Computer-assisted teaching of nutritional anemias and diabetes to first-year medical students[1–3]

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ABSTRACT

Background: Seven computer-based Nutrition in Medicine interactive modules for teaching nutrition are available for instruction in medical schools.

Objective: The goal of this study was to evaluate the instructional efficacy of the Nutritional Anemias and the Diabetes and Weight Management: Aberrations in Glucose Metabolism modules when used by first-year medical students.

Design: The modules were introduced at Meharry Medical College to enhance its nutrition course for first-year medical students. Eighty medical students used the Anemias and Diabetes modules as an obligatory component of the course. Students were divided into 20 study groups of 4 and were required to answer multiple-choice questions to test their nutrition knowledge before and after use of the module.

Results: On average, students spent 1.89 ± 0.99 h studying each module, and most students (70%) reported viewing modules in more than one session. The percentage of correct responses to 12 knowledge questions from each module increased from 25% before use of the module to 74% immediately after its use and remained high (59%) 8 mo later. The pattern of knowledge retention, however, had some unpredictability. On the midterm examination, 72% of the students correctly answered questions related to nutritional anemias and nutrition aspects of diabetes. This was a 15% increase in knowledge of these 2 areas when compared with results obtained from first-year medical students 1 y earlier who had not used the modules.

Conclusions: The modules tested are effective tools for teaching nutritional and health issues of anemias and diabetes to first-year medical students. *Am J Clin Nutr* 2002;75:154–61.

KEY WORDS Computer-based instruction, Nutrition in Medicine curriculum series, nutrition education, nutritional anemias, diabetes, medical students

INTRODUCTION

Dietary habits and nutrition are related to many chronic diseases. Physicians have the primary responsibility of developing appropriate dietary prescriptions based on their knowledge of nutrition, health, and disease interrelations. However, physicians rarely receive formal training in the field of nutrition, despite widely recognized needs for such training (1, 2). For example, less than one-third of medical students currently in school are required to complete any formal nutrition course (1, 3), and 25% of medical schools still do not require or could not quantify nutrition education in their medical programs (2, 4). Although there has been some progress recently, students attending a medical school that requires nutrition education receive an average of <6 h of nutrition-related instruction (4, 5). A shortage of qualified instructors and the already overburdened medical school curriculum are considered major barriers against nutrition education in medical schools (1, 4). This lack of adequate nutrition education has prompted many health profession organizations to call for changes in the medical school curricula and for a wider inclusion of medical-nutrition questions in the US medical licensing examination (5–8). A group of physicians, nutritionists, and educators at the University of North Carolina at Chapel Hill developed a self-administered, computer-based curriculum in the field of nutrition for first- and second-year medical students. The resulting modules (Nutritional Anemias; Nutrition and Stress; Nutrition and Cancer; Diet, Obesity, and Cardiovascular Disease; Diabetes and Weight Management: Aberrations in Glucose Metabolism; Maternal and Infant Nutrition; and Nutrition and Growth) are available at no cost for the purpose of teaching nutrition in US medical schools (9, 10).

Nutrition In Medicine (NIM) is a comprehensive computer-assisted instruction (CAI) nutrition curriculum created to teach medical students the biochemical, clinical, and epidemiologic elements of nutrition science, including the preventive and

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therapeutic perspectives of nutrition (11). It was designed as an innovative, effective, flexible, and transportable nutrition curriculum and was described previously (4).

The purpose of the present study was to determine the efficacy of 2 of the modules, Nutritional Anemias and Diabetes and Weight Management: Aberrations in Glucose Metabolism, when used by first-year medical students (12, 13). The null hypothesis was that there is no difference in the level of knowledge before and after the introduction of the nutritional teaching modules.

METHODS

Study design

All incoming first-year medical students ($n = 80$) at the Meharry Medical College in Nashville, TN, during the 1999–2000 academic year were required to complete the Nutritional Anemias and Diabetes and Weight Management: Aberrations in Glucose Metabolism modules as part of a mandatory nutrition course. These modules were selected by course instructors to replace and enhance current content in these areas. The students completed tests consisting of multiple-choice questions before and after completion of the modules to determine the extent of knowledge they acquired. All printable materials, including learning objectives and key points were distributed to students and were available on the course's website. This CAI was supported by a 1-h live session introducing the topic and its learning objectives. Students' attitudes toward the use of the modules were anonymously assessed at the end of the course and then again 8 mo later after the students had taken the biochemistry examination for board certification.

