

Body weight reduction to avoid the excess risk of type 2 diabetes

Abstract

Background

It is recognised that people who are overweight have an increased risk of diabetes but the quantitative relationship is less well recognised and the extent of weight reduction needed to avoid the excess risk of diabetes through being overweight, is not well appreciated

Aim

To derive a simple clinical algorithm to calculate the weight change needed to achieve a specified goal for reduction of body mass index (BMI, weight/height squared [kg/m^2]) that would avoid the excess risk of diabetes and quantify the preventive effect.

Design and setting

Analysis of the results from two large published cohort studies of the incidence of diabetes in relation to BMI.

Method

Epidemiological data show that the risk of diabetes doubles for every 2.5 unit increase in BMI above a BMI of $22 \text{ kg}/\text{m}^2$ and halves for every 2.5 unit decrease in BMI down to $22 \text{ kg}/\text{m}^2$. The risk of diabetes also approximately doubles for every 10 years of age. From these relationships, a simple algorithm was derived to specify a person's weight-reduction goal to avoid the excess risk of diabetes.

Results

Converting a BMI-reduction goal (for example, $27 \text{ kg}/\text{m}^2$ to $22 \text{ kg}/\text{m}^2$) into a percentage reduction (in this example, 19%) specifies the same percentage weight reduction (19%) because, as a percentage, the reduction is independent of height. This percentage can then easily be converted into an absolute risk reduction (in this example, a 75% reduction in risk).

Conclusion

The algorithm achieves two objectives: (i) it specifies the weight-reduction goal to reverse a person's excess risk of diabetes due to being overweight, and (ii) it quantifies the risk reduction.

Keywords

body mass index; overweight; primary care; risk reduction; type 2 diabetes.

INTRODUCTION

Being overweight increases the risk of type 2 diabetes (hereafter referred to simply as diabetes). An analysis based on the results from two large cohort, one performed on males¹ and the other on females,² studies showed that, above an 'optimal' body mass index (BMI, weight in kg divided by height in metres squared) value of $22 \text{ kg}/\text{m}^2$, a 2.5-unit increase approximately doubles the risk of developing diabetes, regardless of initial BMI levels. This is shown in Figure 1, which is derived from a logistic regression model based on data from the two cohort studies.³ The proportional risk reduction of developing diabetes is $1 - (0.5^{x/2.5})$, where x is the BMI reduction. So, for example, for a person with a BMI of $27 \text{ kg}/\text{m}^2$, the BMI-reduction goal is 5 BMI units and the diabetes relative risk reduction for this BMI unit reduction is:

$$1 - (0.5^{5/2.5}) = 1 - (0.5^2) = 1 - 0.25 = 0.75, \text{ or } 75\%.$$

For a particular person who knows his or her BMI, it is simple to determine the BMI-reduction goal (by subtracting 22) but their weight-reduction goal depends on their height. This study aimed to derive a simple clinical algorithm to calculate the weight change needed to achieve a specified BMI-reduction goal that would avoid the excess risk of diabetes and quantify the preventive effect.

METHOD

The incidence of diabetes for males and

females was estimated based on an a 10-year risk of diabetes with a BMI of $22 \text{ kg}/\text{m}^2$ as 6 per 1000 in males aged 40–75 years and 4 per 1000 in females aged 30–55 years, derived from a poisson regression of the incidence of diabetes on BMI, using data from each of the two cohort studies.^{1,2} There is little or no difference in the risk of diabetes between males and females at a given age [supported by other studies^{4,5}], but at a given BMI there is an independent effect of age. Allowing for the different age distribution in the two cohort studies,^{1,2} the 10-year incidence of diabetes in males and females combined at a BMI of $22 \text{ kg}/\text{m}^2$ and an age of 50–54 years was estimated as 5.268 per 1000.

