Effect of Computer-Based Learning on Diabetes Knowledge and Control

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Two interactive computer-based systems have been evaluated: a teaching program with text and animated graphics and a multiple-choice knowledge-assessment program (KAP) with optional prescriptive feedback. One hundred seventy-four routine-attending insulin-dependent diabetes mellitus (IDDM) and non-insulin-dependent diabetes mellitus (NIDDM) patients were allocated to active and control groups to determine the effect of these programs on knowledge and control after a 4- to 6-mo follow-up period. Interactive computer teaching (ICT) resulted in a significant knowledge increment in both IDDM and NIDDM patients ($P < .05$), together with a mean fall of 0.8 and 0.7%, respectively, in HbA_{1c} ($P < .05$ and $P > .1$), but no changes were observed in respective control groups. The KAP with feedback also produced a significant knowledge increment in both IDDM and NIDDM patients ($P < .05$), of similar magnitude to the ICT program, and a mean fall in HbA_{1c} of 1.2 and 1.3%, respectively ($P < .05$), with no changes in the corresponding control groups. Even when KAP was used without prescriptive feedback, smaller but significant mean falls in HbA_{1c} of 0.7 and 0.8% ($P < .05$) were seen in IDDM and NIDDM patients, respectively, suggesting a motivational effect resulting from program participation. An inverse correlation was demonstrated between knowledge increment and final HbA_{1c} in the ICT and KAP/feedback groups, which was significant for NIDDM patients ($r = -.43$, $r = -.45$; $P < .05$) but not for IDDM patients ($r = -.2$, $r = .25$; $P > .1$). Our studies confirm positive educational benefit of both computer-based programs, probably acting through enhancement of both knowledge and motivation. DIABETES CARE 1986; 9:504–508.

Despite major efforts directed toward innovative educational programs in diabetes, there is still comparatively little documentation of resulting change in either knowledge or diabetic control. Furthermore, many diabetic clinics are hampered by the cost of establishing and maintaining effective education that will embrace all diabetic patients; in most centers, only newly diagnosed diabetics are involved in any systematic instruction or evaluation, yet reevaluation and updating may be of greater importance to long-term well-being than the education of the newly diagnosed patient. There is therefore a need to consider new techniques that might achieve this goal in a cost-effective manner.

Computer-based instruction has been used in a few clinics with either direct system-patient interaction[1] or an intermediate operator.[2] Our study was undertaken in an attempt to use the maximum potential of a computer in learning; i.e., to systematically provide information at a rate determined by the patient, to examine priority areas of knowledge, and to maintain patient interest and involvement by the extensive use of animated graphics and by emphasis on continuous interactive involvement with the learning process without an intermediate operator. The purpose of our study was to examine separately two programs recently developed in this department to define any effects on knowledge and diabetic control.

MATERIALS AND METHODS

The computer programs used have been recently described in detail.[3,4] In brief, the interactive computer teaching (ICT) program consists of sequences of text and animated graphics dealing with general diabetes concepts, hypoglycemic drug action, glucose control, blood and urine monitoring, com-

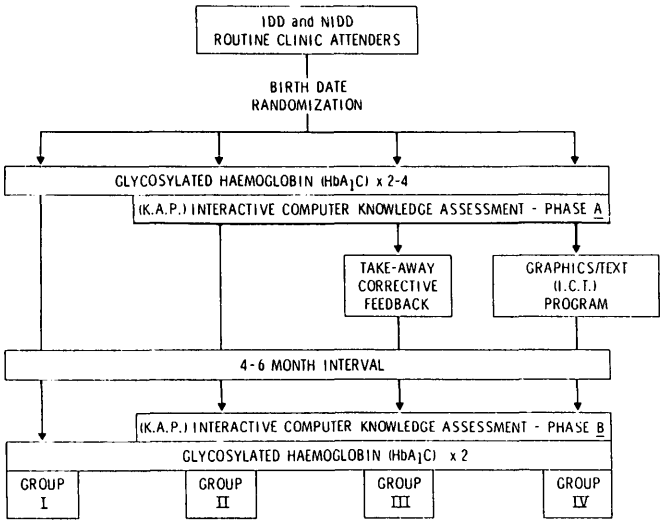

FIG. 1. Flow chart of study protocol.

