**Journal of Diabetes Science and Technology**
Volume 1, Issue 1, January 2007
© Diabetes Technology Society



# Teaching Diabetes to Middle-School Students with the www.2aida.net AIDA Online Diabetes Software Simulator

Andres Palacio, M.D.,[1] Eldon D. Lehmann, M.B. B.S., B.Sc. (Hons.), Ph.D., F.R.C.R.,[2,3]
Darin E. Olson, M.D., Ph.D.[1,4]

## Abstract

***Introduction:***
The lifetime risk of developing diabetes for students born in the new millennium in the United States is estimated to be 27% to 52%. Many students need to learn about diabetes for their personal care, or desire to learn about diabetes to develop a career in healthcare. Most teenagers are adept at learning through Web-based computer tools.

***Methods:***
Twenty-one students entering 8th and 9th grades (aged 12 to 14 years old) enrolled in a Biotechnology Summer Camp focused on diabetes. Lectures on pathophysiology and clinical aspects of diabetes were followed by simulated cases using the AIDA online diabetes software simulator accessed via the internet at *www.2aida.net*. Two cases demonstrated glycemic effects and pharmacokinetics of insulin administration, diet, and exercise in insulin-dependent (Type 1) diabetes and non-insulin-dependent (Type 2) diabetes. Students filled out standardized evaluations at the end of the session to assess receptiveness to this type of learning; opinions on the utility, information, and ease of use; and perceived risks of using the online simulator to understand diabetes.

***Results:***
All students were receptive to this educational tool. The majority found AIDA online useful (17/21 [81%]), educational (21/21 [100%]), worthy of wider distribution (20/21 [95%]), and would recommend the program to others with diabetes or wanting to learn about diabetes (18/21 [86%]). A minority (2/21 [9.5%]) found the program risky regarding the information given to the students. Positive comments included the ability to visualize concepts being taught in earlier lectures, and recognized the rigors required to manage diabetes. Fewer negative comments reflected frustration with the web-based user interface, the course materials, or difficulty in achieving good simulated glycemic control.

***Discussion:***
Teaching pathophysiology of diabetes and pharmacology of insulin to middle school students is enhanced with the AIDA online diabetes simulator. Future versions of this program, and development of similar programs, could be useful in teaching adolescents who have diabetes, and might help stimulate interested students to learn more about the care of people with diabetes.

*J Diabetes Sci Technol 2007; 1:106-115*

**Author Affiliations:** [1] Division of Endocrinology Metabolism & Lipids, Emory University School of Medicine, Atlanta, Georgia, [2] Department of Imaging (MRU), Imperial College of Science, Technology and Medicine (NHLI), Royal Brompton Hospital, London, United Kingdom, [3] Department of Imaging, University of Toronto, Ontario, Canada, [4] The Atlanta VAMC, Atlanta, Georgia

**Abbreviations:** (BG) blood glucose; (PC) personal computer

**Key Words:** AIDA, computer, diabetes, simulation, software

**Corresponding Author:** Dr. Eldon D. Lehmann, Ph.D., F.R.C.R., c/o www.2aida.org Diabetes Simulator Development Team, P.O. Box 38265, London NW3 7XZ, United Kingdom, *www@2aida.org*

## Introduction

Diabetes is one of the most common chronic diseases in children and adolescents. An estimated 150,000 people below the age of 20 in the United States have diabetes.[1] Historically, diabetes occurring in childhood has most commonly been due to insulin-dependent (Type 1) diabetes mellitus.[1] However, in the last 20 years non-insulin-dependent (Type 2) diabetes has been reported among children and adolescents in the United States with increasing frequency.[1] If the obesity epidemic is not tackled, it has been estimated that the risk of developing diabetes for students born in the new millennium in the United States will be about 27% to 52% during the course of their lives.[2]

Dealing with and understanding the treatment of diabetes is a complex process. Young patients and their family members have multiple outlets of information including physicians, diabetes educators, pharmacists, and other individuals with diabetes. Increasingly, computers have become available; a 2003 census found computers in over 60% of households in the United States,[3] and the Internet can be accessed by over 87% of American teens.[4] We are interested in advancing the ability to teach students about both Type 1 and Type 2 diabetes using computer-based methods.

AIDA is a freeware computer program that permits the interactive simulation of plasma insulin and blood glucose (BG) profiles for demonstration, teaching, self-learning, and research purposes.[5] The downloadable personal computer (PC) program (AIDA v4) has been available for free on the internet for over 10 years.[6,7] It has been described in detail elsewhere in the literature.[8] The program is a self-education tool, particularly for people with diabetes and their relatives, as well as for heath care providers and students.[9]

The software is not designed for individual patient simulation, but is meant to create a learning environment for users to better understand diabetes. Previous versions of AIDA have been useful in recreating clinical situations that allow the user to better understand insulin and glucose metabolism via a stand-alone program on a desktop computer.[10]

A web-based version of the program, called *AIDA online*, has been available on the World Wide Web since 1997/1998 as a non-commercial contribution to diabetes education (accessible directly at *www.2aida.net*). AIDA online includes a standard Web-browser interface. The web-based version includes tutorials to learn about the program, descriptions of the mathematical model that comprises the program, and sample cases to illustrate the effects of standard insulin preparations on BG levels. The program allows manipulation of example patient parameters such as weight, insulin sensitivity, renal function, and threshold for glycosuria. Input parameters include carbohydrate ingestion and insulin dosing. The output of the program is the simulated BG, with supplemental information regarding the simulated plasma insulin values. User reviews of AIDA online,[11] a summary of its development,[12] and an overview of how it works[13] can be found elsewhere in the literature.