For the evaluation of the modules' efficacy, results of a pretest given before the CAI were compared with the results of a test given 3 mo after instruction. A retention test was also administered 8 mo after the CAI. Twelve questions from each module were selected on the basis of questions asked to the prior year's first-year medical students and on the basis of specific learning objectives in these areas of anemia and diabetes, as outlined in the course objectives. Students were required by the school to purchase laptop computers at the beginning of the academic year. At the beginning of the course, the pretest was given in a proctored, written format. After the test, modules and floppy disks for recording patterns of use and durations of computer-based instruction were distributed to students, who were asked to voluntarily divide themselves into groups of 4 and who were encouraged to work in these groups. Students were asked to sign a consent form and were informed that the material contained in the modules would be covered on midterm and final examinations. Students were told that they could use the 3 separate board certification–style examinations containing 60 questions that were included in each module as a study guide for these examinations, and that they should take these module tests independently. A final grade incentive for taking ≥1 of the 3 examinations from each module was offered. The scores from these examinations were automatically recorded on the floppy disk.

Students were advised to complete a minimum of 2 or 3 two-hour sessions per module. Each group was asked to establish a time for regular biweekly sessions. However, there was no mechanism to record or monitor these sessions. An instructor was available for consultation and possible participation in these sessions. All information related to the course, modules, and examinations was distributed as a part of printed course materials and made available to the students on the course's website. The website contained a link to the NIM website and other online sources relevant to these 2 topics. This site served also to communicate students' questions and comments about the modules, examinations, and course. An instructor sent responses via e-mail usually on the same day. Modules were distributed to each small group free of charge; however, students were required to return the instructional compact discs at the end of the course.

Five weeks later, students took a midterm examination that contained 16 independently generated questions related to nutritional anemias and nutrition and diabetes. The performance on the midterm examination was compared both with the performance on the initial test and on the examination taken in the previous year (1998) by medical students who had not used the modules.

At the end of the 12-wk course, the 24-question test, with changes in both the sequence of questions and response choices, was administered as a written examination. This set was a part of a final examination that contained 56 additional questions related to other topics in biomedical nutrition. The students' scores on the examination counted toward their final grade for the course.

At the end of the course, students were asked to evaluate the modules by using a questionnaire that consisted of demographic information, questions related to the modules, and overall module rating. Both modules were evaluated with the use of a single questionnaire. At the beginning of the second year of medical school, 8 mo after the final examination, students, who were then enrolled in pathology, were asked to participate in a retention test. The test consisted of the same 24 questions, but the sequence of the questions and the order of the response choices were rearranged. This retention test, like the second test, was given in a proctored, written format. Students were not aware of the content of the test. As a reward for their participation, however, students who answered >50% of the questions correctly were offered bonus points (0.5% of total grade) to their pathology grade. During the retention test, students were asked to rate their attitudes toward knowledge acquired from the modules and to rate how this knowledge was helpful in the mandatory examination for board certification biochemistry, which includes nutrition-related topics. An evaluation of the performance on the biochemistry examination, however, was not part of the present study.

Teaching materials

NIM modules were designed to teach medical students the biochemical, clinical, and epidemiologic elements of nutrition science, including the preventive and therapeutic perspectives of nutrition, through the use of interactive lessons and simulated patient case videos. The modules used in this evaluation, Nutritional Anemias (12) and Diabetes and Weight Management: Aberrations in Glucose Metabolism (13), consist of ≈100 lesson pages with interspersed interactions, animations, pop quizzes, and practice cases.

In both modules, the simulated patient cases present students with the opportunity to apply nutrition knowledge to clinical problems. By working with a virtual physician mentor and with other health care provider role models, students perform an assessment, evaluate patient understanding and compliance, and make treatment recommendations. In the anemias module, the student is faced with a patient with Crohn disease who has a nutritional anemia: the student must diagnose which kind of anemia the patient has and make the treatment recommendations. In the diabetes module, the student is presented with 2 patients:

TABLE 1
Abbreviated contents of the Nutritional Anemias module

Clinical symptoms
Vitamin B-12, iron, and folate (clinical and neurologic deficiency symptoms, mechanisms, and risks)
Folate biochemistry
Structure, folylpolyglutamates, dihydrofolate reductase, tetrahydrofolate
Transfer of one-carbon units
Absorption, binding proteins, and storage
Vitamin B-12 biochemistry
Vitamin B-12 structure, cobalt and nitrous oxide
Absorption of vitamin B-12 and transcobalamins
Iron biochemistry
Iron oxidation and oxygen transport
Heme- and nonheme-iron absorption
Megaloblastic anemia
Folate, purine synthesis, deoxythymidine monophosphate, folate deficiency, and DNA synthesis
Structures of folate and vitamin B-12
Methionine synthase and the methyl trap theory
Vitamin B-12 and intrinsic factor and atrophic gastritis
Microcytosis
Microcytic erythrocytes and hemoglobin
Iron coordination to heme, heme synthesis, and regulation
Disease prevention: folate, vitamin B-12, and iron
Daily reference intakes, deficiency, sources, and bioavailability
Deficiency prevention
Iron
Recommended dietary allowances, food sources, and absorption enhancers and inhibitors
Causes of iron loss and poor intake
Iron deficiency worldwide and in the United States and prevention
Anemias in pregnancy
Folate deficiency during pregnancy
Iron needs during pregnancy
Diagnosis: laboratory values
Complete blood count: differential diagnosis of anemias
Laboratory tests: hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin, red blood count, and red cell distribution width
Reticulocytes
Blood smears: normal and abnormal blood smears, and practice exercises
Nutrient deficiencies: folate, vitamin B-12, and iron
Stages and causes of deficiency, laboratory tests and values, storage of nutrients, and practice exercises
Deficiency treatment: folate, vitamin B-12, and iron
Improving dietary intake, supplements, and drug interactions
Iron overload: risk factors, tissue damage, and laboratory tests, treatment, and prevention

1 with type 1 and another with type 2 diabetes. In the case of the patient with type 1 diabetes, a noncompliant teenager, the student must recognize the signs and symptoms of hypoglycemia. In the case of the patient with type 2 diabetes, the student must actively participate in the intervention process, leading to changes in the lifestyle and long-term behavior of the patient. Lesson pages present the nutritional biochemistry, epidemiology, and practice-based material. The abbreviated content of the anemias and diabetes module is shown in **Tables 1** and **2**, respectively. Various interactive exercises help the student integrate the information being learned. Detailed descriptions of the modules are presented elsewhere (4).

Generation of test items

By selecting the highest ranked group of 25 questions from each module's set of 60 questions, a preliminary 50-item test set, containing questions from areas defined as *biochemistry*, *practice*, and *epidemiology*, was generated by several internal reviewers. Some of the questions and answers were then modified based on answers given by a group of 20 predental or allied health profession students taking a human nutrition class at Tennessee State University. Students answered the questions on the preliminary test both before and after the specific material was presented to them in conventional lectures supported by the modules. These modified questions were tested in a group of medical students from Meharry's Medical College ($n = 6$ for the anemias and $n = 7$ for the diabetes module), who completed a human nutrition course in which the modules were not used. Students were asked to answer respective sets of questions before and after using the module for ≥6 h. On the basis of the students' answers, a set of 12 of the best questions from each module that contained a predetermined number of questions from *biochemistry* ($n = 6$), *practice* ($n = 5$), and *epidemiology* ($n = 1$) was selected for use in the study.

Statistical analysis

Data were analyzed by using SPSS for PC 10.0 (SPSS Inc, Chicago). The statistical significance of instructional effects was calculated by analysis of variance. Correlation coefficients were calculated to detect associations between answers to the questions and test outcomes. An unpaired t test was used to compare performance on the midterm test with results from students of the previous year. A paired t test was used to compare performance on midterm and final tests for students of the current year and performance on the post- and retention tests.

RESULTS

Knowledge assessment

Results of the knowledge assessment are shown in **Table 3**. Most students completed the pre- ($n = 78$), post- ($n = 80$), and retention ($n = 71$) tests. The overall percentage of correct answers increased from 25% on the pretest to 73.5% on the posttest, and then decreased to 59.1% on the retention test administered 8 mo after completion of the nutrition course. The α values for the reliability of the post- and retention tests were 0.583 and 0.235, respectively. Average scores on the pre-, post-, and retention tests are shown in **Figure 1**. There was greater variability in the answers on the post- and retention tests than on the pretest. The percentage of correct responses to some questions on the retention test had a reverse pattern when compared with the those on the posttest.

The percentage of correct answers given before introduction of the material was not greater than would be expected if the students had chosen the answers randomly (20%). This indicates that, on average, students did not have previous knowledge about nutritional anemias and nutritional aspects of diabetes. Some questions, however, were answered correctly by more students than would be expected from the probability prediction (20%). For example, 41% of the students correctly answered questions related to the epidemiology of iron deficiency anemia. We could not trace knowledge in this area to any of the concurrently

TABLE 2
Abbreviated contents of the Diabetes and Weight Management: Aberrations in Glucose Metabolism module