plications, diet, and foot care. The curricula are based on separate books for insulin-dependent diabetes mellitus (IDDM) and non-insulin-dependent diabetes mellitus (NIDDM) that are normally used for instruction of newly diagnosed patients.[5] Each teaching program uses the principle of questioning after each provision of fact, followed either by optional or compulsory rerun of the fact sequence if inadequate performance is recorded for any subject. Separate programs were constructed for IDDM and NIDDM; in each case, these programs require 45–60 min to complete, the rate of progress being entirely under the control of the patient.

The knowledge-assessment program (KAP) consists of a newly devised panel[3] of multiple-choice questions (34 IDDM; 21 NIDDM) dealing with all major topics covered by the ICT program. Eighty-eight percent (IDDM) and 82% (NIDDM) of question options satisfy the validation criterion of a facility index in the desirable range of 30–90%.[6] Responses are automatically scored and filed on disk for later analysis; a printout can be automatically generated on conclusion, giving the score and a prescriptive (corrective) feedback on options omitted or incorrectly answered in the form of a personalized listing. The marking system used allotted a +1 score for correctly chosen options, −1 for incorrectly chosen options, and a maximum negative score equivalent to the number of options for a "don't know" response. This program requires 20–40 min for completion. Programs were written in BASIC for a Research Machines RML 380-Z 56K microcomputer with dual disk drives, allowing data storage and analysis. Patient interaction and user friendliness are achieved by a specially constructed six-digit keypad with additional YES, NO, and DON'T KNOW key entries. Once powered up for each day's operation, the system is totally independent of any skilled operator, except for initial entry of the hospital record number with the conventional keyboard.

For 2 mo, patients regularly attending the diabetic clinic at Charing Cross Hospital and who had diabetes for ≥2 yr were entered in a study whose structure enabled the separate potential of ICT and KAP programs to be evaluated according to the flow chart (Fig. 1). Assignment to test groups was randomized by year and month of birth. Group I patients were unaware of the study and had evaluation only of HbA_{1c} levels. For groups II–IV, ~25% of patients approached for inclusion in the study declined because of the time required and potential inconvenience. Group II patients had 2 KAP assessments 4–6 mo apart. They were provided only with a total score, and no prescriptive feedback was provided until after the study was terminated. Group III patients were provided with both score and printed prescriptive feedback immediately after the first KAP assessment. Group IV patients were identical to those of Group II except that the ICT program was performed by the patient within 1 wk of the first KAP program. Reevaluation (phase B) was carried out 4–6 mo later in all groups as indicated, both of knowledge status and diabetic control. HbA_{1c} was assayed by the Bio-Rad column method after overnight incubation at 37°C to remove unstable adducts (normal range for this laboratory, 4.5–7.5%). In all cases, phase-A HbA_{1c} was the mean of three or four measurements taken during the preceding 2 yr. The second assessment of HbA_{1c} was the mean of two sample values taken 6 wk apart on conclusion of the study.

A total of 174 IDDM and NIDDM patients were evaluated; group characteristics are shown in Table 1 and show no significant variation by age or diabetes duration. Sex ratio in groups varied from 0.42 to 0.60. All patients had previously received some instruction, mainly by a diabetes type–specific teaching text[5] together with individual counseling at various stages of their diabetic history. Only two patients commencing the study subsequently defaulted, one because of anxiety induced by the procedure and the second for logistic reasons.

Results are expressed as the mean ± SE unless otherwise stated. Comparisons were evaluated with the Student's *t* test for paired values with the statistical package for the social sciences on the University of London computer.

TABLE 1
Patient characteristics classified by study group

Group	*N*	Age (yr)	Duration (yr)
IDDM			
I (control)	20	42 ± 16	11 ± 8
II (2 KAP assessments)	24	44 ± 17	13 ± 8
III (KAP-FB-KAP)	22	45 ± 16	14 ± 6
IV (KAP-ICT-KAP)	20	41 ± 18	12 ± 6
NIDDM			
I (control)	21	55 ± 21	7 ± 4
II (2 KAP assessments)	22	57 ± 23	8 ± 5
III (KAP-FB-KAP)	24	58 ± 17	6 ± 4
IV (KAP-ICT-KAP)	21	56 ± 16	8 ± 5

Age range: IDDM, 17–68 yr; NIDDM, 42–75 yr.
FB, feedback.

