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Exploring the glycemic response to food intake with undergraduate students at the University of La Réunion

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Tarnus E, Bourdon E. Exploring the glycemic response to food intake with undergraduate students at the University of La Réunion. *Adv Physiol Educ* 32: 161–164, 2008; doi:10.1152/advan.00102.2007.—Diabetes constitutes an increasingly prevalent disease, dramatically associated with an enhanced mortality risk in the developed world. A high prevalence of diabetes has recently been described at Réunion Island, a French department located in the Indian Ocean. At the University of La Réunion, a laboratory course involving students was designed to teach them blood glucose measurements and to examine the influence of food intake on their glycemic response. Using glucose meters, test strips, lancet devices, and sterile lancets, students determined their basal and postprandial glycemia. After plotting the variation over time of their glycemia, students calculated their glycemic response to a meal as the area under the curve. First, students observed that their glycemia had increased rapidly after food intake to values of <1.4 g/l and then decreased to normal values, proving the existence of a physiological regulatory system for glycemia. Using impedance balances, students then determined their body mass index and fat mass percentages. Positive and significant correlations were established between students' fat mass percentages and the glycemic response to the meal. A higher postprandial response was indeed noticed for students having higher fat percentages. Therefore, this laboratory allows students to observe the regulation of glycemia. It also alerts them to the correlation between higher body fat content and a higher glycemic response, which can be related to diabetic disorders. This laboratory constitutes an active illustration of their plenary lesson in endocrinology and particularly for the session dealing with glucose regulation.

diabetes; glycemia; glycemic control

THE INCIDENCE OF DIABETES IS INCREASING, with a worldwide prevalence estimated to double by 2030, primarily because of sedentary lifestyle and obesity (12). A strong link between obesity and diabetes is now well established, with >70% of diabetic people being overweight. Type 2 diabetes represents ~85% of all cases of diabetes. This disease, which is characterized by hyperglycemia and insulin resistance, is closely associated with severe complications. Indeed, diabetes increases the risk of developing cardiovascular disease, which represents the leading cause of mortality in Western countries but also leads to chronic renal failure and nerve and vascular damage (9). Although Type 2 diabetes remains more common in aged patients, this pathology is increasingly emerging in the 8- to 19-yr age group (8). The American Diabetes Association recommends screening high-risk youths every 2 yr with a fasting plasma glucose test and also supports educational interventions to promote healthy eating and physical activity (8).

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In the Indian ocean, the inhabitants of La Reunion Island, a French overseas department, exhibit an increasing prevalence of Type 2 diabetes and elevated waist-hip ratios, markers of central adiposity (4). The island provides an example of rapid urbanization and a drastic change in the way of life over just a few decades (4). In one generation, lifestyle, such as eating habits, has evolved from traditional to Western-type habits.

The island is characterized by a very young population, with ~40% of the population under 20 yr old. The prevalence of Type 2 diabetes mellitus in Reunion Island is high, up to 17.5%, among the population aged 30–69 yr, with frequent, early, and severe complications (1, 2, 4, 5). The age of diagnosis is lower than in metropolitan France (3), and 25% of Type 2 diabetic patients are on insulin treatment. A strong association of diabetes with intra-abdominal fat, decreased physical activity, and high-energy intake has been shown in local surveys (4).

At the University of La Reunion, a practical laboratory class on glucose regulation was designed for third-year undergraduate students in physiology. During the laboratory, students were able to measure their blood glucose concentration (glycemia) and could evaluate the impact of food intake on its variation over time. In addition, students measured their fat mass using impedencemetry balances and their body mass index (BMI). The main objective of this laboratory was to make students practice blood glucose measurements and experience glycemia regulation, thus illustrating their plenary lesson on endocrinology. Moreover, through correlations, they could also establish links between high body fat mass and an elevated glycemia response to food intake.

LABORATORY COURSE PROCEDURES

Participants

Students were in their sixth semester preparing for a Bachelor's degree in Biology at the University of La Réunion. During this semester, they attended 38 h of lectures on endocrinology regulation in addition to 10 h of classroom exercises related to endocrinology. They also had to participate in three 4-h long laboratory courses in physiology. The present practical course was the last course and took place during the morning from 8 AM to noon.

Fifty-one students were divided into three groups. All students signed a consent agreement allowing the use of their anonymous data for publication in *Advances in Physiology Education*, and the laboratory activity was approved by the Institutional Review Board.