Diabetes was chosen as the focus of study for a Biotechnology Summer Camp for middle school students. We chose to use the AIDA online program to help the students understand some basics of insulin pharmacology, as well as the effects of insulin in a simulated young patient with Type 1 diabetes, and the effects of both insulin and changes in diet and lifestyle in a young patient with Type 2 diabetes.

In this report the methods of demonstrating the different principles with AIDA online are described. Students' responses to AIDA online were recorded using a similar questionnaire to that previously used to evaluate AIDA v4.[14] The main aims of the current study were: 1) to establish what children thought about AIDA online, 2) to assess the utility of the program, 3) to identify problems experienced by users, and 4) to identify features that students felt were important, and to see if they could be incorporated in later releases of the program.

## Methods

### *Participants and Program Design*

Twenty-one children aged 12 to 14 years old participated in a two week Biotechnology Summer Camp run by a set of school science teachers from June 12th to 23rd, 2006 at the Georgia Institute of Technology in Atlanta as part of a National Science Foundation grant that includes a component of community outreach open to all students. Two of the authors acted as instructors, accompanied by two middle school science teachers monitoring the course. They devised extra questions to ask the students at the end of the workshop. The teachers have found the program to be a popular *day camp* for American students who do not attend school during the summer.

The students were given a one-hour lecture on the morning of June 13th, 2006 as an introduction to the course, and received a one-hour general lecture on the morning of June 14th about clinical diabetes. The workshop tutorial with

AIDA online was held on June 14th in the afternoon. The students and lecturers met from 12:30pm to 3:00pm. The first 15 minutes were spent over-viewing AIDA online, before starting the interactive workshop tutorial session, which lasted approximately 2 hours from 12:45pm until 2:45pm. AIDA online remained available to the students to use informally on their own in the classroom for 15 to 30 minutes after the end of the formal workshop tutorial.

Two new case scenarios were created using AIDA online to illustrate different principles regarding the effects of diabetes in school-age children. Students were led through the case scenarios with a PowerPoint™ presentation given by one of the authors. Students worked alone or in pairs on computers connected to the internet. As the instructor described each step, the students implemented the changes in the AIDA online parameters to illustrate the principles being taught. The instructions for each step of the procedure, and the expected output, were reflected in the PowerPoint™ presentation, reinforcing diabetes concepts while students independently experimented with AIDA online.

### *Understanding Insulin Pharmacology*

Students were first instructed to focus on the effects of insulin injections in an example of a subject with Type 1 diabetes. Students explored the pharmacokinetics of regular and NPH insulin injections given at different times of the day by looking at the resulting plasma insulin levels, and the effect of insulin by looking at the BG values. Initial parameters reflected no endogenous or exogenous insulin. In order to run the program without insulin input and get values that would make sense in testing the pharmacokinetics of insulin injections, some carbohydrate values had to be entered. We arbitrarily chose to put in small amounts of carbohydrate at several time points in order to mimic basal endogenous glucose production. The input parameters for the insulin injections were initially set to zero (see **Figure 1** for details of the initial regimen).