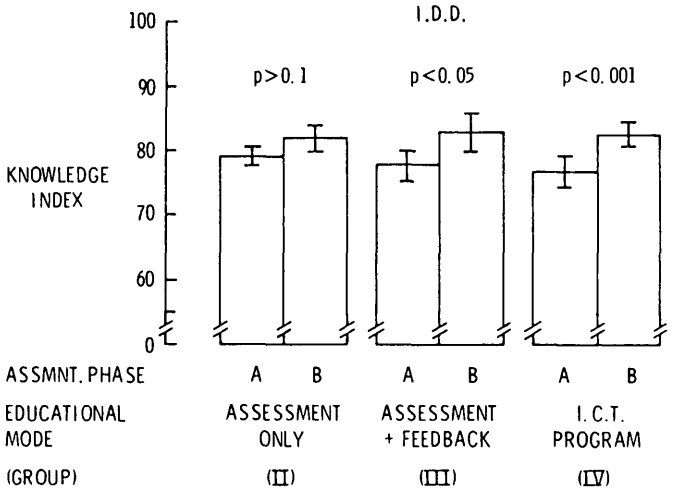

FIG. 2. Changes in knowledge index in IDDM subjects (mean ± SE).

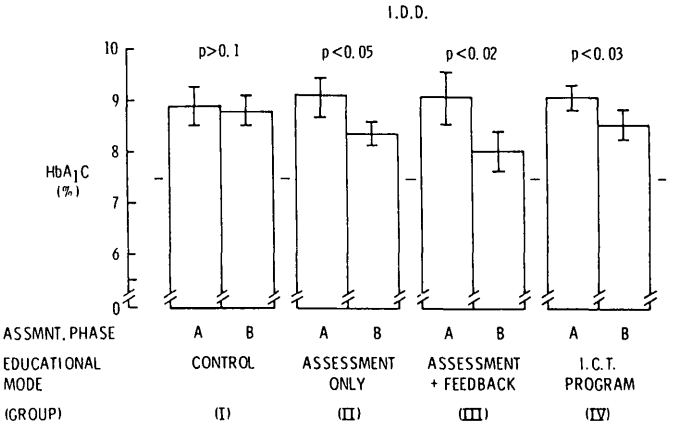

FIG. 4. Group comparisons of HbA_{1c} in IDDM subjects (mean ± SE).

RESULTS

Knowledge index. In IDDM patients (Fig. 2), group II subjects showed a small but insignificant rise of index (79 ± 2 to 82 ± 2) in assessment phase B ($P > .1$). In both prescriptive feedback (group III: 78 ± 2 to 83 ± 3) and teaching program (group IV: 77 ± 2 to 83 ± 2) groups, a significant knowledge increment was demonstrated ($P < .05$ and .01, respectively).

In NIDDM patients (Fig. 3), baseline (phase A) knowledge index was significantly higher in the assessment-only group (group II) than in the other test groups ($P < .03$), with no change in assessment phase B. In both prescriptive feedback (group III: 64 ± 2 to 73 ± 2) and teaching program (group IV: 60 ± 3 to 70 ± 2) groups, significant knowledge increments were demonstrated ($P < .01$ and $< .05$, respectively). There was no significant difference between specific knowledge areas positively influenced by these educational programs, except for major improvements in diet knowledge in NIDDM with either program ($P < .001$) and in knowledge of control and hypoglycemia in IDDM with KAP/feedback ($P < .001$).