Students were from 19 to 25 yr old. A multiethnic background characterizes the population of La Réunion, with a wide cultural and religious diversity. Malabars or Tamil of Indian origin represent one-quarter of the island's inhabitants. About 35% of the population has African/Malagasy origin. White Europeans make up approximately one-quarter of the population. The remaining 15% of the population is composed of Métis, Vietnamese, and Chinese people. About the same percentages was found in our student group.

Prelaboratory Readings

About 1 wk before the session, students were given a two-page document to acquaint them with the objectives and protocols of the laboratory. The following text corresponds to the prelaboratory readings:

Laboratory no. 3: Animal Physiology (4 h). The glycemic response after food intake. AIMS. The objectives of this laboratory are to learn one technique for glucose blood concentration (glycemia) measurement and to experience its variation over time following food intake (one "pain au chocolat" and one glass of fruit juice). You will be able to analyze your glycemic response and relate it to other data collected during the laboratory, such as fat mass percentage. It should be noted that glycemia measurement is medically important as it is used in the diagnosis of diabetes. Normal glycemia values measured in a fasting person are between 0.73 and 1 g glucose/l plasma (73–100 mg/dl). When values higher than this range are obtained repeatedly, a case of diabetes could be presumed. You will have the possibility to measure your fasting glucose concentration; to do so, you should come to the laboratory without eating or without eating overnight. Beyond this main aim, your teachers would like to share this experience with the teaching and scientific community through an article in the *Advances in Physiology Education* journal. It is absolutely necessary to read this document in which all events of the laboratory are explained. You will then be able to decide whether you would like to measure your own glycemia. It is of major importance to understand that if you do not want to determine your own glycemia, you will participate in all other laboratory activities (instructions, data analyses, and food intake). Students who volunteer for glycemia measurement will not receive any compensation for their participation in this session. Students who want to measure their glycemia can change their mind at any time during the session and decide not to continue their blood glucose measurement.

EXPERIMENTAL PROCEDURES AND LABORATORY PLANNING. The goal of the experiment is to measure glycemia before and after food intake. Blood glucose concentration is measured in a blood drop obtained from a fingertip. A fairly painless puncture is made on the fingertip with a lancet holder using single-use sterile lancet. The blood drop is then placed on a test strip, which is inserted into a calibrated glucose meter. After a few seconds, this electronic device will give your blood glucose concentration. Please note that these procedures and devices for glycemia determination have been accredited and patented by the French Health Ministry. This protocol for blood glucose monitoring is currently used by diabetic people at home.

Laboratory Procedures

The laboratory course started with a brief introduction to acquaint students with the objectives and methods of the exercise. A precise descriptive demonstration of the tools used for glucose monitoring was performed (OneTouch Ultra Blood Glucose Monitoring System, Lifescan).

Volunteers were then asked to start the experience. In May 2007, when this laboratory was done for the first time at the University of La Réunion, 28 of 51 undergraduate students volunteered for glycemia monitoring. Students were divided into working groups (2 or 3 students/group) containing at least one volunteer. Teachers reiterated one more time that volunteers could stop their glycemia measurements at any time during the laboratory. Each group was given a two-page sheet on which students reported their results and interpretations. This data sheet contained the following:

- Questions about the age and sex of the anonymous volunteer. In addition, volunteers indicate BMI values and fat mass percentages. The latter was determined through an impedance balance during the laboratory class and according to instructions that students already knew from a previous practical course (11).
- A table to be filled in with glycemia values (in g/l). Eight values were obtained (G_0 through G_7), which corresponded to glycemia values at *time 0* (basal fasting glycemia before food intake) and 15, 30, 45, 60, 90, 120, and 150 min after food intake.
- A millimeter grid where students plotted their variation curve of glycemia over time.

On data report sheet, students had the following four other questions to answer before they left the classroom:

- Students determined the time when the maximal value of glycemia was obtained.
- Students calculated the area under the curve (AUC), reflecting the importance of the glycemic response of the subject to food intake. Students used the equation for the area of a trapezoid to calculate the areas of seven trapezoids formed by drawing vertical lines from the data points to the baseline (Fig. 1). More precisely, they calculated the AUC using the following formula:

$$\mathrm{AUC}(\mathrm{g \cdot l^{-1} \cdot min}) = \Sigma\{(G_{tx+1} + G_{tx}) \times [(tx + 1) - tx]\}/2$$

where G_{tx} is the glycemia value (in g/l) at time tx (in min) and G_{tx+1} is the glycemia value (in g/l) at time point $tx + 1$ (in min).

For example,

$$\mathrm{AUC} = [(G_{t15} + G_{t0}) \times (15 - 0)]/2 + (\ldots) + [(G_{t150} + G_{t120}) \times (150 - 120)]/2$$

The last two section of the data report left more than two-thirds of the page for students to write their comments and conclusions.