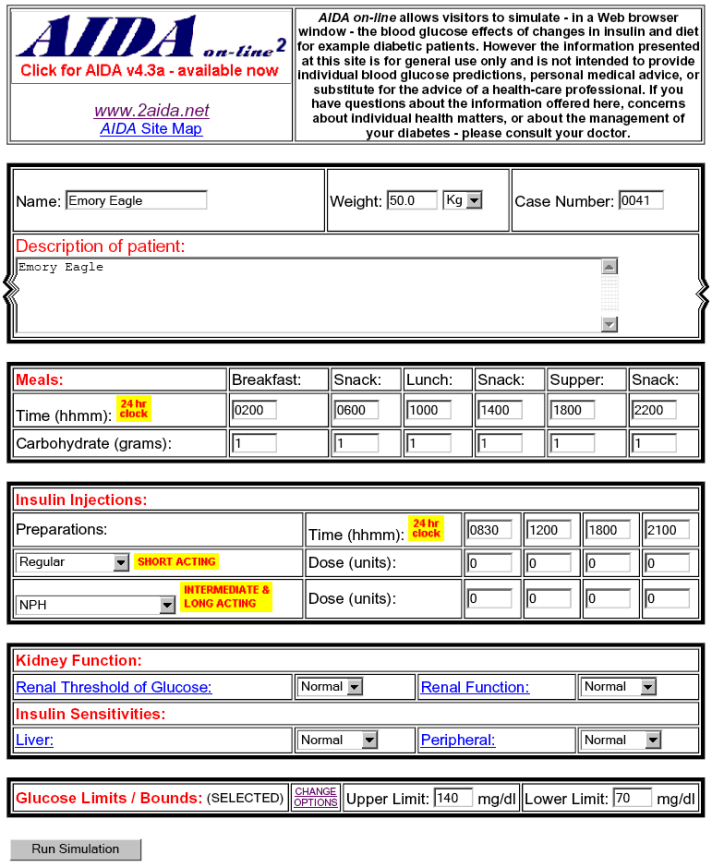


**Figure 1.** Example of input screen for AIDA online @ www.2aida.net showing the initial input parameters for case number 0041 (especially created for this workshop tutorial); a thin teenage boy with Type 1 diabetes and no complications. Weight set to 50 kg, initial carbohydrate inputs set to mimic basal endogenous glucose production. No exogenous insulin injections. Initial physiological parameters including renal function and insulin sensitivities all set to normal.

Students were instructed to run the simulation to observe elevated glucose values in the absence of any insulin injections in Type 1 diabetes. Pharmacokinetics were then evaluated in the following way: Students were instructed to look at the plasma insulin levels after single injections of regular insulin, multiple doses of regular insulin, single doses of NPH insulin, twice-daily dosing of NPH insulin, and finally NPH and regular insulin given together or separately at several times during the day.

After becoming familiar with the timing of insulin entering the blood, the students focused on the effects of insulin on BG. The students were instructed to look at the BG curves with the initial settings of low background carbohydrate input, and typical values of NPH and regular insulin added to the initial example. Glycemic targets were arbitrarily chosen to be 80 to 120 mg/dl (4.4-6.7 mmol/l) fasting, and 100 to 150 mg/dl (5.6-8.3 mmol/l) one to two hours after a meal. Students were asked to identify the times when the blood sugar was outside these ranges. Students were expected to acknowledge that insulin levels drove sugar down, and the next step would be to normalize the glycemic curves by including mealtime carbohydrate ingestion and adjusting the timing, dose, and frequency of NPH and regular insulin to match three meals a day.

### *Understanding the Effect of Meals, Insulin, Diet and Lifestyle in Type 2 Diabetes*

The second case was designed to illustrate the effects of Type 2 diabetes and insulin resistance. The example patient was a teenage girl who was obese, with impaired insulin sensitivity, but normal renal function and glycosuric threshold. Relative insulin deficiency was implemented in the initial parameters of the example by including relatively low doses of regular insulin at three mealtimes, and relatively low doses of NPH insulin twice a day. Meal sizes were chosen that would approximate the number of calories necessary to maintain slow weight gain in a 100 kg youth, arbitrarily assuming that carbohydrates made up approximately 30% of total daily caloric intake.

Students were first instructed to notice the elevated BG at all times. It was pointed out that this occurred despite insulin levels similar to those that achieved normal glycemia or hypoglycemia in the first example, highlighting that insulin resistance with relative insulin deficiency leads to hyperglycemia. Students were then instructed to increase insulin doses at mealtimes and with twice daily NPH insulin to attempt to achieve glycemic goals. After noticing that high levels of insulin were required to maintain normoglycemia on the initial diet, the students were instructed to explore the effects of reducing meal sizes. Once meals were adjusted, students were instructed to further reduce the simulated insulin injections to achieve normal BG.

On the reduced diet, it was assumed that insulin sensitivity would improve and weight would decrease. These changes were made to the input parameters, and simulations run to illustrate the glycemic benefits of reduced diet. If blood sugar got too low after making these changes, as expected, the students were instructed to adjust the insulin injections according to their understanding of the effects of regular and NPH insulin.

### *Exploring Diabetes and Insulin Resistance in Personal Examples*

After the two cases, the students were encouraged to create new examples based on their own weight, diet, and estimated insulin sensitivity and renal function. The underlying supposition was that the students could explore how insulin would be expected to work in their own bodies, and give an idea of the decision-making process that a student with diabetes would experience daily. Students were instructed to look at the BG curve and record the BG readings before meals, one to two hours after a meal, and at bedtime. Students were then encouraged to experiment with different values of insulin and mealtime carbohydrate ingestion until glycemic goals were achieved, while recording BG, insulin doses, and meals. They were also asked to recognize what changes in input parameters made BG values go high or low.

### *Survey of Students' Opinions after using AIDA online*

A survey was taken retrospectively by the children based on a previously published questionnaire.[14] The survey questionnaire was divided into three main sections. The first section covered the interest and utility of AIDA online. The second section covered the limitations of, and possible safety issues with, AIDA online. The third section of the questionnaire asked for specific comments about the students' experience with AIDA online. In addition, students were asked to describe features they would like to see in future versions of the software, as well as their subjective responses to the workshop tutorial.

All survey data were separately analyzed at the Emory University School of Medicine by independent authors (AP and DO) who were not involved with the original development of either AIDA v4 or AIDA online.