Diabetic control. In IDDM patients (Fig. 4), HbA_{1c} did not differ significantly between the evaluation groups at initial assessment. In the control group (group I), there was no change (8.9 to 8.8%). In all other groups, a significant fall in HbA_{1c} was demonstrated ($P < .05$): from 9.1 ± 0.2 to 8.4 ± 0.1% in group II (assessment only); from 9.3 ± 0.5 to 8.1 ± 0.4% in group III (prescriptive feedback); and from 9.3 ± 0.2 to 8.6 ± 0.3 in group IV (teaching program). In NIDDM patients (Fig. 5), there was a considerable and unexplained difference between groups in the initial HbA_{1c} values. However, no change was seen in the control group (8.7 to 8.5%). In group II (assessment only) HbA_{1c} fell from 9.6 ± 0.4 to 8.8 ± 0.3% ($P < .05$), and in group III (prescriptive feedback) from 9.2 ± 0.4 to 7.9 ± 0.4% ($P < .01$). In group

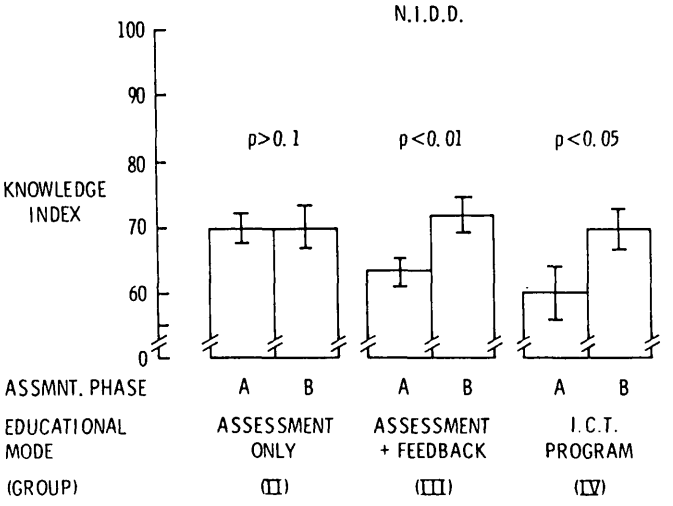

FIG. 3. Changes in knowledge index in NIDDM subjects (mean ± SE).

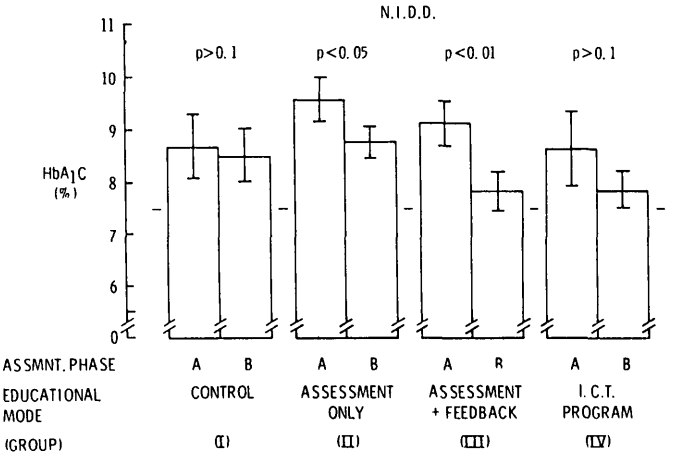

FIG. 5. Group comparisons of HbA_{1c} in NIDDM subjects (mean ± SE).

IV (teaching program) HbA_{1c} fell from 8.7 ± 0.7 to 7.9 ± 0.6%, which was not significant ($P > .1$).

Other relationships were also examined; in NIDDM, groups III and IV demonstrated an inverse correlation between knowledge increment and phase-B HbA_{1c} ($r = -.43$, $P < .05$; and $r = -.45$, $P < .05$, respectively). Although the correlation trend was similar in IDDM subjects ($r = -.2$ and -0.25), these relationships did not achieve significance ($P > .1$). There was no significant relationship between age or sex and either knowledge increment or HbA_{1c} decrease in any group.

DISCUSSION

The philosophy and principles of feedback correction have been previously examined in some detail.[7,8] When applied to diabetic patient learning, both this highly individualized method of linked evaluation and education as well as the graphics/text program have now been shown to be associated with knowledge increments that were significant in all test groups compared with controls. The absolute changes, although small, were significant because the system of marking resulted in a narrow range of final scores; 90% lay within the range 50–80%.

