Preferred meal patterns in non-insulin-dependent diabetes

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Current advice on the across-the-day distribution of energy and carbohydrate intakes in non-insulin-dependent diabetes (NIDD) is based on inadequate evidence. We have addressed this by a comparison of an even as opposed to a main evening meal pattern in 11 subjects with NIDD. Contributions of macronutrients to energy intake were fat 29%, protein 20% and carbohydrate 51% with each meal pattern. The peak glycaemic response in the morning was not as good as the response in the evening ($P<0.01$), where an even energy and carbohydrate spread was used; this contrasts with previous reports in healthy subjects where the morning response to glucose is better than that later in the day. This difference between peak morning and peak evening glycaemic response was not seen with a main evening meal. There was a lower overall glycaemic response with a main evening meal compared with an even meal pattern ($P<0.01$, by area comparison). The overall insulin response was not significantly different between the two meal patterns, although the sensitivity for insulin appeared better in the evening where there was an evening main meal.

Introduction

Most contemporary nutritional advice for those with non-insulin-dependent diabetes (NIDD) is given on the basis that patients should be spared excessive quantities of carbohydrate on any one eating occasion[1]. This has been even more consequential as efforts have been made to increase the proportion of energy from carbohydrate in the diabetic diet[2,3].

However, in most western food cultures, there is a main meal, often in the evening, and a change from this pattern can be socially disruptive. Despite the fact that 24 hour glucose and insulin profiles have been well described in healthy subjects[4] and in diabetes, it is by no means certain that those with NIDD are advantaged in their glycaemic control by avoidance of a main evening meal in favour of a more even spread of carbohydrate over the day. We have studied a group of subjects with NIDD with two different meal patterns in order to resolve this question.

Methods

Subjects

Studies were performed after an overnight fast with only water to drink. The two meal studies were separated by two weeks. Non-insulin-dependent diabetics were selected for this study. All but one, who was on glibenclamide, were managed by diet alone. Each subject gave informed consent. Apart from diabetes, those recruited were in good health. Their characteristics are shown in Table 1. One subject was on digoxin and frusemide to control cardiac failure on the basis of ischaemic heart disease.

Table 1. Characteristics of 11 subjects (4 men and 7 women NIDD).

Subjects	Age (years)	BMI $Kg.m^{-2}$	BP (mmHg)	Years since diagnosis of diabetes
Men (n=4)	63.8±5.0	25.4±0.5	92.5±3.2	3.9±0.6
Women (n=7)	70.0±3.5	28.1±1.1	102 ±1.1	6.4±0.8

One person, a woman, took her usual 2.5 mg glibenclamide at the commencement of breakfast.
(1) The number of subjects is shown in parentheses
(2) The Mean ± SE are shown
(3) BMI = Body Mass Index
(4) BP = the geometric mean blood pressure

$$= \frac{\text{Systolic BP} + 2\ \text{Diastolic BP}}{3}.$$

Meals

We devised two meal patterns, an even and main evening meal, whose energy distribution is shown in Table 2. Total energy was provided on the basis of 20 calories (82KJ) per kg body weight. We devised meals or snacks so that the macronutrient composition was fat 29%, protein 20% and carbohydrate 51%. The carbohydrate was principally from unrefined sources being wholemeal bread, fruit and vegetables, with up to 10% of total energy as added sucrose. In this study, no leguminous vegetables were used. The protein came principally from lean lamb, but bread and small quantities of cheddar cheese also contributed.