## Results

### *Utility of AIDA online*

AIDA online was readily accessed simultaneously by 12 computers. **Figure 2** shows an example of how the workshop tutorial was organized with students following guidance from the lecturer via an overhead projector (showing the PowerPoint™ presentation).


**Figure 2.** Shows just under half of the Biotechnology Summer Camp class, with students running the AIDA online simulations under the guidance of one of the authors (AP).

Intermittent interruptions were experienced with internet access to *www.2aida.net* that were resolved by restarting the examples. Similar interruptions were not encountered when running the simulations from a single computer. During the course of June 14, 2006 (the date of the workshop tutorial) approximately 550 simulations were run at AIDA online, compared with approximately 100 simulations per day for a more representative (non-workshop) day (Lehmann, personal communication).

Questionnaire surveys were collected at the end of the workshop tutorial from each of the students (**Table 1**) and eighteen of them (86%) reported AIDA online to be of interest as an educational tool. Seventeen participants (81%) found the program to have utility, and 12 (57%) expressed a desire to continue using the software. Of the four negative responses about the utility of the program, only two found it "*confusing*" or "*complicated*," one desired "*more choices*," and the other was otherwise positive in all responses expressing a desire for an expanded program of "*diabetes that you can play* [*with*]". All of the children (100%) believed that local and national diabetes associations might be interested in finding out more about AIDA online, and that AIDA online was worthy of wider distribution. Only three (8.6%) of the participants had come across any tools like AIDA online for diabetes self education, while the majority (86%) had no previous experience with such a simulation approach. Eighty-six percent were willing to recommend the program to friends, colleagues, or people with diabetes. In terms of safety, the majority of children (90.5%) thought the program was safe. However, only 13 children (62%) thought the caveats provided with AIDA online made the limitations of the program clear.

**Table 1.** Outline of selected responses to the AIDA online questionnaire (based on the AIDA v4 questionnaire in Tatti & Lehmann).[14]

| Abbreviated question | Replied, n | Yes, n (%) | No, n (%) |
|---|---|---|---|
| Does AIDA online have educational value? | 21 | 18 (85.7%) | 3 (14.3%) |
| Does AIDA online have some utility? | 21 | 17 (81%) | 4 (19%) |
| Will you continue to use AIDA online? * | 22 | 12 (54.5%) | 10 (45.5%) |
| Is AIDA online likely to be of interest to local/national diabetes associations? | 21 | 21 (100%) | 0 (0%) |
| Would you inform other people about AIDA online? | 21 | 18 (85.7%) | 3 (14.3%) |
| Could AIDA online be considered in any way unsafe? | 21 | 2 (9.5%) | 19 (90.5%) |
| Have you come across any tools like AIDA online for diabetes self education? | 21 | 3 (14.3%) | 18 (85.7%) |

* one child answered both yes and no to the same question.

### *Illustrations of Insulin Pharmacokinetics with AIDA online*

Using the first case, and a single insulin injection of 5 units of regular insulin given at 0800 hrs, the students observed modeled plasma insulin levels (**Figure 3**). The observations were extended for repeating regular insulin injections at each meal (examples not shown), then repeated to see the difference with NPH insulin given once a day (**Figure 4**), or more (examples not shown). Student responses to this section of the workshop tutorial included recognizing AIDA online "*shows how hard it is for diabetic patients and doctors to see the amount of insulin*," and comments that having an instructor was useful for this level of student "*if you don't have an instructor guiding you through it, it can be rather confusing*."

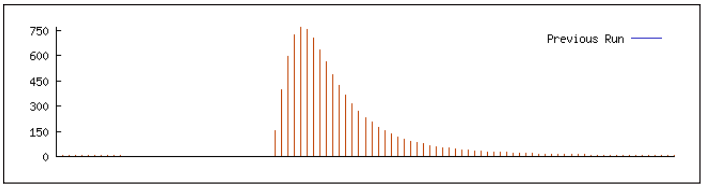


**Figure 3.** AIDA online calculation of systemic insulin levels in mU/L after injecting 5 units of regular insulin subcutaneously in a 50 kg subject with normal renal function. Previous Run not shown.

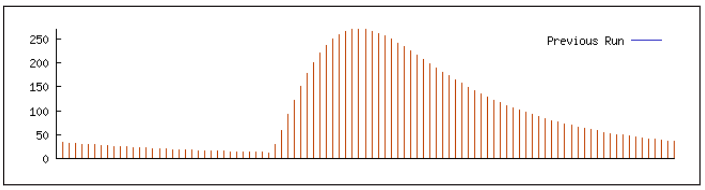


**Figure 4.** AIDA online calculation of systemic insulin levels in mU/L after injecting 5 units of NPH insulin subcutaneously in a 50 kg subject with normal renal function. Previous Run not shown.

### *Demonstration of Glycemic Control in Type 1 Diabetes*

After several iterations of changing meals, timing of insulin injections, and doses of insulin, the students came up with methods of achieving the BG goals and avoiding severe hypoglycemia in the simulation (**Figure 5 -** *see right column*). Students were more engaged during the parts of the workshop tutorial that involved changing the parameters (Palacio and Olson, personal observation) feeling that they were discovering "*to teach how to cure type one diabetes*"; "*how to make a plan for diabetes*"; and commenting "*I never knew it was so hard to control blood sugar levels*."