Glucose metabolism
Carbohydrate absorption, enzymes, and transport to liver
Cellular glucose transporters, storage, and mobilization
Glycolytic pathway, pentose phosphate pathway, citric acid cycle, and Cori cycle
Glucose regulation
Integrated regulation: fed compared with fasted states
Insulin, receptor activation, glucose transporters, and glycogen
Glucagon, epinephrine, and cortisol
Aberrations
Diabetes mellitus: etiologic classification, diagnosis, and histology
Development of type 2 diabetes
Fuel metabolism
Metabolic regulation, energy balance, and insulin resistance
Adaptation to obesity
BMI and body fat: increased rates of obesity in the United States
Relation of glycemia to body fatness and meal size
Energy restriction
Energy requirements, benefits and problems with restriction, and adaptation to fasting
Health effects
Health risks, gallstone development, and mortality risk
Gluconeogenesis
Lifestyle effects on health outcomes
Appetite regulation
Short-term compared with long-term effects, external compared with internal stimuli
Role of hormones, gut hormones, neuropeptide Y, galanin, corticotropin-releasing hormone, cortisol, and insulin
Satiety and appetite, serotonin and diet, dopamine, and endorphins
Appetite and weight
Appetite regulation: long-term effects, biological diversity, and permanent weight loss
Glucose metabolism
Energy balance: glucose homeostasis and acute and chronic consequences of imbalance
Glycemic response
Normal compared with abnormal glucose profiles, hypoglycemia, and hyperglycemia
Glycemic index
Health outcomes
Pathophysiology of hyperglycemia and medical outcomes
Diabetes management style and health outcomes
Dietary guidelines and tools
Medical nutrition therapy
Recommendations: type 1 and 2 diabetes, exchange lists, and carbohydrate counting
Simple compared with complex carbohydrates and myths of diabetes management
Blood glucose monitoring and targets for metabolic control
Tools: insulin (diet and medication), insulin activity, and oral hypoglycemic agents
Exercise and glucose uptake

offered lectures. The question regarding hormonal regulation of gluconeogenesis was answered correctly by 43% of the students. Because metabolism of carbohydrates was a lecture topic in biochemistry, acquired knowledge in this course most likely affected the higher than predicted correct response rate.

One-half of the questions about anemias and diabetes were related to key concepts and principles of nutritional biochemistry. Overall, the percentage of correct answers increased from 26% on the pretest to 73% on the posttest ($P < 0.001$). In some areas on the posttest, >90% of the students chose the correct answers. In the anemias module, questions were related to the role of transferrin and ferritin and to principles of iron storage. In the diabetes module, the question about hormonal regulation of gluconeogenesis was correctly answered by 94% of the students. In contrast, the percentage of correct posttest answers in certain areas was 15% below the average, suggesting some deficiencies in instruction. For example, only 58% of the students identified a defect in the conversion of homocysteine to methionine as a cause of megaloblastic anemia in a patient with adequate folate intake and no signs of malabsorption. One-third of the students chose the conversion of methylhydrofolate to tetrahydrofolate and 10% chose the conversion of dihydrofolate to tetrahydrofolate as a cause of described, combined vitamin B-12 and folate deficiency. After 8 mo, the percentage of students who correctly answered this question decreased to 41%. We analyzed this answer further and found that all students who incorrectly answered this question on the posttest also gave an incorrect answer on the retention test. In the same area, however, ≈80% of students properly recommended testing for vitamin B-12 and folate as laboratory assays necessary for diagnosis of vitamin deficiencies leading to elevated homocysteine concentrations. This suggests that students were familiar with the role of these vitamins in a pathway of homocysteine metabolism but were not familiar with all the details of homocysteine metabolism. This is a clear indication that instruction related to the role of homocysteine in megaloblastic anemia requires more detailed tutoring and explanation.

In the Diabetes module, 64% of the students correctly identified thermogenesis as a result of hormonal changes in semistarvation. Because this rate was lower than average (75%), a relevant explanation was posted on the course's website after the final examination. Nevertheless, the rate of correct answers to this question on the retention test decreased to 42%, which is 17% below the average. Further analysis showed that most of the incorrect answers pointed to gluconeogenesis as a metabolic consequence of hormonal changes occurring in semistarvation. This suggests that students did not fully learn or understand the concept of metabolic adaptation during semistarvation, and that the topic needs additional explanation.

Five questions in the anemias module and 5 in the diabetes module were related to medical practice. In both modules, there was a significant ($P < 0.0001$) increase in the number of correct answers (29% compared with 71% and 20% compared with 70% in the anemias and diabetes modules, respectively). A posttest question about the health consequences of iron deficiency in pregnancy was answered correctly by 90% of the students. In contrast, 30% of the students incorrectly identified blood hemoglobin as a laboratory test necessary to identify the initial stages of iron deficiency in a 19-y-old female runner. Although 58% of the students correctly identified serum ferritin as the proper assay for diagnosing iron deficiency, we considered this as a deficiency area requiring attention, explanation, and further instruction. In the diabetes module, 63% of the students correctly identified delayed glycemic response as a metabolic effect of intestinal glucosidase inhibitors in a patient with type 2 diabetes. This rate of correct responses to this question increased to 79% on the retention test. This positive trend suggests that the students received more in-depth information

