Effect on the postprandial glycaemic level of the addition of water to a meal ingested by healthy subjects and Type 2 (non-insulin-dependent) diabetic patients

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Summary. The effects on postprandial glycaemic reactions of adding a glass of water to a meal were studied in 7 healthy male subjects and 20 Type 2 (non-insulin-dependent) diabetic patients for a period of up to 3 h. The subjects were served a meal of potatoes and meat, with or without 300 ml of water, in random order on two mornings after a 12-h fast. The diabetic patients were considered as well-controlled or not well-controlled according to HbA_{1c} and blood glucose fasting values. Water addition increased the peak blood glucose ($p < 0.02$) and serum insulin ($p < 0.02$) levels in healthy subjects, and the blood glucose concentration in well-controlled diabetic patients ($p < 0.02$). The addition of water also increased the overall blood glucose response, calculated as the positive in-

cremental area, in healthy subjects by $68 \pm 25\%$ ($p < 0.02$) and in well-controlled diabetic patients by $40 \pm 14\%$ ($p < 0.01$). In poorly-controlled diabetic patients, however, the addition of water did not display significant effects, probably due to the varying fasting glycaemia in these patients. Thus, altering the physical property of a meal by dilution with water can affect the physiological responses; the results are considered to be relevant for the on-going discussion concerning the use of physiological responses to foods as a basis for diet instructions to diabetic patients.

Key words: Type 2 (non-insulin-dependent) diabetes, postprandial glycaemia, water ingestion, glycaemic index.

Physiological responses to carbohydrate foods have been suggested as a basis for instructions to diabetic patients [1, 2] preferable to the traditional exchange system built on quantity and molecular weight of the carbohydrate content [3]. This is a conclusion from studies which have shown varying postprandial blood glucose responses after the ingestion of comparable and isocaloric food items. The blood glucose rise following the consumption of potatoes is higher than after the consumption of most other starchy foods [1, 4, 5]. Moreover, the plasma glucose response in healthy subjects is 40–60% lower when a monosaccharide or starch is served as a solid meal, than when the same carbohydrate is given as a liquid [6]. The physical property of starchy foods has also been shown to affect blood glucose and hormonal levels following meals [7, 8].

The identification of meal characteristics that attenuate the glycaemic response is far from complete. In many countries, it is common to drink during a meal, but knowledge of the effects of adding liquids to meals on the postprandial response is limited. It has been re-

ported in abstracts that adding water to meals can increase the glycaemic response in healthy subjects [9, 10]. The effect of drinking during meals on the glycaemic response in diabetic patients is, however, virtually unknown. The rate of gastric emptying affects the absorption rate of meal components and is related to the postprandial blood glucose level after meals [5, 11, 12]. Solid foods of meat, labelled by radioactive isotopes to measure gastric emptying, have been shown to empty separately from, and more slowly than labelled liquids [13, 14]. The initial gastric emptying of another protein-rich solid food (labelled egg), however, is accelerated by the addition of a liquid [5]. A liquid phase which alters the gastric emptying rate of a carbohydrate-rich meal may affect the postprandial glycaemic response.

The following study was performed to measure the glycaemic effect of changing the physical property of an ordinary lunch or dinner, including meat and potatoes, by the addition of a glass of water to be ingested with the meal. Test meals were given to one group of non-

Fig. 1. Mean blood glucose and serum insulin levels before and following ingestion of meals with potatoes and meat, without (■) or with 300 ml of tap water (□), in seven healthy subjects. I = SEM. * = $p < 0.05$; * = $p < 0.02$

diabetic male subjects and to Type 2 (non-insulin-dependent) diabetic patients divided into two groups according to their HbA_{1c} and blood glucose fasting values.

Subjects and methods

Subjects

Seven non-diabetic male subjects (mean age 26 years, range 23–31, mean body mass index (BMI) 23.6 kg/m², range 21.0–29.4) participated in the study on two separate mornings by ingesting a meal (once with 300 ml of water and once without) after a 12-h fast. Similarly, 20 diabetic patients were also studied, divided into two groups according to glycaemic control. One group was defined as well-controlled: twelve patients (10 males and 2 postmenopausal women, mean age 57 years, range 46–67, mean BMI 25.8 kg/m², range 21.5–31.8) with HbA_{1c} lower than 8.0% (mean 6.4%, range 5.1–7.7); their average blood glucose fasting value was 7.3 mmol/l (range 5.6–10.5), and the disease had been diagnosed on an average of four years (range 2–7) before the study. Seven patients were treated with diet alone, four were under treatment with oral sulfonylurea preparations and one with a biguanide derivative. The second group was defined as poorly-controlled: eight patients (all males, mean age 57 years, range 44–71, mean BMI 23.8 kg/m², range 19.2–27.6) with HbA_{1c} values higher than 8.0% (mean 9.8%, range 8.7–11.1); their average blood glucose fasting value was 13.4 mmol/l (range 10.8–16.4) and the mean disease