### *Demonstrating Pathophysiology of Type 2 Diabetes with AIDA online*

The second example was started with arbitrary doses of insulin chosen to simulate inadequate plasma insulin levels that might be seen in an obese individual with relative beta-cell failure, in the setting of reduced insulin sensitivity. The resulting BG levels are shown in **Figure 6**, as well as the BG levels that would result from a reduced diet. Further benefits of diet and lifestyle changes were incorporated into the workshop tutorial, by assuming that a reduced calorie diet combined with exercise would lead to a decrease in weight and normalize insulin sensitivity. The subsequent BG levels were reduced in response to elevated plasma insulin levels (**Figure 7**), as a function of the same insulin injections into a smaller body, and the improved insulin sensitivity due to exercise. Not shown in **Figure 7**, but pointed out to the students, was that the initial insulin levels which were chosen to model relative beta-cell failure were still inadequate to restore normal BG, meaning that treatment for Type 2 diabetes would still be warranted in the example. Some of the students had trouble incorporating the information from all of the graphs in the output, calling the extra graphs "*confusing*," and requiring "*more explanation*." However, other students wished to know more specifics and requested the addition of "*exercise*," per se, to the simulations.

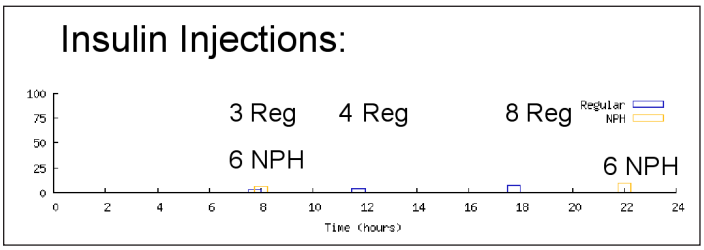


**Figure 5A:** Insulin Injections

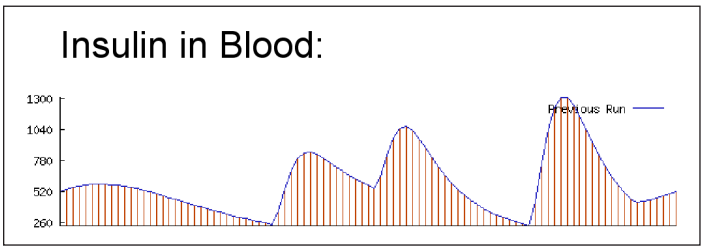


**Figure 5B:** Insulin in Blood

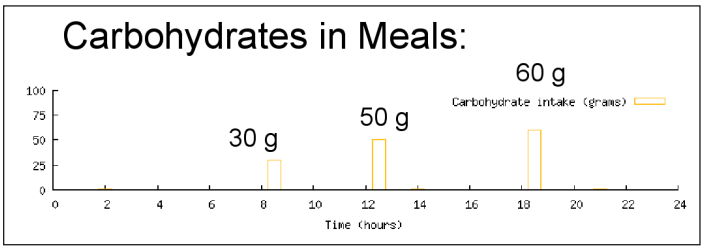


**Figure 5C:** Carbohydrates in Meals

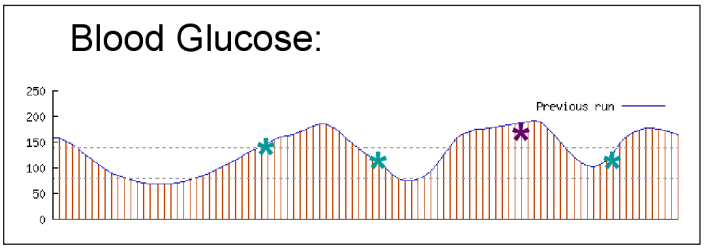


**Figure 5D:** Blood Glucose

**Figure 5.** AIDA online output for simulated insulin injections (**Figure 5A**), systemic insulin levels (**Figure 5B**), carbohydrate-containing meals (**Figure 5C**), and blood glucose levels (**Figure 5D**) in a 50 kg subject with Type 1 diabetes receiving insulin injections at the times indicated in **Figure 5A**, and meals with differing amounts of carbohydrates indicated in **Figure 5C**. Insulin doses expressed in units, insulin levels expressed in mU/L, carbohydrate content expressed in grams of carbohydrate at each meal, and BG expressed in mg/dl. * indicate BG values if checked before meals and at bedtime. This level of glycemic control was calculated by AIDA online to result in an HbA1c level of approx. 6%. [18 mg/dl = 1 mmol/l of glucose].