This two-page data report was filled in by each working group of students during the laboratory and was given to the teacher at the end of the session. We insisted that every student actively contributed to the report. Only the scientific quality of the reports with calculations and the pertinence of interpretations would be evaluated, not the students' personal data.

During two of the intervals between glucose measurements, students were reminded of the principles of glucose regulation, which were recalled through an eight-slide PowerPoint presentation.

RESULTS AND DISCUSSION

Glycemia Monitoring Before and After Food Intake

Values obtained by students are shown in Table 1. Means and SDs were calculated for all data, and subgroups were also

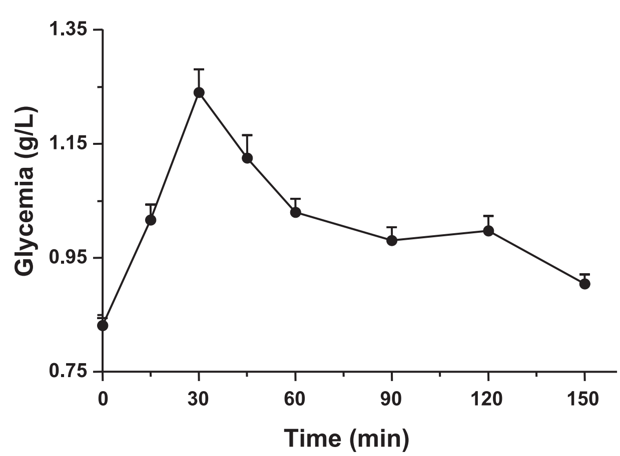

Fig. 1. Recordings (over 2.5 h) of blood glucose in students. Blood glucose measurements were performed at 0, 15, 30, 45, 60, 90, 120, and 150 min after breakfast ingestion. Each point corresponds to the mean ± SE of values obtained by the 23 student (fasting) volunteers for the glycemia measurement. To create trapezoids for calculating the area under the curve (AUC), students drew vertical lines from each data point to the baseline.

Table 1. *Student data*

	Men	Women	Total Group
No. of students	8	15	23
Age, yr	21.3 ± 1.2	21.6 ± 1.5	21.5 ± 1.4
BMI, kg/m^2	22.0 ± 4.3	22.4 ± 5.0	22.3 ± 4.7
Fat mass, %	12.7 ± 6.3	24.6 ± 7.4	20.5 ± 9.0
Basal glycemia, g/l	0.86 ± 0.04	0.82 ± 0.07	0.83 ± 0.06
Maximum glycemia, g/l	1.23 ± 0.18	1.30 ± 0.19	1.28 ± 0.18
AUC, g·l^{-1}·min	150 ± 7	155 ± 14	153 ± 12

Values are means ± SD for student volunteers. BMI, body mass index; AUC, area under the curve.

created according to sex. Basal glycemia results were all in the normal range. We explained to students that glycemic control in patients with Type 2 diabetes is usually assessed by measurements of three markers: percentage of glycosylated hemoglobin, fasting plasma glucose, and postprandial glucose. These markers are commonly described as the "glucose triad" (7).

Even if students know that an experiment should contain a control, they often find it difficult to define exactly what a control is (6). In the present laboratory, students realized that each volunteer was his/her own control and that the basal glycemia result would be the control value. All students (volunteers for blood puncture or not) were then invited to a small food intake consisting of a chocolate roll ("pain au chocolat") and one glass of fruit juice, which actually represents a typical breakfast for young students at the University of La Reunion. We think that it is definitely necessary that all students have the small snack because if only volunteers had access to the snack, that could have been perceived as a compensation for being a volunteer. After washing their hands, students took their snack, which was provided on a table outside the laboratory room.

All volunteers started glycemia measures at the same time. They ate their snack for 10 min so that there was no big difference in the experiment progression for all of them.

Changes in postprandial glycemia were plotted (Fig. 1) on the data report, and students calculated the AUC, which expresses the glycemic response to food intake.

Examples of Student Comments for the Interpretation of the Experiment

The following are examples of student comments regarding the interpretation of the experiment:

- "Our basal glycemia is in a normal range (between 0.8 and 1.1 g/l of glucose). The glycemia increases rapidly after food intake to values less than 1.4 g/l and decreases to normal values, proving the existence of a physiological regulatory system for glycemia."
- "Blood glucose levels are regulated by insulin/glucagon ratio. This way, during the postmeal period, glycemia, after a moderate increase, comes back to basal values because of insulin action. Insulin stimulates glucose absorption by the peripheral tissues (muscles and fat) and activates the synthesis of glycogen and lipids."
- "We observed a big increase in glycemia during the first 30 min following food intake but also a very slight one about 100 min after the snack. We hypothesize rapid/simple sugar in our meal induced the first important glycemic response and slow/complex sugars also present in our snack were responsible for this moderate and delayed second glycemic response."