The slope of the regression line, m, relating BMI to age-adjusted relative risk of diabetes in Figure 1 is given by the equation $\log_{10}(\text{relative risk}) = mx + c$, where $m = 0.1122054$, $c = -2.469$ and x is BMI. In the cohort study of females, after adjustment for BMI, females aged 60–64 years had a relative risk of 3.4 [95% confidence interval (CI) = 2.5 to 4.6] compared with females aged 40–44 years;¹ it is likely that a similar pattern exists in males. Given the relative risk of 3.4, and assuming the same in males, the risk of diabetes will be approximately doubled for people 10 years older (relative risk 1.84) compared with a 52-year old (the middle age of the two cohort studies). For a specific age, the relative risk compared with a 52-year old is given by the equation $\log_{10}(\text{relative risk}) = 0.02657 \times \text{age} - 1.3818$. These two equations

NJ Wald, FRCP, FRS, director and professor of environmental preventive medicine; **JP Bestwick**, MSc, lecturer in medical statistics; **JK Morris**, PhD, professor of medical statistics, Wolfson Institute of Preventive Medicine, Barts and the London School of Medicine and Dentistry, Queen Mary University of London, London.

Address for correspondence

Nicholas J Wald, Wolfson Institute of Preventive Medicine, Barts and the London School of Medicine

and Dentistry, Queen Mary University of London, Charterhouse Square, London, EC1M 6BQ.

E-mail: n.j.wald@qmul.ac.uk

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How this fits in

Being overweight puts people at increased risk of diabetes. This study shows that the risk doubles for every 2.5 unit increase in body mass index (BMI) above 22 kg/m² and estimates the weight reduction goal to avoid excess risk of diabetes from being overweight. This study derived a simple algorithm, which is available as an online 'Beat Diabetes Calculator', to calculate an individual's weight-reduction goal.

were used to determine the change in risk for a given change in BMI, which was converted into a person's percentage weight reduction required to achieve a BMI of 22 kg/m².

RESULTS

Table 1 shows the relative risk of developing diabetes, the weight-reduction goal, and the relative and absolute reductions in risk on achieving a weight-reduction goal according to BMI for a person aged 52 years. The footnotes indicate the calculations necessary to complete the table, given a person's BMI and indicate the calculations necessary for people of different ages. The relative risk estimate increases from 1.0 (at a BMI of 22 kg/m²) to >30 (at a BMI >37 kg/m²). Table 1 shows that a 2.5 unit reduction in BMI in a person with a BMI of 24.5 kg/m² would reduce the 10-year risk of diabetes by 5 per 1000 (reducing the risk by 47%). Figure 2 shows the percentage reduction in risk of diabetes according to percentage weight reduction. A 10% reduction in weight approximately halves the risk of developing diabetes and a 20% reduction reduces the risk by about three-quarters.

DISCUSSION

The effect of body weight on the risk of type 2 diabetes is substantial and the preventive effect of reducing weight to achieve a BMI of 22 kg/m² is, in turn, considerable. A person's weight-reduction goal can be determined directly without calculating BMI, using the formula: (weight in kg) – 22 (height in metres)², but this would have the disadvantage of not using a measure that directly translates into a person's excess risk of diabetes, which is the case with BMI, and not with weight. The proposed approach using percentage of body weight simultaneously informs people of the weight reduction required to avoid the excess risk and the resulting risk reduction.

An approximate conversion of a percentage reduction in the risk of diabetes to an absolute risk reduction can be obtained by dividing the percentage risk reduction by its complement (for example for an 80% reduction, 80/20) and multiplying this by 5. This yields the absolute risk reduction per 1000 people over 10 years. So, for example, a 75% risk reduction in a person would achieve an absolute risk reduction of 75/25 × 5, that is, 15 per 1000 people over 10 years, or 1.5%.

This algorithm is based on data relating to US health professionals, collected about 20 years ago, but this should not affect the generalisability of the algorithm, particularly with respect to the increase in relative risk with increasing BMI. Since the studies were performed, the prevalence of overweight and diabetes has increased. This does not affect the validity of the algorithm, but does increase the scope for prevention through weight reduction.