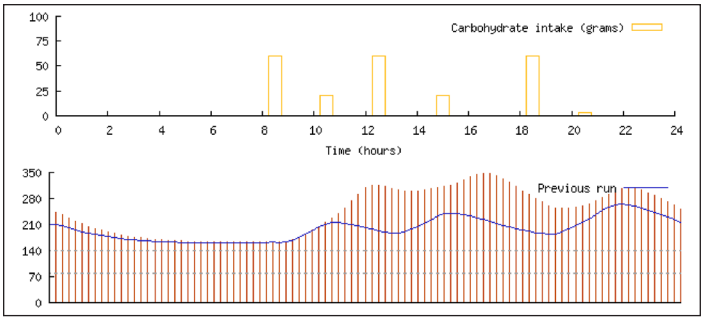


**Figure 6.** AIDA online output of carbohydrate intake (upper panel) and blood glucose levels (lower panel, expressed as mg/dl) in example of 100 kg subject with reduced peripheral and hepatic insulin sensitivity, and arbitrarily chosen level of "insulin deficiency" incorporated into the baseline model while eating a diet consisting of approximately 35% carbohydrate content in a total of 3,000 kCal (kCalories) daily. AIDA online calculated this level of glycemic control would achieve an HbA1c of approx. 10%. The blue line labeled as Previous Run indicates the sugar values with smaller meals (modeled on the earlier example shown in **Figure 5**) and the newly chosen degree of insulin resistance and beta-cell failure.

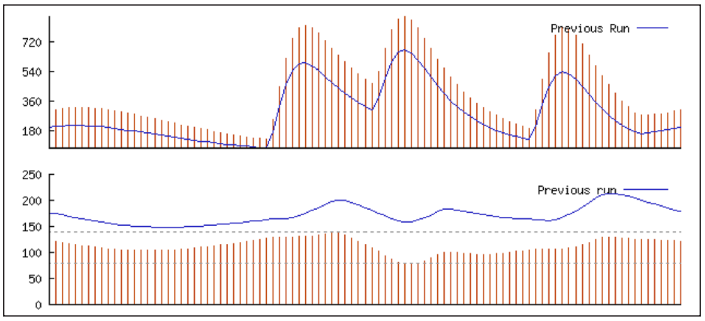


**Figure 7.** AIDA online output of systemic insulin levels (upper panel in mU/L) and blood glucose (BG, lower panel in mg/dl) after making pharmacological and physiological changes to the patient shown in **Figure 6**. Changes include reduced diet to 1,600 kCal (kCalories) a day with no snacks between meals, reduction in weight from 100 kg to 80 kg, addition of daily exercise to improve insulin sensitivity from low to normal, and addition of insulin injections using mealtime regular insulin and bedtime NPH insulin. The blue lines indicate the insulin levels and BG for the same diet and insulin injections before losing weight and while still insulin resistant.

### *Additional Responses from Participants*

Students were asked how they understood the program, and what they felt would improve AIDA online. A few students suggested making the program less complicated for them (n=4). Two participants wished exercise was formally incorporated into the AIDA online simulator. The students also commented that AIDA online could include more animation (n=1), more choices (n=1), and other disease processes (n=1). One student recommended making a Sim model for diabetes that would be based on the principles within AIDA online. Several responses recognized the use of AIDA online as a teaching and simulation tool not meant to titrate therapy (n=8), but five responses overstated the role of AIDA online as a means of adjusting insulin or BG in a person with diabetes. One student misunderstood the program to be a way of identifying diabetes in the user, while another wrote "*I see it as a solution to diabetes*."

Favorite parts of the program were related to the interactive nature of viewing the changes in insulin levels and BG in the graphs immediately after changing the inputs. Recurring themes in describing favored aspects of the program were the desire to introduce family members with diabetes to this type of program, and new perspective on what it is like to have diabetes, "*I realized that diabetes is much harder to control, and I partially understand what my two diabetic friends go to [through]*."

The middle-school teachers observing the workshop tutorial were strongly positive regarding the use of computers to teach the summer school program. Questions fielded during the sessions indicated that the students were impressed by how hard it is to adjust insulin and that dietary changes were very effective to control glucose. Physicians teaching the sessions expressed a desire to incorporate more types of insulin analogs in future versions of AIDA online. The only consistently negative experience related to local Internet connections of a minority of the computers that were interrupted while trying to run the simulations. This was overcome by returning to the starting page of AIDA online, and may have been related more to local internet connectivity issues, rather than central AIDA online server issues.

## Discussion

### *Teaching pharmacokinetics of insulin*

The pharmacokinetics of two different kinds of human insulin, NPH and regular, given at different times of the day were analyzed, as well as the effect on BG. Insulin administration is typically taught to patients and caregivers by experts in physician's offices, visits to diabetes educators, by pharmacists, and sometimes in group settings. These teaching methods are inherently limited by availability of the experts. Traditional textbooks are also available.[15] However, the Internet has become a widely accessible tool with a variety of animation options, and with comfort of use among teens that has been unrivalled in the past.[4] The ability to graphically display simple pharmacokinetics, and rapidly expand the illustrations, makes AIDA online a valuable approach to teach young teenagers with minimal knowledge of insulin about the complex relationship between the timing of an insulin injection and the effect of insulin within the blood. Although no formal testing of retention of the concepts taught using AIDA online was assessed, the development of presentations described here could be implemented as a tool to help young patients with diabetes learn about and explore the expected effects of insulin injections.

