Psychometric Development of an Instrument to Measure Acquisition of Diabetes Knowledge

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Methods are described for validating a knowledge test for evaluating the information provided by "About Your Diabetes," an interactive video program for educating patients with diabetes. The psychometric analysis included the estimation of: (*i*) content validity by a panel of judges; (*ii*) readability levels using three readability formulae; (*iii*) internal consistency using the Kuder-Richardson 20 formula; and (*iv*) item statistics, including the point-biserial correlation coefficient, difficulty index, and the ability of items to discriminate between control and experimental groups. The instrument was tested using a posttest-only control group design and was found to be sensitive to information acquisition resulting from exposure to the educational program. The final test instrument consisted of 33 questions, each exhibiting desirable psychometric properties. This project represents the first of a series of steps in the comprehensive evaluation of an innovative method for educating patients with diabetes.

INTRODUCTION

Over the past several decades, the proportion or health care services targeted at the management of chronic disease has increased greatly compared to acute illnesses. One consequence of this shift has been a significant expansion of the role of the health care provider with greater emphasis on patient education and counseling. Commitment to the education of patients with diabetes, for example, has significantly expanded in recent years. While there are many aspects that affect the overall care of patients with diabetes, education has proven an essential element in the promotion of effective diabetes management.

In most communities, however, the provision of diabetes education through one-to-one counseling and other intensive personal approaches often demands more resources than is financially feasible. Given limited resources and increasing client load, the health care industry is turning to computer-assisted programs to augment other educational activities(1). In response to this need the prototype interactive video system, USP-DI Visualized "About Your Diabetes," has recently been developed as a joint effort of The United States Pharmacopeial Convention, Inc., The American Diabetes Association, and Auburn University.

It is generally accepted that knowledge is not a sufficient predictor of behavior, but when developing new methods of patient education there still remains a need to assess patient knowledge to assure that necessary information acquisition has occurred. Many test instruments have been developed over the years to assess diabetes-related knowledge, but it was not until recently that researchers became concerned with the systematic analysis of the instruments. To understand the value of a test score, one must first closely examine the characteristics of the overall test, its subsections, and each individual item. The use of test instruments that have not been psychometrically analyzed renders results difficult to interpret and potentially invalid. In a review of the literature, only five identified studies of diabetes knowledge test instruments reported psychometric data (2-6). Although the instruments previously described in the literature were designed to evaluate educational programs that did not include interactive video, the methods employed for psychometric analyses are similar. This includes estimates of the instrument's validity, reliability and readability level, and the computation of item statistics.

The purpose of this study was to develop a diabetes knowledge test instrument for measuring acquisition of information provided by four sections of USP-DI Visualized "About Your Diabetes." Our objective was not to develop an instrument exhibiting properties similar to a typical "classroom test," but to develop questions that provide health care providers with useful information about the acquisition of diabetes information and the extent to which the program contributes to that acquisition. This report describes the procedures in developing the test instrument and is the first of a series of steps necessary for a comprehensive evaluation of the effectiveness of a new and innovative method of educating patients with diabetes.

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METHODS

Educational Program and Instrument Development

The interactive video program consists of three major modules, "About Your Diabetes," "About Your Treatment," and "Self-Monitoring," which are further divided into sub-modules. The program utilizes CD-ROM and interactive display technology via a personal computer. The interactive screen, or touch-screen, enables patients to "interact" with the computer by touching the screen, rather than by using a keyboard. No prior computer knowledge or typing skills are necessary. Through the use of realistic, full-motion videos with audio reinforcement, the program is designed to ensure that the meaning of the spoken and printed information is conveyed by combining the narration or text with visual examples. The software has the unique capability of being able to customize the presentations to individual patients. One distinct advantage of the "About Your Diabetes" instruction system is that it includes interim testing for information acquisition throughout the program. Specifically, patients are periodically prompted to respond to questions by touching their selected answers on the screen. Answers are recorded by the computer for review by the health care provider at the end of the session.

For this study, four sub-modules of the diabetes program were chosen: (*i*) general information; (*ii*) oral antidiabetes agents; (*iii*) exercise; and (*iv*) foot care. The information from these sub-modules, excluding the interim test questions, was extracted from the overall interactive video program and transferred onto a videotape. It should be clear to the reader that the effect of the interactive display technology was not measured for this study. That will be done in a future study. The first step was to develop a valid measure of information acquisition. In this regard, forty multiple choice test questions with five possible answers were developed to target key points in the program. Multiple choice was chosen as the format because it offers reliable, objective scoring.