TABLE 3
Percentage of correct answers on the pre-, post-, and retention tests

Question content	Topic	Pretest	Posttest	Retention test
			%	
Nutritional Anemias module				
Iron storage and anemia	Biochemistry	24	95	87
Vitamin B-12 deficiency	Biochemistry	23	66	50
Megaloblastic anemia and nutrient intake	Biochemistry	27	56	45
Pathways in homocysteine metabolism	Biochemistry	22	58	41
Role of transferrin in anemia	Biochemistry	16	63	58
Role of ferritin in iron deficiency anemia	Biochemistry	28	92	78
Iron deficiency in pregnancy	Practice	45	90	82
Laboratory testing for nutritional anemias	Practice	27	58	43
Diet and iron absorption	Practice	27	70	68
Intervention for vitamin B-12 deficiency	Practice	24	67	50
Nutritional deficiencies in Crohn disease	Practice	23	71	60
Epidemiology of iron deficiency anemia	Epidemiology	21	83	53
Total		26 ± 7[1]	73 ± 14	58 ± 13
Diabetes and Weight Management: Aberrations in Glucose Metabolism module				
Insulin and adipose cells	Biochemistry	32	79	58
Metabolism of carbohydrates in muscle	Biochemistry	25	70	64
Carbohydrate craving and serotonin metabolism	Biochemistry	17	68	47
Hormonal changes in semistarvation	Biochemistry	26	64	42
Insulin and brain signaling	Biochemistry	27	71	50
Hormonal regulation of gluconeogenesis	Biochemistry	43	93	68
Insulin resistance in type 2 diabetes	Practice	19	69	69
Glycemic response in type 2 diabetes	Practice	16	63	79
Low-fat diet in diabetes	Practice	31	81	62
Reduced-energy diet and fat metabolism	Practice	18	66	56
Carbohydrate counting in diabetes	Practice	18	72	59
Anthropometric measurements in obesity	Epidemiology	19	93	89
Total		24 ± 8	75 ± 10	60 ± 12
Total for both modules		31 ± 7	73 ± 12	59 ± 13

[1] $\bar{x}$ ± SD.

on this topic in the physiology course taught between the post- and retention tests.

One question in each module was about nutritional epidemiology. In both modules, the percentage of correct answers on the posttest was higher than average in areas of nutritional biochemistry and medical practice. In the anemias module, 83% of the students identified correctly young children from poor communities as a population in which iron deficiency has the most devastating effect. In the diabetes module, 93% correctly remembered anthropometric criteria for overweight and obesity in adult populations. This correct response remained high (73% and 90%, respectively) on the retention test.

Six weeks after introduction of the modules, 10 questions about nutritional anemias and diabetes were included in a set of 60 questions on a midterm examination. The average percentage of students who correctly answered these questions was significantly higher than the percentage who answered correctly the remaining 50 questions about other topics taught during the course in a lecture format ($P < 0.001$). The results were also compared with those for students who took the course 1 y earlier. The percentage of students who correctly answered these questions increased from 56% to 68%. Students in the upper tertile also showed a significantly higher gain in score between the pretest and posttest ($P = 0.023$).

To receive a course credit, students were required to complete ≥1 of the 3 board–certification style examinations in each module. Approximately 75% of the students completed one examination with an average score of 94 ± 9%. The remaining 25% of the students completed 2 or 3 examinations with an average score of 90 ± 8%. The difference between these scores was not significant. Students who completed 2 or 3 examinations received significantly higher scores on the posttest than did students who completed one examination (independent- samples *t* test: 75 ± 4% compared with 67 ± 4%; $P = 0.037$). This group also received a higher overall score on the final examination (independent-samples *t* test: 78 ± 7% compared with 71 ± 6%; $P = 0.027$).

The student's mean performance on the retention test decreased significantly (paired *t* test: $P < 0.0001$). Individual scores on the retention test were plotted against the scores on the posttest. As shown in **Figure 2**, a forecast of knowledge retention carried some unreliability, at least over the 8-mo period. For example, one student who scored 86% on the posttest (top one-third of the cohort) scored only 46% on the retention test (lowest one-third). In contrast, a few students scored higher on the retention test than on the posttest, and several scored similarly on both test ($r = 0.5400$). The overall regression equation was as follows: retention test (%) = 18.56 + 0.55 × posttest (%).

Usage tracking

The duration of module use was recorded on floppy disks. All students returned their disks after completing the course. On average, students spent 1.89 ± 0.99 h studying each module.