### *Teaching the importance of matching meals and lifestyle with insulin dosing*

Students were able to focus on the effects of insulin and to understand that it is essential for BG metabolism. A strong emphasis was placed on the importance of diet in the management of diabetes in this presentation, as well as effects of weight loss on insulin sensitivity. The simulated diet and lifestyle modifications were especially appreciated by students who reported family members being affected by diabetes in the questionnaires.

### *AIDA online vs AIDA v4 PC program or other simulation programs*

Even though only a minority of children had previous experience with similar programs, all of them were able to follow the cases without difficulty. There were no complaints about the Windows-based interface.[16] There were fewer requests for additional features to be added to the program than with prior surveys using a similar questionnaire.[17] The requests were related to the desire to incorporate exercise into the simulation model. The lack of requests may reflect the limited diabetes background of this group of students, with no participants in the summer camp known to have administered insulin in the past, or have diabetes. Prior requests had been to include Type 2 diabetes within the model,[17] which was done artificially in the current workshop tutorial by using purposefully low starting doses of insulin meant to mimic inadequate endogenous insulin secretion. This example showed the balance of insulin sensitivity, body weight, and meals with insulin doses, but the students generally felt that the guidance of the presenter was necessary to help them understand the examples and graphs. Some features that emerged from prior surveys have been implemented in AIDA online and were demonstrated here. These include the use of kilograms or pounds to define weight, the ability to simulate body weight greater than 99 kg, the calculation of glycosylated hemoglobin, and the simultaneous display of graphs and data. There are also now physiological descriptions included in a separate tutorial section of AIDA online,[18] that were not used in favor of the separate lecture given the availability of two diabetologists during the workshop.

Requests that were listed by the students included more animation, and the development of animations to follow the BG in time, or add the properties of the AIDA online model to characters similar to The Sims™ (Electronic Arts, Redwood City, CA) that could be followed through a lifetime of diabetes.

Interestingly some students downloaded the PC version of AIDA (v4) after the workshop tutorial, and left comments at the main AIDA website (Lehmann, personal communication).

### *Problems and Limitations Using AIDA online*

AIDA online was valued by the instructors and students as an educational program, with some limitations. First, the lack of readily accessible online support to allow the students to independently address medical or technical problems was noticed by the participants, who are used to extensive support and help files in other software. In this workshop tutorial the limitation was overcome by having two of the authors available during the entire session to provide assistance. Second, AIDA online lacks the newer insulin analogs, which currently are widely used in the United States, and potentially allows users to understand the effects of more physiologic insulin administration. Third, the lack of simulated hepatic glucose output during fasting initially gave artificially low BG values, which were artificially compensated for by adding frequent small meals meant to simulate endogenous glucose production.

Computer-based education systems are clearly not intended to provide a complete answer for education; rather they are one more tool that can be used to increase awareness in those with and without diabetes, and also improve diabetes care. Most of the students were keenly aware of these limits, but some students still made evaluations of the utility of AIDA online as being more than just a simulation. Given the ages of the workshop participants (12-14 years old) this may not be surprising.

### *Subjective evaluation of students' experience with AIDA online*

Overall, there was a high degree of satisfaction both from the lecturers and the students with AIDA online as a user-friendly, well-designed teaching tool that allows people to better understand diabetes, glucose, and insulin metabolism.

This small retrospective study demonstrates through a simple survey that 12 to 14 year olds found AIDA online educational and enjoyed the interactive aspects of the program. Positive comments from the students remarked on the ability to visualize concepts introduced in earlier lectures and recognize the difficulty of managing diabetes. Fewer negative comments reflected frustration with the difficulty in achieving good simulated glycemic control.

The ease with which the majority of students with minimal prior knowledge of diabetes and insulin managed to use the simulator within a 2-hour session suggests that the concepts would be readily accessible to teens with diabetes or with other needs to learn the basics of insulin administration. Comparisons could be made prospectively to evaluate knowledge and outcomes in patients using multiple daily insulin injections after exploring AIDA online, compared to more traditional forms of education about insulin pharmacokinetics.

Despite the continued advancement of computer access and capabilities, we recognize that there remains limited information on the benefits of using computer simulations in diabetes education, and acknowledge the need for more randomized controlled trials in this area.[19,20]

## Summary

Diabetes is an epidemic affecting our younger generations. Education is crucial in trying to prevent the development of diabetes by making the public more aware of the importance of healthy diet and exercise. Additionally, those already affected by the disease are in need of accessible tools to learn about the pathophysiology and management of diabetes beyond learning purely by experience. By educating highly motivated students through a computer-based system we believe we can have an impact on their own well-being, as well as the well-being of the people they know. A simple survey gave interesting feedback from a group of young participants who were learning about diabetes, and using diabetes software, for the first time. The students were able to use AIDA online themselves, although initially guided by a PowerPoint presentation. In general, users in the current study found the program to be of educational value. All of them believed it was worthy of wider distribution, and would be of interest to diabetes associations. Most of them would recommend the program to family and friends. A high level of satisfaction was described by the students and educators involved in the workshop tutorial. Most important, school-age students, who will face a higher burden of diabetes in their peer-group in the foreseeable future than any other generation before in our history, realized by the end of the session how difficult it is to control diabetes with insulin injections and the importance of avoiding or minimizing the impact of diabetes where possible with lifestyle changes.