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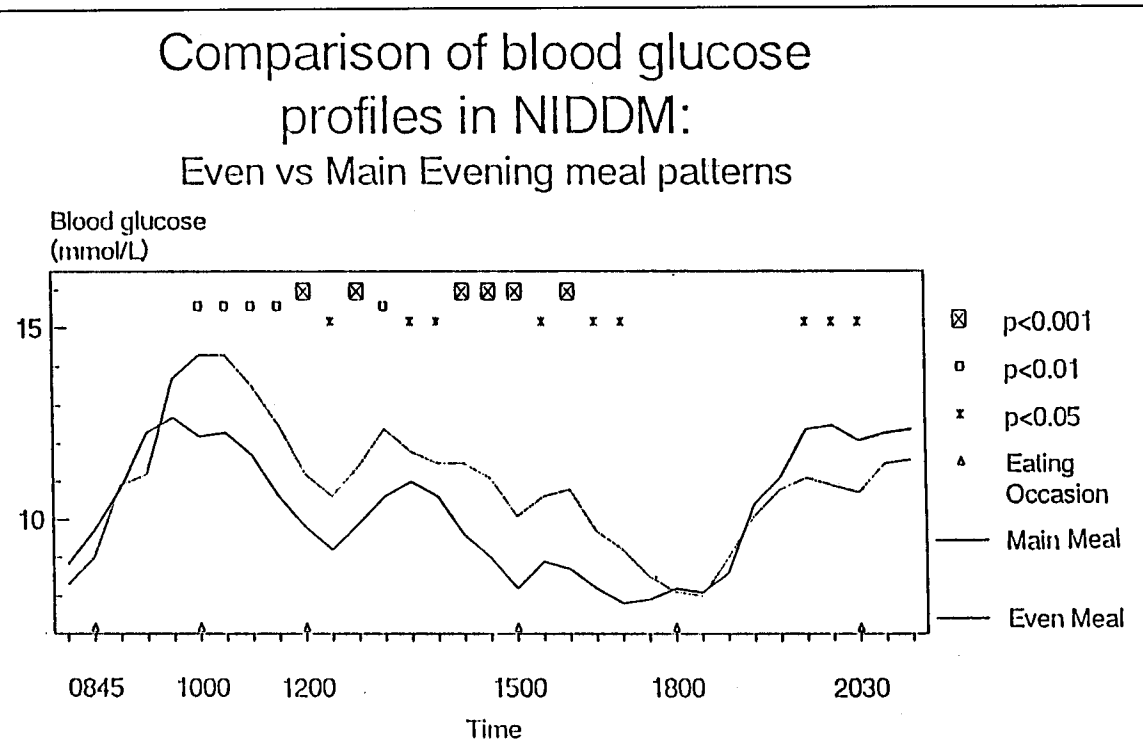

Fig. 1

Table 2. Distribution of energy intake (%) during 24 hours with an 'even' meal distribution or a main evening meal eating pattern.

Meal	Even	Main evening meal
Breakfast	27	14
Mid-morning	6	6
Lunch	27	14
Mid-afternoon	6	6
Evening	27	40
Supper	7	20
	100	100

Time for each subject to ingest a particular meal or snacks was the same, within 5 minutes, for each meal pattern.

Breakfast was at 08.45, mid-morning snack at 10.00, lunch at 12.00, mid-afternoon snack at 15.00, evening meal at 18.00 and supper at 20.30 hours. Where blood glucose or plasma insulin response areas were calculated, they were those from the commencement of one eating episode to the commencement of the next or, for supper, to the conclusion of the study at 21.30 hours.

Analytical methods

Blood glucose was measured by a glucose oxidase method[5]. The CV was 2.3% at 18.4 mmol. L^{-1} n=44. Plasma insulin was measured by radioimmunoassay[6]. The CV was 5.0% at 10–100 $\mu u.ml^{-1}$ n=10.

Statistical method

Paired t-tests were the basis of comparison between meal patterns of particular points in the day where blood glucose or plasma insulin were measured or where areas under the response curves were compared. Area was calculated according to the rule of polygons. Peak glycaemic and insulin responses in the morning and evening were also compared using paired t-tests.

Results

The blood glucose profiles from 08.30 to 21.30 hours for 11 diabetic subjects are shown in Figure 1. The commencement of the six eating occasions of (three meals and three snacks) are indicated by arrowheads. With an even meal distribution, blood glucose concentration was significantly higher in the morning and lower in the evening than with a main evening meal. The total blood glucose response (calculated as area) was greater with an even meal distribution than with a main evening meal (Table 3).