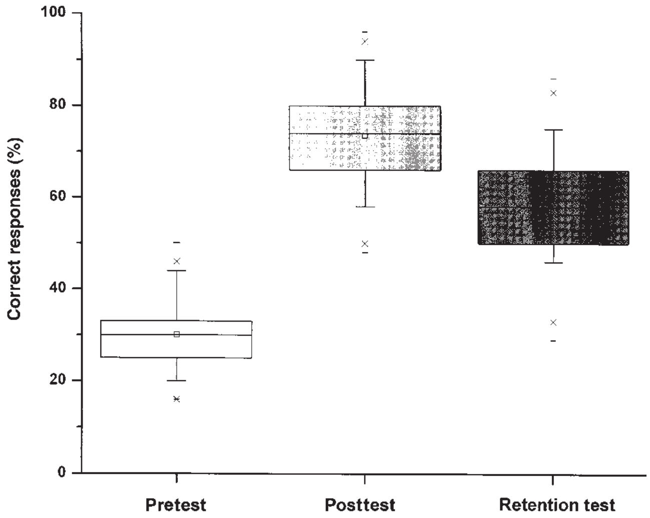

FIGURE 1. Distribution of correct responses by medical students on the pre-, post-, and retention tests derived from 5 percentiles. The top and bottom of each box represent the 75th and 25th percentile, respectively. The middle 50% of students' scores are represented within the box, with the line representing the median. The thickness of each of the boxes represents the degree of homo- or heterogeneity of the performance of the middle 50% of the class.

These recorded durations were lower than the average duration reported by students on the questionnaires at the end of the course (2.99 ± 1.10 h per module). Most students (70%) reported viewing modules during more than one session.

Approximately one-half (49%) of the students reported using the glossary, 53% the index, 70% the references, and 63% the help features of the modules. Among the students who used the glossary, 76% considered it helpful. Similar results were reported for the index (72%). Fewer students considered the references (45%) and the help (42%) features as useful supports to the instruction.

Self-assessment of skills and attitudes

Most students taking the human nutrition course agreed that knowledge regarding the nutritional aspects of anemias (90%) and diabetes (92%) was an important part of their medical education. When asked about their overall knowledge regarding nutritional anemias and diabetes and their ability to offer nutritional advice to patients, ≈30% of students showed a high level of confidence. Another one-third of students were neutral on this issue. An equal number of students, however, did not think that they had sufficient knowledge to offer nutritional advice to patients with anemia (28%) and diabetes (32%). This suggests that further instruction should emphasize the clinical aspects of nutritional disorders.

After the retention test, students were asked how the nutritional modules helped them in preparing for the board certification examination in biochemistry taken 2 wk after finishing the nutrition module instruction. Two-thirds of the students agreed or strongly agreed that both modules were helpful in preparaing for this examination, 5 students did not think that the modules were helpful, and ≈25% did not have a clear opinion on the role of the anemia and diabetes modules in their preparation for the examination.

DISCUSSION

In the present study, we evaluated the instructional efficacy and acceptability of the Nutritional Anemias and Nutrition and Diabetes and Weight Management: Aberrations in Glucose Metabolism CAI modules when used by first-year medical students. We found a significant increase in the percentage of correct test answers after the instruction. Moreover, students retained acquired knowledge for 8 mo after the instruction. This suggests a substantial increase in knowledge in the areas of biomedical nutrition covered by the modules.

Our results show teaching effectiveness similar to results reported recently by Kohlmeier et al (14) who tested the effectiveness of the Nutrition and Cancer module from the NIM series in a group of 137 first-year medical students. Because the present study was conducted with the use of similar methods, it is possible to make several comparisons. For example, the overall increase in knowledge after instruction was >50% in both studies. This suggests that different NIM modules have similar effectiveness in teaching principles of relevant nutrition topics.

Similarly, the difference between the post- and retention tests was ≈20%, even though the time between these tests in the present study and the Kohlmeier et al (14) study was different. A decline in the medical students' recollection of information over time was expected, but before analysis, the magnitude was uncertain. It is reasonable to assume that students forget information at similar rates or that the rate of forgetfulness varies on the basis of initial performance, eg, students with lower initial scores would forget at a greater rate than would those with higher initial scores. The overall decline must be tempered with the fact that the students had no opportunity to prepare specifically for the retention test. Nevertheless, a forecast of knowledge retention in our study had some unreliability.