**Acknowledgements:**

The authors would like to thank the participants in this summer camp for their feedback and suggestions. The authors would also like to acknowledge the staff at the Georgia Institute of Technology, and the middle school science teachers, for their assistance in helping to organize the Diabetes Summer Camp. This work was supported in part by funding from the Georgia Tech / Emory Center (GTEC) for the Engineering of Living Tissues, an Engineering Research Center (ERC) Program of the National Science Foundation (NSF) under Award Number EEC-9731643.

**Disclosure:**

The AIDA and AIDA online software referred to in this report is an independent, noncommercial development that is being made available free-of-charge via a not-for-profit Web site as a noncommercial contribution to continuing diabetes education. Dr. Lehmann is a co-developer of the AIDA and AIDA online diabetes simulators, and Webmaster of www.2aida.org and www.2aida.net.

**References:**


1. Centers for Disease Control and Prevention: Epidemiology of Type 1 and Type 2 diabetes mellitus among North American children and adolescents. National Center for Chronic Disease Prevention and Health Promotion. Diabetes Public Health Resource. www.cdc.gov/diabetes/projects/cda2.htm Accessed 4th September 2006.
2. Narayan KMV, Boyle JP, Thompson TJ, Sorensen SW, Williamson DF: Lifetime risk for diabetes mellitus in the United States. JAMA 2003; 290:1884-1890.
3. Cheeseman Day J, Janus A, Davis J: Computer and Internet Use in the United States: 2003. U.S. Census Bureau. October 2005.
4. Lenhart A, Madden M, Hitlin P: Teens and Technology. Youth are leading the transition to a fully wired and mobile nation. Pew Internet & American Life Project Report, July 2005.
5. Lehmann ED: Experience with the Internet release of AIDA v4 – an interactive educational diabetes simulator. Diabetes Technol Ther 1999; 1:41-54.
6. Lehmann ED, Deutsch T: A physiological model of glucose-insulin interaction. In: IEEE EMBS Proceedings, 13th Annual International Conference of the IEEE Engineering in Medicine and Biology Society 1991; 13(5):2274-2275.
7. Lehmann ED, Deutsch T, Broad D: AIDA: an educational simulator for insulin dosage and dietary adjustment in diabetes. British Diabetic Association, London, 1997. ISBN 1-899288-55-4.
8. Lehmann ED, Deutsch T: A physiological model of glucose-insulin interaction in Type I diabetes mellitus. J Biomed Eng 1992; 14:235-242.
9. Lehmann ED: Development, evaluation, and usage of 'AIDA' – an interactive educational diabetes simulator. Ph.D. Thesis. University of London / Imperial College of Science, Technology and Medicine, 2004.
10. Tatti P, Lehmann ED: Use of the AIDA diabetes simulation software – www.2aida.org – as an interactive educational tool for teaching student nurses. Diabetes Technol Ther 2001; 3:655-664.
11. Lehmann ED: User reviews of AIDA online: A web-based interactive educational diabetes simulator. Diabetes Technol Ther 2000; 2:329-342.
12. Lehmann ED: Usage of a diabetes simulation system for education via the Internet. Intl J Medical Informatics 2003; 69:63-69 [letter].
13. Lehmann ED, DeWolf DK, Novotny CA, Gotwals RR Jr, Rohrbach RP, Blanchard SM: Dynamic interactive educational diabetes simulations using the World Wide Web. Diabetes Technol Ther 2001; 3:A17-A20 [abstract].
14. Tatti P, Lehmann ED: Utility of the AIDA diabetes simulator as an interactive educational teaching tool for general practitioners (primary care physicians). Diabetes Technol Ther 2001; 3:133-140.
15. DeFronzo R, Ferrannini E, Keen H, Zimmet P (eds.): International textbook of diabetes mellitus, 3rd edition, Wiley, Chichester, 2004.
16. Lehmann ED: The freeware AIDA interactive educational diabetes simulator – http://www.2aida.org – (1) A download survey for AIDA v4.0. Medical Science Monitor 2001; 7:504-515.
17. Lehmann ED, Chatu SS, Hashmy SSH: Retrospective pilot feedback survey of 200 users of the AIDA version 4 educational diabetes program. (1) Quantitative survey data. Diabetes Technol Ther 2006; 8:419-432.
18. Reed K, Lehmann ED: Interactive educational diabetes / insulin tutorial at www.2aida.info Diabetes Technol Ther 2006; 8:126-137.
19. Tatti P, Lehmann ED: A randomised-controlled clinical trial methodology for evaluating the teaching utility of interactive educational diabetes simulators. Diabetes Nutr Metab 2001; 14:1-17.
20. Tatti, P, Lehmann ED: A prospective randomised-controlled pilot study for evaluating the teaching utility of interactive educational diabetes simulators. Diabetes Nutr Metab 2003; 16:7-23.