Table 3. Comparison of glucose area (mmol.l^{-1} min) between 'even' meal and main evening meal eating pattern.

	n	Even meal	Main evening meal
Fasting	11	8.3±0.8	8.8±1.0
Breakfast	11	47.5±5.2	45.8±5.1
Mid-morning	11	38.8±5.9*	33.3±4.5
Lunch	11	80.0±11.1*	69.4±10.4
Mid-afternoon	11	47.6±7.1**	40.5±6.0
Evening	11	61.1±3.5	64.8±6.2
Supper	11	11.6±1.4	12.4±1.4
Total	11	285.2±35.5**	264.2±32.7

(1) n=the number of subjects
(2) The mean ± SE are shown
(3) The significant differences between 'Even meal' and 'Main evening meal' patterns is indicated by *$P<0.05$ and **$P<0.01$.

The peak glycaemic response in the morning was greater than in the evening with an even meal pattern ($P<0.01$), but there was no significant difference in these glycaemic responses with a main evening meal (see Figure 1).

Apart from the evening at 20.30 hours when plasma insulin was greater with an even meal pattern than a main evening meal (Figure 2), there were no significant

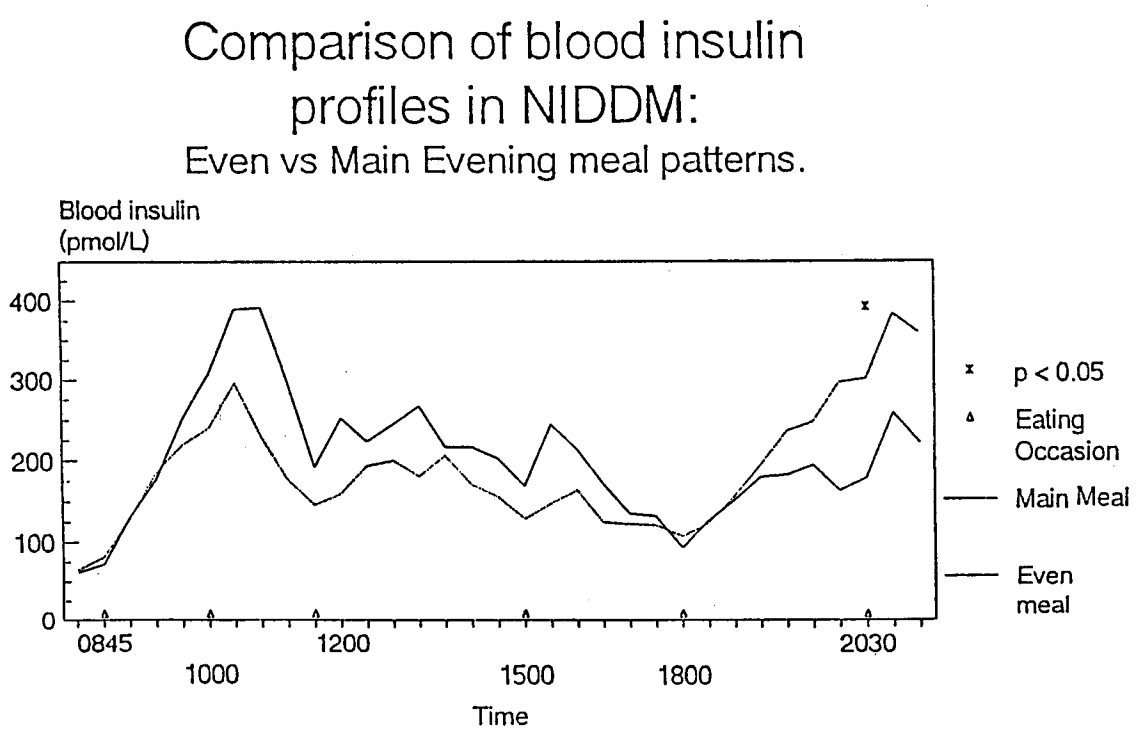

Fig. 2

differences in insulin responses (Table 4). However, the peak insulin responses in the morning were less than the evening ($P<0.05$) for the even meal pattern, but the reverse ($P<0.05$) for the main evening meal pattern.