duration was 11 years (range 4–21). One of these patients had been treated with diet only before and during the study; five were treated with sulfonylurea and biguanide, and two with either biguanide or sulfonylurea. The patients had their usual morning tablets before each test.

All the subjects were asked to keep their usual habits in diet and physical activity the days before and during the tests.

The subjects received written information about the study and gave their consent. The study was approved by the Local Ethical Committee at Sahlgren's Hospital.

Test meals

The test meal eaten by 7 healthy subjects and 20 diabetic patients was composed as a lunch or dinner with fresh potatoes boiled in water for 25 min and then peeled and weighed to the used amount (280 g). The potatoes were served with beef (80 g, inside round) fried in margarine (5 g). The nutritional content of the meal was calculated from food composition tables [16]. Each meal consisted of 415 kcal, with 55% of the energy as carbohydrate. The calculated amount of dietary fibre was 2.8 g. The meal was ingested on 2 separate occasions by each subject, once with a glass of tap water (300 ml) and once without. Supplementation of the meal with a glass of tap water was randomly determined. The subjects were asked to drink the water during the meal and maintain a similar time schedule for both test meals. No other food or drink ingestion, and no smoking was permitted on the test mornings.

Analytical methods

Blood samples were drawn through an indwelling intravenous catheter before the intake of the test meal and at regular intervals up to 180 min after the meal. Blood glucose was analysed by the glucose oxidase method (Merck, Darmstadt, FRG) and serum insulin by a radioimmunoassay technique (Diagnostic products corporation, Los Angeles, Calif., USA). The effect of the water addition on the overall glycaemic response was calculated as the change (per cent) in the positive incremental area under the blood glucose curve. The time at which the maximal blood glucose value was reached was also noted. HbA_{1c} was analysed by an ion-exchange HPLC-technique (normal range 3.4–5.4%).

Statistical analysis

The two-tailed Wilcoxon signed ranks test, paired observations, was used for calculation of differences and a p value < 0.05 was considered statistically significant [17]. The data are given as mean $\pm$ SEM. The Systat program (Systat 4.0, statistics & graphics) was used for all the calculations (Systat, Evanston, Ill., USA).

Results

Healthy subjects

Figure 1 shows the average blood glucose and serum insulin curves following the test meals. Both curves were higher after the meal with water compared to that without added water. The overall glucose response to the meal taken with a glass of water was $68 \pm 25\%$, higher than that after the reference meal ($p < 0.02$). The time taken to reach the maximal blood glucose or serum in-

Fig. 2. Mean blood glucose levels before and following ingestion of meals with potatoes and meat, without (■) or with 300 ml of tap water (□), in twelve well-controlled Type 2 (non-insulin-dependent) diabetic subjects. I = SEM. * = $p < 0.05$; ** = $p < 0.02$

Fig. 3. Mean blood glucose levels before and following ingestion of meals with potatoes and meat, without (■) or with 300 ml of tap water (□), in eight Type 2 diabetic patients ($HbA_{1c} > 8.0\%$, blood glucose fasting value > 10.5 mmol/l). I = SEM

sulin value did not differ significantly following the 2 meals, 36 ± 3 min and 37 ± 4 min, respectively, after the meal with a glass of water, as compared to 41 ± 3 min and 43 ± 4 min following that without ($p > 0.05$).

Diabetic patients

The 12 well-controlled patients showed a higher increase in blood glucose after the meal with a glass of water than after the meal without added water, see Figure 2. The glucose response to the meal with the glass of water was $40 \pm 14\%$ higher than the response to the other meal ($p < 0.01$). The maximal value in blood glucose concentration after the meal with water was reached earlier, at 58 ± 5 min, than after the meal with no drink, 69 ± 6 min ($p < 0.05$).

Ingestion of the test meals by 8 patients with fasting blood glucose values above 10.5 mmol/l and HbA_{1c} above 8.0% resulted in the blood glucose responses shown in Figure 3. The overall glucose response was $12 \pm 14\%$ lower following the meal with a glass of water than following the response to the reference meal (NS, $p > 0.05$). The times at which maximal blood glucose levels were reached did not differ significantly, but were 69 ± 10 min after the meal with a glass of water and 88 ± 13 min after that without ($p > 0.05$).