The present study was not designed to compare CAI with other forms of instruction. Typically, students cram over the few days and hours before an examination, and their short-term memories may not translate proportionally the retention of information for each student (15). Because our model was designed for students to acquire knowledge by using NIM modules during

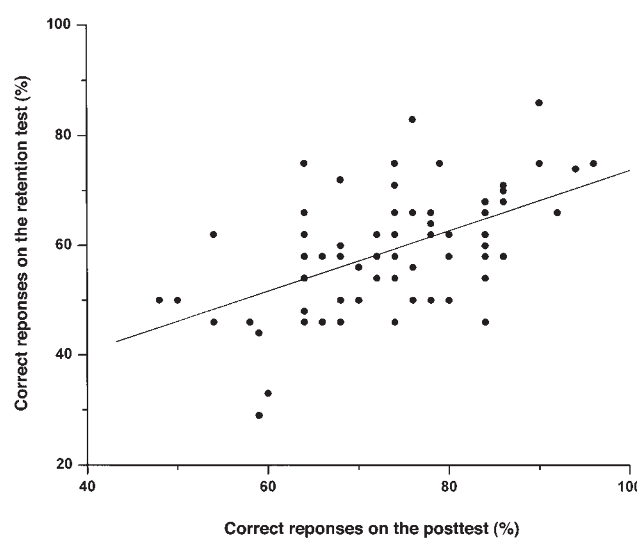

FIGURE 2. Correlation between the percentage of correct responses by medical students on the retention test and posttest.

small group sessions over several weeks, we speculated that the retention rate would be similar or higher than that associated with a traditional lecture-type instruction. Currently, there are no reports available of comparisons between knowledge retention rates after the use of NIM modules and other methods of instruction. We tested knowledge retention over months, laying a basis for determining whether a change in teaching methods improves students' comprehension of nutrition in a meaningful way. More studies that use different teaching strategies are required to fully evaluate the effectiveness of NIM modules to teach nutrition in the integrated medical curriculum.

Computers are increasingly being used to teach basic and specialized skills in medical schools (16–18). In general, there are many advantages to CAI in medical schools, and the NIM series is a good example of how to use this new comprehensive technique to teach principles of nutrition to medical students at different stages of medical education. The flexibility of NIM programs allows instructors to use the program modules in a variety of ways and to tailor the depth of instruction to the specific course learning objectives. In this study, we introduced each module to students during 1-h sessions that included an overview of module objectives, navigation directions, and a suggested sequence for completing the program. Each study group of 4 students was allowed to work at their own pace to complete the modules and turn in disks with examination scores at the end of the semester. Results of both post- and retention tests clearly showed that our strategy was efficient in achieving goals of teaching principles of nutritional anemias and diabetes to medical students. More studies are warranted that use this and other teaching approaches at different medical schools and at different levels of medical education. Another advantage of the NIM modules is their electronic features, eg, tests, grades, and evaluations. In our study, we used most of these features, except the web-based evaluation. At the time that we conducted our study (winter 2000) we did not have the necessary infrastructure to use the NutraQuiz offered by the NIM modules.

We suggest that comprehensive evaluation of nutrition curricula with NIM modules as a component should include an assessment of student's progress by comparing results of testing not only before and after intervention, but also immediately after instruction and at a time more remote from the educational experience under analysis. Subsequent studies should also explore how further instruction would affect the amount of knowledge retained and how this retention might be affected during further stages of nutrition education in the medical curriculum.

Acceptance of CAI by the students in our study was very good; ≈85% of the students said they would recommend this program for use by future medical students. In addition, two-thirds of the students agreed that they learned more from the module material than they would have from a book or lectures. In the NIM series, each program is designed to provide 3–5 h of learning material for the medical student, although research by Kohlmeier et al (14) indicates that students can spend widely varying amounts of time with the programs. Experience indicates that instructors need to give students guidance about the time to be spent on the material in each module when it is used outside of the classroom. We advised students that they would need ≤6 h to learn relevant material from each module and to be prepared for the examination. Students were required to take ≥1 of the 3 examinations in each module, a design feature used in this evaluation. There was a significant difference in the number of these examinations completed and in the scores on the posttest. Students who completed 2 or 3 examinations answered more questions correctly than did students who completed only 1 examination. Moreover, this group of students received, on average, a better score on the final examination. Because there was no difference in the average scores received on the board certification–style examinations between the 2 groups, the results suggest that the modules' examinations are an integral part of the learning process. Therefore, students should be encouraged to take all examinations after completing the modules.

In our teaching model, it was possible to expand material presented in the modules and reinforce some concepts during the lectures. For example, a topic of iron nutrition in pregnancy was also covered in a lecture on nutrition in pregnancy and infancy presented 3 wk before the posttest. This might have affected the higher-than-average rate of correct responses in this area.