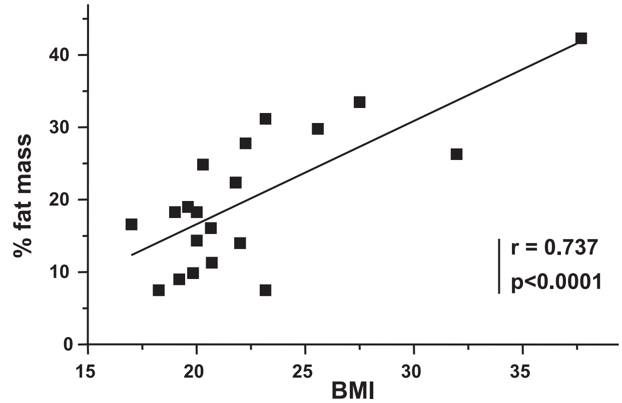

Fig. 2. Correlation between fat mass measured with an impedance balance and the body mass index (BMI). Fat mass percentages were determined with an impedance balance, and BMI (in kg/m2) was calculated as weight (in kg) divided by height (in m^2).

Most of the students participated in this laboratory had attended a laboratory entitled "evaluation of body composition" (11) 1 yr before. The association of BMI and obesity was again demonstrated here to students by the establishment of a positive correlation between BMI values and fat mass percentages (Fig. 2). All participants' data showed a positive correlation (Fig. 3) between fat weight percentage and the glycemic response, a practical illustration of the link between fat composition and the development of Type 2 diabetes. Teachers in this laboratory agreed in a procedure to handle abnormal results should they occur. In particular, students who exhibited glucose intolerance (glucose >1.4 g/l after 2 h) would be sent with their results to their physician or to the University Health Service.

Conclusions

This laboratory course was conducted to allow students to experience glycemia regulation. During this session, students addressed the following three questions:

1. Why should one evaluate his/her glycemia or postprandial glycemic response? During the laboratory, special emphasis was put on the strong link existing between obesity and

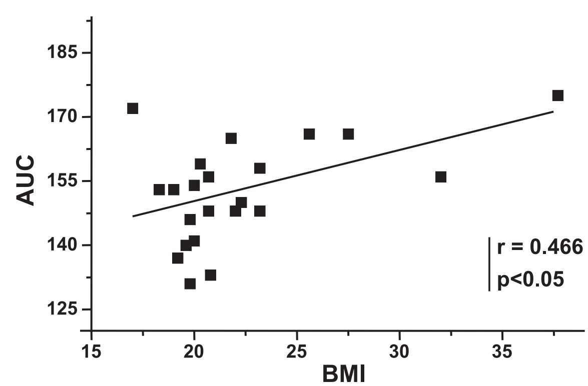

Fig. 3. Positive association of the glycemic response (AUC) with BMI. The glycemic response to food intake was estimated by calculating the AUC using a summed trapezoid method as explained in LABORATORY COURSE PROCEDURES. BMI (in kg/m^2) was calculated as weight (in kg) divided by height (in m^2).

metabolic syndrome. The two teachers involved in this class are also researchers working on the interaction between inflammation and adipocytes in Type 2 diabetes/obesity pathophysiology (3, 10), and they used recent scientific data to illustrate the link between Type 2 diabetes/obesity and enhanced morbidity.

2. How can glycemia be evaluated? The major part of this laboratory consists of students using contemporary techniques for glycemia data acquisition. Students learned to make accurate measurements using the same equipment used in clinical settings.

3. How can experimental data obtained during the laboratory be analyzed? This exercise provided students with the opportunity to collect, graph, and evaluate data and interpret their results using a simple two-page report.

In addition to these three main objectives, the laboratory engages students in a real public health problem. Diabetes symptoms do not appear until the pathology has become well established, sometimes for years. Glycemia monitoring remains the best method to detect prediabetic states and also make people sensitive to the influence of their livestyle (rapid sugar consumption, BMI, fat content, etc.) on the physiology of their body and on their health.

Students' reactions to this laboratory were very positive. All students participated very actively, even those who did not volunteer for the glycemia measures. More than half of the students volunteered to monitor their own glycemia. The quality of their written reports was, in most cases, very satisfactory.

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