Table 4. Comparison of insulin area (pmol.l^{-1} min) between 'even' meal and main evening meal eating pattern.

	n	Even meal	Main evening meal
Fasting	11	66±13	63±10
Breakfast	11	690±106	745±158
Mid-morning	11	597±101	988±264
Lunch	11	1259±163	1450±158
Mid-afternoon	11	642±123	604±286
Evening	11	1358±298	1051±177
Supper	11	356±83	243±40
Total	11	4971±804	5511±1177

(1) n=the number of subjects
(2) The mean ± SE are shown
(3) There were no significant differences between 'Even meal' and 'Main evening meal' patterns ($P<0.05$).

Discussion

Diurnal variation in blood glucose

In healthy subjects, glucose tolerance is better earlier than later in the day[7] with an even meal distribution, in the non-insulin diabetics studied, the reverse is the case. However, a main evening meal restores the pattern of blood glucose towards that of healthy subjects. On the day of the study subjects had a low fat intake with the carbohydrate mainly unrefined, it may not be possible to extrapolate our findings to other macronutrient profiles.

Relative values of even versus main evening meal pattern

Morning hyperglycaemic is often a problem in the management of non-insulin-dependent diabetes. From our findings, it would seem possible to improve the morning situation, without overall reduction in glycaemic control, by a move towards a main evening meal pattern. The total glycaemic profile by area was significantly less with a main evening meal than with an even meal pattern, although the full extent of this difference over 24 hours is difficult to judge as the study finished at 21.30 hours.

For many people, especially those with an Anglo-Celtic food and work culture, there is a social advantage in a main evening meal which, for those with diabetes, will be preferred as well. Further consideration also needs to be given to whether the maintenance of a main evening meal pattern long-term would be as beneficial as it appears, in the present study, after changes to it in a single day.

Insulin responses to different meal patterns

The total insulin response, by area, was not significantly different between the two meal patterns. Thus, the improved overall glycaemic control with main evening meal was not at the expense of hyperinsulinaemia. Indeed, plasma insulin was actually greater in the evening with an even meal as opposed to a main evening meal pattern.

Hyperinsulinaemia is said to be adverse for macrovascular disease[8], blood glucose is more important than plasma insulin in the determination of arterial compliance[9]. Whether blood glucose or plasma insulin is regarded as important for macrovascular disease, the main evening meal pattern would still be acceptable. If, in the event that we have measured mainly pro-insulin, as suggested by a recent UK study[10], our findings may not represent an increase in insulin sensitivity in the evening with a main meal pattern, but a changing pattern of pro-insulin to insulin conversion.

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非胰島素依賴性糖尿病（NIDD）患者膳食模式的建議

摘要

目前建議非胰島素依賴性糖尿病(NIDD)患者全日的能量分配和碳水化合物進食量的依據是不足的。我們以１１個NIDD患者爲對象，比較了三餐平均能量分配的膳食模式和以晚餐爲主要能量來源的膳食模式。這兩種膳食模式中，宏觀營養素進食占總能量的百分數是：脂肪占２９％，蛋白質占２０％和碳水化合物占５１％。當進食三餐能量和碳水化合物平均分配的膳食時，糖血反應峰在早晨較傍晚高；這與以前健康對象的研究報告相反，早晨糖血反應峰低于以后的其他時間。當進食以晚餐爲主要能量來源的膳食時，糖血反應峰在早晨與傍晚并無區別。同時，糖血反應峰全面低于三餐平均能量分配的膳食模式。（P＜０．０１，以血糖面積比較）。雖然以晚餐爲主要能量來源的膳食模式對胰島素的敏感性較佳，但兩種膳食模式在全面胰島素反應方面并無明顯差异。