Our study must be interpreted within the context of our experimental design. First, the number of tested questions generated from each module was limited to 12. In our model, each module was one of the components of a mandatory biomedical nutrition course offered to first-year medical students and therefore more questions covering topics of nutritional anemias and diabetes would limit our ability to test knowledge in other areas of nutrition covered by the course. Second, we divided students into 20 small study groups and encouraged working together in these groups. It is possible that some students were more active during the study sessions and that the group took examinations together, although we specifically asked students to take examinations individually. Study instructors did not monitor or actively participate in small group sessions. Relatively high correlation (paired *t* test: $r = 0.675$) between the results of the posttest and the results from other questions on the final examination suggest, however, that most students followed our instructions. Finally, our retention test was given 8 mo after the instruction was completed. During that time, students were taking a physiology course and it is possible that the knowledge related to anemias and diabetes acquired in this course could have affected the results on the retention test.

In conclusion, the NIM modules Nutritional Anemias and Diabetes and Weight Management: Aberrations in Glucose Metabolism are useful and effective tools in teaching biomedical nutrition to first-year medical students. Our long-term strategy for teaching nutrition as a part of an integrated medical curriculum at Meharry Medical College includes the introduction of the modules Diet, Obesity, and Cardiovascular Disease and Nutrition and Stress during the pathophysiology course offered to second-year medical students and of the module Maternal and Infant Nutrition and Nutrition and Growth during the pediatric and obstetric and gynecology clerkships offered to third- and fourth-year medical students. We believe that this strategy will lead to a significant increase in the nutrition knowledge base of medical students and, consequently, to more efficient nutrition counseling of the students' future patient populations.

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REFERENCES

1. Young EA. Nutrition education in US medical schools. Am J Clin Nutr 1997;65:1558.
2. Schulman JA. Nutrition education in medical schools: trends and implications for health educators. Med Ed Online. Internet: http://www.med-ed-Online.org/f0000015.html (accessed 16 September 2000).
3. Feldman EB. Educating physicians in nutrition—a view of the past, the present, and the future. Am J Clin Nutr 1991;54:618–22.
4. Cooksey K, Kolhmeier M, Plaisted C, Adams K, Zeisel SH. Getting nutrition education into medical schools: a computer-based approach. Am J Clin Nutr 2000;72(suppl):868S–76S.
5. Association of American Medical Colleges. 1991–1992 AAMC curriculum directory. Washington, DC: The Association of American Medical Colleges, 1991.
6. Kushner RF, Thorp FK, Edwards J, Weinsier RL, Brooks CM. Implementing nutrition into the medical curriculum: a user's guide. Am J Clin Nutr 1990;52:401–3.
7. Weisner RL, Booker JR, Brooks CM, et al. Priorities for nutrition content in a medical school curriculum: a national consensus of medical educators. Am J Clin Nutr 1990;50:707–12.
8. Hark LA, Iwamoto C, Melnick DE, et al. Nutrition coverage on medical licensing examinations in the United States. Am J Clin Nutr 1997;65:568–71.
9. Nutrition in Medicine. NIM home page. Version current 4 September 2001. Internet: http://www.med.unc.edu/nutr/nim (accessed 29 October 2001).
10. Maillet JO, Young EA. Position of the American Dietetic Association: nutrition education for health care professionals. J Am Diet Assoc 1998;98:343–6.
11. Zeisel SH, Fussell S, Kohlmeier M, Lasswell A, Cooksey K. The Nutrition in Medicine project. Acad Med 1996;71:107–8.
12. Fussell S, Cooksey K, Kohlmeier M, Lasswell A. Zeisel SH, ed. Nutritional anemias [module on CD-ROM]. Chapel Hill, NC: University of North Carolina at Chapel Hill, 1998.
13. Plaisted C, Kohlmeier M, Cooksey K, et al. Zeisel SH, ed. Diabetes and weight management: aberrations in glucose metabolism [module on CD-ROM]. Chapel Hill, NC: University of North Carolina at Chapel Hill, 1998.
14. Kohlmeier M, Althouse L, Stritter F, Zeisel SH. Introducing cancer nutrition to medical students: effectiveness of computer-based instruction. Am J Clin Nutr 2000;71:873–7.
15. Sisson JC, Swarta RD, Wolf FM. Learning, retention and recall of clinical information. Med Educ 1992;26:454–61.
16. Evans LA, Brown JF, Heestand DE. Incorporating computer-based learning in a medical school environment. J Biol Comput 1994; 21:10–7.
17. Richardson D. Student perceptions and learning outcomes of computer-assisted versus traditional instruction in physiology. Am J Physiol 1997;273(suppl):S55–8.
18. MacFayden JC, Brown JE, Schoenwald R, Feldman RD. The effectiveness of teaching clinical pharmacokinetics by computer. Clin Pharmacol Ther 1993;53:617–21.