Significant mean HbA_{1c} reductions of 1.0 and 1.3% in IDDM and NIDDM, respectively, were seen with KAP/feedback and were of similar order or greater than the groups with the teaching (ICT) program. However, the means by which these improvements in control were achieved could not be clearly defined. Diet changes were not monitored nor were individual situation-dependent insulin-dose changes. However, in groups III and IV IDDM, twice as many patients as in groups I and II altered their routine insulin doses with or without the advice of the diabetic care team. It is also possible that both these computer-based approaches may influence the frequency of hypoglycemia and foot problems, important elements of behavior and performance that are being evaluated on a longer-term basis.

The KAP used in our study also allows audit of clinic knowledge profiles and a subsequent logical modification of teaching priorities for newly diagnosed diabetics. In our evaluation, a particularly high prevalence of ignorance was identified in the domains of "foot care" in NIDDM and "complications" in IDDM. These identified knowledge defects and their correlation with age, diabetes control, and duration are reported separately. The improvements in both knowledge and control with the ICT program suggest that basic concepts of knowledge and understanding are often deficient and that the inclusion of this particular program in the schedule of instruction for newly diagnosed diabetics may be very valuable; a further randomized prospective study comparing standard teaching with an ICT/standard teaching combination is currently in progress.

The significant fall of HbA_{1c} in both IDDM and NIDDM patients in whom score but no feedback (group II) was provided represents an unexpected finding. For these groups, no significant knowledge increment could be demonstrated in phase B; indeed, group II was designed as the reference group for evaluating the educational value of prescriptive feedback. However, both in IDDM and NIDDM patients, these HbA_{1c} reductions were less than in the corresponding groups (group III) in which feedback was additionally provided.

A confident explanation for the improved control without a knowledge increment as seen in group II cannot be provided from our study. However, motivation for improving diabetic control is far more complex than the simple provision of knowledge. We believe that increased motivation, achieved through awareness of critical objectives, together with a final score, as presented in the multiple-choice assessment, were responsible through behavioral change for the demonstrated falls in HbA_{1c}.

Duration of benefit beyond the 4–6 mo evaluated in our study cannot be anticipated. However, the KAP assessment now forms a regular component of our annual diabetes review program, and it is possible that such repeated ongoing evaluation and feedback will reveal not only maintenance but even progressive enhancement of knowledge status and control.

Recently, it was claimed that a 15-item questionnaire can fulfill certain criteria for knowledge status.[9] However, for comprehensive assessment and for use as an educational tool, we believe that a larger questionnaire, as in our study, is essential; without this broader spectrum, area-specific feedback cannot be meaningfully provided. Indeed, the question banks used in our study have been modified recently and extended (K. Meadows, B. Fromsen, and P. H. Wise, unpublished observations), allowing more thorough evaluation of all knowledge areas while maintaining an optimal range of facility indices. The current computer system has also been modified to provide both immediate on-screen as well as final hard-copy corrective feedback, together with subclassification of score into specific knowledge areas. In this way, patients can be selectively invited to subject-specific seminars dealing with their area(s) of greatest need.

Simple cross-sectional studies have found no relationship between HbA_{1c} and knowledge status either in this or other studies.[10] However, in our evaluation, knowledge increment from phase A to phase B did not correlate with final level of glycemic control, although significantly only in NIDDM patients. Nevertheless, the low order of this correlation suggests that only part of the benefit of computer-based learning is likely to be mediated by knowledge increment. Once again, enhanced motivation by the use of a novel teaching approach may be a more realistic explanation of the demonstrated improvement in diabetes control.

Our study was performed on equipment requiring an outlay of $5000, including a high-quality fast dot-matrix printer and monitor. Advances in computer technology with associated diminishing costs have allowed recent transposition of both programs to a system costing only $800, thereby allowing multiple modules to be operated concurrently and rendering such an education system feasible for use in a large diabetic clinic.

In conclusion, both for diagnosis and research, these com-

puter-based learning programs can be established as useful instruments, with evidence both of improved knowledge and control of sufficient magnitude to justify incorporation into routine clinic practice.

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