On average, an increased BMI reflects an excess in fat tissue but this is not always the case. For example, athletes may have a high BMI due to an increased muscle mass rather than an excess in body fat. The weight-reduction goals shown in Table 1 apply to people on average, but are not applicable to individuals who have a high BMI due to increased muscle rather than excess fat. A simple working rule would be to regard males with a waist circumference of <85 cm (33.4 inches) and females with a waist circumference of <75 cm (29.5 inches) (approximately the 15th centile among 45–54 year old people in England)⁶ as not being at excess risk, regardless of their BMI.

The practical implication of people changing their BMI is difficult to grasp because a person's weight can be reduced but not their height. It is not immediately obvious, for example, what weight reduction

Figure 1. Relative risk of developing type 2 diabetes according to body mass index, based on results from Chan et al 1994 (males)¹ and Colditz et al 1995 (females)².

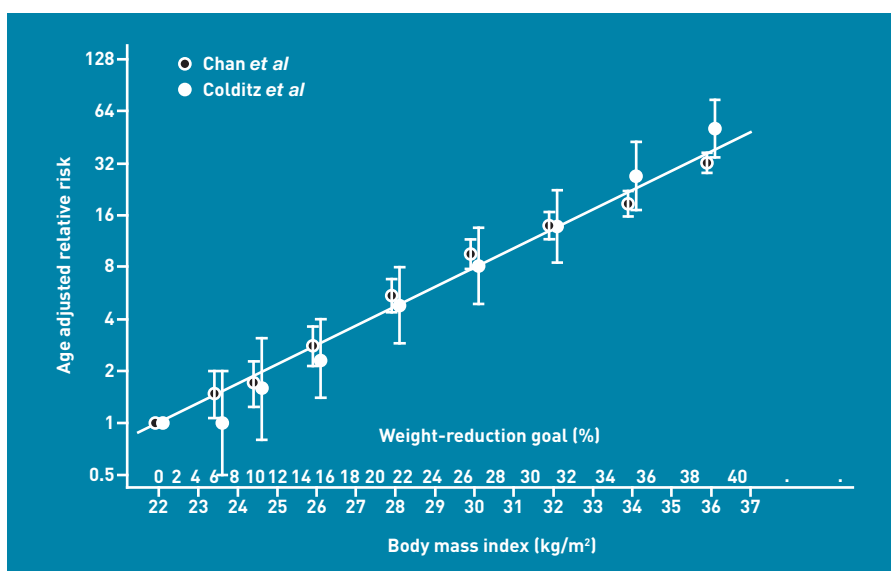


Table 1. Relative risk of developing diabetes, weight reduction goal, and relative and absolute reductions in risk obtained on achieving the weight reduction goal according to BMI

BMI (kg/m ²) (a)	Excess BMI >22 kg/m ² (b)	Relative risk of type 2 diabetes compared with person with BMI of 22 kg/m ² (c)	Weight reduction goal to achieve a BMI of 22 kg/m ² (d)	Relative risk reduction on achieving weight reduction goal (e)	10-year risk of diabetes (per 1000) (f)	Reduction in 10-year risk of diabetes following weight reduction (per 1000) (g)
22	0	1.0	0%	0%	5	0
24.5	2.5	1.9	10%	47%	10	5
27.0	5	3.6	19%	72%	19	14
29.5	7.5	6.9	25%	85%	37	32
32.0	10	13.2	31%	92%	70	65
34.5	12.5	25.3	36%	96%	133	128
37.0	15	>30	41%	>97%	>157	>153
39.5	17.5	>30	44%	>97%	>157	>153
42.0	20	>30	48%	>97%	>157	>153

c, f and g relate to people aged 52 years. For people of different ages the calculations are: $b = a - 22$; $c = 10^{0.1122b - 1.3818 + 0.0265 \times \text{age}}$; $d = b/a$; $e = [1 - 1/(10^{0.1122b})]$; $f = c \times \text{incidence of diabetes for BMI of 22 kg/m}^2 \text{ from Chan et al. 1994}^1 \text{ and Colditz et al. 1995}^2$; $g = f - 10^{-1.3818 + 0.0265 \times \text{age}} \times \text{incidence of diabetes for BMI of 22 kg/m}^2 \text{ from Chan et al. 1994}^1 \text{ and Colditz et al. 1995}^2$.

