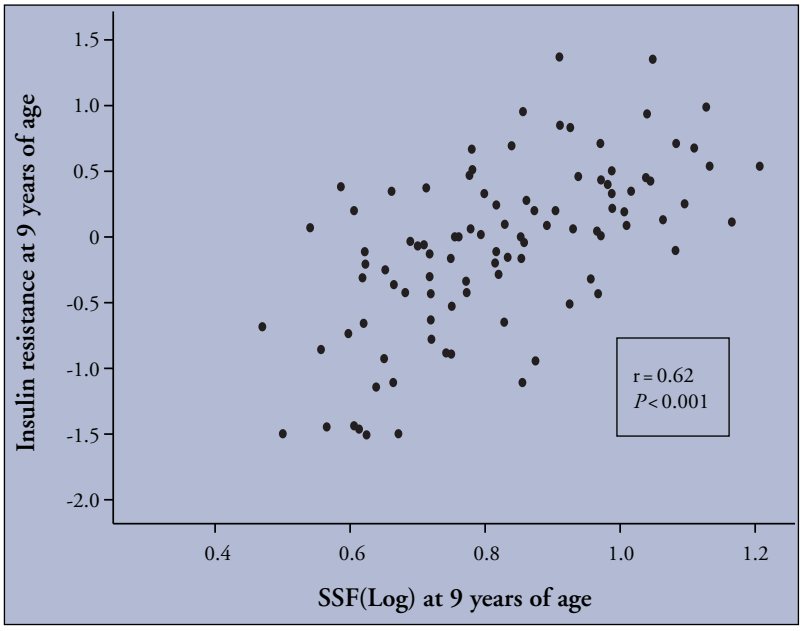

Figure 2. Scatter plot showing insulin resistance and the sum of five skin folds (SSF) at age 9 years in girls.

Table 3. Predictions of insulin resistance at 9 years from BMI, waist circumference and sum of five skin fold measurements at 5 and 9 years of age.

	Boys (n=127)			Girls (n=96)		
Age	**BMI**	**WC**	**SSF**	**BMI**	**WC**	**SSF**
5 years	0.053	0.061*	0.075*	0.112*	0.109*	0.146**
9 years	0.167**	0.178**	0.155**	0.289**	0.320**	0.385**

*P<0.01, **P<0.001

r^2 predictive values were obtained by regression analysis.

increased risk are those with both a BMI and WC over the 91st centile, a family history of type 2 diabetes and those who are ethnically black or South Asian. These children should be referred to their GP or practice nurse for a fasting blood glucose or oral glucose tolerance test,and followed up regularly thereafter. Although single measures allow some assessment of risk, serial measures will give early warning of deteriorating metabolic function.

DSNs have a pivotal role to play in raising diabetes awareness in the families with whom they are in contact, among other health professionals and in the wider community. ■

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