Discussion

The present study shows lower glycaemic response in healthy subjects and in well-controlled diabetic patients after a meal without a glass of water, compared to the response after an identical meal ingested with 300 ml of tap water. These differences in the glycaemic responses seem to be comparable to the different glycaemic responses of fibre-depleted and fibre-containing meals [11, 18, 19].

To explain the effect of the addition of water to a meal, gastric emptying must be taken into consideration. A more rapid gastric emptying of a meal's carbohydrate-rich solid food, induced by a glass of water, was followed by a higher blood glucose level (unpublished observations). The effect of water addition in the present study on the glycaemic response might, therefore, be explained by an acceleration of the gastric emptying rate of carbohydrates.

A disturbed control of gastric emptying has been described as a rare late complication to diabetes [20, 21]. An impaired gastric emptying pattern of solids and a disturbed ability of the stomach to distinguish solids from liquids have been observed in diabetic patients as compared to healthy controls [22, 23], while other investigations report no such findings in diabetic patients [24]. A different mechanism of action in the digestion process and an altered control of the gastric emptying may explain the proportionally lower difference between the glycaemic responses in well-controlled diabetic patients following ingestion of test meals with varying water contents, as compared to younger, healthy subjects. Disturbed digestion might also explain why no effect of water on the glycaemic response was found in the group of poorly-controlled diabetic patients. A more convincing reason, however, seems to be the difficulties in studies of patients with high blood glucose fasting values. High and varying blood glucose fasting values have been shown to be disturbing factors in the evaluation of effects from different meals [25]. This is supported by a negative correlation between the preprandial blood glucose level and the glycaemic response [26]. Reduced renal excretion of excess glucose due to a lack of water may partially explain the late postprandial hyperglycaemia following the test meal without added water in the group of poorly-controlled

diabetic patients. The findings in this group should be viewed with caution, as they may be a result of poorly-controlled diabetes.

Blood glucose responses to various foods can be reported in absolute values, as in the present study, or as a change from the fasting value [5, 8]. The latter method gives a decreased variation in the blood glucose response, as can be seen in our group of well-controlled diabetic patients. The average SEM for the postprandial values was 0.5 mmol/l (range, 0.1–0.8 mmol/l), as compared to 0.8 mmol/l (range, 0.5–1.0 mmol/l) when absolute values were used. The method also affected the statistical evaluation, as the difference between the postprandial responses following the two meals was clearer when the change from the fasting values was used (significant at 15 ($p < 0.05$), 30 ($p < 0.02$) and 45 min ($p < 0.01$)). Furthermore, use of the glycaemic index, which accounts for the positive incremental area [1], yields a lower inter-subject variation [26]. The importance of the method of calculation for the interpretation of postprandial glucose levels has been pointed out earlier by Gannon and Nuttall [27]. In the present study, however, these methods of calculation have not altered the primary results.

The glycaemic index was developed in order to be used as a method for classifying carbohydrate foods according to their effect on the postprandial blood glucose [1, 26]. The concept is based on a standard calculation method, but it has been pointed out that the composition of the meal and the way in which the food is prepared may alter the predicted glucose concentrations [27–29]. This study has added water to the long list of factors capable of affecting the glycaemic responses to foods. The clinical relevance of the glycaemic index system [1] has been questioned because of the many different factors which may influence the postprandial blood glucose and which have not been sufficiently studied [25, 27–29].

Drinking during meals might have an impact on the control of energy intake. A positive correlation has been observed between gastric transit time and satiety [30] and the texture of food has been shown to affect satiety after meals [31, 32]. Furthermore, the ingestion of a carbohydrate food which gives a low postprandial glycaemic level also delays the return of hunger after the meal in comparison to a high-response food [33]. A drink with a meal, resulting in a more rapid gastric emptying of the meal as well as a higher postprandial glycaemic level (as shown in our study), may therefore affect the short-term feeling of satiety and stimulate energy intake.

In conclusion, our results show that altering the physical property of a meal by the intake of a liquid, demonstrated in this experiment by a glass of water, increases the glucose response in healthy young subjects, as well as in well-controlled Type 2 diabetic patients. No significant effect was seen in poorly-controlled Type 2 diabetic patients. The results are considered to

be of importance in the attempts to gain further knowledge of factors affecting physiological responses to meals.

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