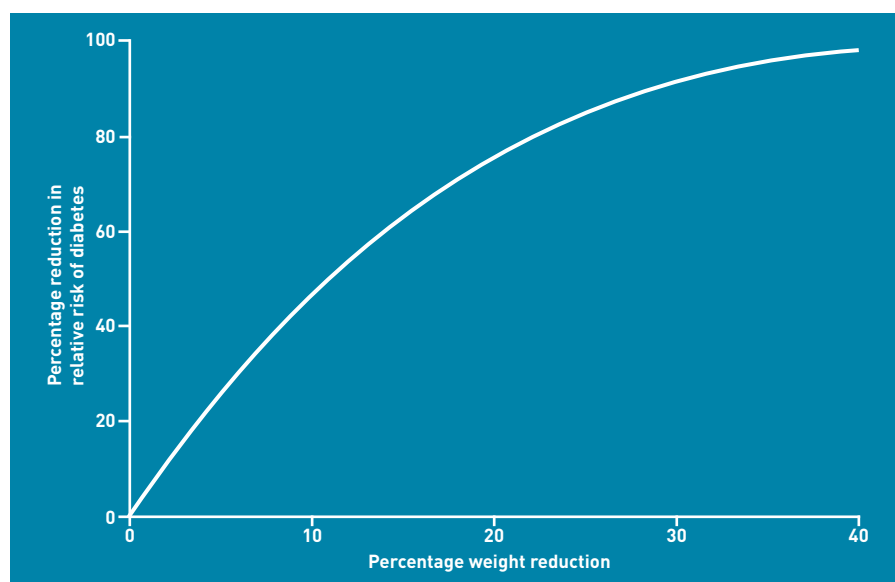


Figure 2. Reduction in risk of diabetes plotted against weight reduction.

is needed to move from a BMI of 25 to 22 kg/m². It is clearer to know that weight needs to be reduced by 12%, the same proportion as the BMI reduction, that is, (25 - 22)/25. This can be converted into an absolute reduction, so, for example, a 70 kg person with a target weight reduction of

10% needs to lose 7 kg. Table 2 sets out the steps involved in determining a person's weight-reduction goal and the consequent reduction in relative risk for type 2 diabetes.

The algorithm is available as an online 'Beat Diabetes Calculator' (<http://www.lmsalpha.co.uk/beatdiabetes/>) that can be accessed free of charge for general use. It calculates an individual's weight-reduction goal to reverse a person's excess risk of diabetes due to being overweight, and calculates the resulting reduction in their risk of developing diabetes in the next 10 years, presenting this numerically and graphically. It produces a printable report that can be given to each individual and kept with his or her medical records.

Informing a person of their weight-reduction goal (rather than their BMI-reduction goal), together with a quantitative estimate of the benefits of achieving that goal, should help focus attention on what needs to be known to avoid the substantial risks of diabetes arising from being overweight. Even if a person's weight-reduction goal is only partially achieved, the gains are considerable and still worthwhile.

Table 2. Calculating a person's weight-reduction goal

Instruction	Worked example for weight = 75 kg (165 lb) and height = 1.7 m (5ft 6 in)
1. Calculate BMI: weight (kg)/height ² (m ²)	$75/1.7^2 = 75/2.89 = 26 \text{ kg/m}^2$
2. Calculate BMI-reduction goal (b): subtract 22	$26 - 22 = 4 \text{ kg/m}^2$
3. Calculate percentage BMI-reduction goal: $100 \times \text{BMI-reduction goal/current BMI}$. This is the weight-reduction goal	$100 \times 4/26 = 15\%$
4. Calculate the absolute weight-reduction goal: current weight \times weight-reduction goal	$75 \times 15\% = 11 \text{ kg}$
5. Approximate relative risk reduction for type 2 diabetes: $1 - 0.5^{b/25}$	$1 - 0.5^{4/25} = 67\%$

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