To estimate content validity, four judges were chosen for their expertise with diabetes and educational programs. The judges included two Masters-level academicians trained in patient education, one representative from the American Diabetes Association, and one representative from USP-DI. All four members of the panel were instrumental in the development of "About Your Diabetes." Content validity was assessed by having each judge compare the series of questions with the typewritten script from the program. The instrument was assessed to assure that the questions accurately represented the domain of information provided by the four sub-modules. Questions were revised based on the suggestions of the judges. When the final draft of the test instrument was completed, readability levels for the questions and answers were determined using the Grammatik IV[7] software package. Grammatik IV determines readability using three separate formulae: the Flesch Reading Ease, Gunning Fog Index, and Flesch-Kincaid Grade Level.

The Flesch Reading Ease score is calculated using the average number of words per sentence and the number of syllables per 100 words to predict the readability level of written text. Values can range from 0 (most difficult) to 100 (most easy). The Flesch-Kincaid formula also incorporates the average number of words per sentence and average number of syllables per word, but will indicate the average number of years of schooling that are necessary to understand the text. The formula used to determine the final score within Grammatik IV, the Gunning Fog Index, is based on the average number of words per sentence and the number of words with three or more syllables. The Fog Index is another estimate of the grade level a reader must have completed to comprehend written text.

Subjects and Study Design

A posttest-only control group design was used for this evaluation. This design was selected instead of the one-group pretest-posttest design, employed in a previous study of this type[6], primarily because it protects against the effects of testing, a threat to internal validity. The study population consisted of student volunteers at a major university who received extra course credit for participation. All subjects who volunteered were allowed to participate, but data were used only from subjects who did not have diabetes or did not have an immediate family member with diabetes. While it would have been ideal to use patients with diabetes for this initial phase of the evaluation, it was thought that because the subjects in the final sample did not require the information for self-care or care of a significant other, they would have limited motivation to learn the presented material. Although it is possible that this could limit the generalizability of the results, the investigators believed that it would yield conservative results from testing while also removing the burden of research participation from newly-diagnosed patients.

Participating subjects signed up for one of nine scheduled session times. The individual sessions were then randomized to conditions (exposure and control groups). Initially, 88 subjects (51 men and 37 women) volunteered to participate. Sixteen subjects failed to attend their scheduled times, yielding a total of 72 participants. After random assignment of session times to conditions, there were 41 subjects in the exposure group (21 men and 20 women) and 31 subjects in the control group (17 men and 14 women). The discrepancy between the total number of participants in the control and experimental groups is due to unequal numbers of subjects in the sessions; attrition was proportional across conditions. Of the 72 participants, four (one woman from the exposure group, and two men and one woman from the control group) were either patients with diabetes or had an immediate family member with diabetes. These four subjects were allowed to participate in the study, but their data were not used in the analyses. The average age of the exposure group was 21.56 years and the average age of the control group was 21.54 years.

Subjects in the exposure group viewed the videotaped presentation from "About Your Diabetes" that was immediately followed by a 10-minute distractor videotape, the administration of an evaluation form, and the administration of the test instrument. The purpose of the distractor and the evaluation form was to prevent a learning recency-effect that may have resulted in a ceiling effect. The time length of the overall presentation, including the distractor, was 39 minutes. Subjects in the control group viewed an unrelated videotape program of similar duration followed by the same distractor videotape, evaluation form and test instrument.

Instrument Analysis

Questions in the instrument were individually analyzed. Item statistics that were calculated using experimental group data only included the difficulty index and the point-biserial correlation coefficient. Items were also analyzed for their ability to discriminate between control and experimental

groups. Items exhibiting undesirable psychometric properties were identified and eliminated. The internal consistency of the final instrument was estimated using the Kuder-Richardson 20 formula for internal consistency, which is the form of Cronbach alpha used for dichotomous data.

Items for the final test instrument were selected based on their difficulty index, point-biserial correlation coefficient, and ability to discriminate between conditions. The point-biserial correlation coefficient (r_{pb}) was used to estimate the ability of a test item to discriminate individuals who perform well on the test as a whole and individuals who perform poorly on the test as a whole[8]. The difficulty index was calculated as the number of subjects who answer an item correctly divided by the total number of subjects attempting it.

Before examining the data, the following question was addressed: What is the purpose of the test instrument? The objective of the current study was not to develop a test instrument exhibiting similar characteristics as the typical "classroom test." While the psychometric methods employed in this study are similar to those used in the evaluation of classroom tests, in the classroom it is generally desirable for tests to exhibit a "normal" distribution of grades. To accomplish this, some items are intentionally designed to be more difficult and/or more discriminating than others. This characteristic differs for instruments designed to simply measure knowledge acquisition. Our goal was to develop questions that provide diabetes educators and other health care providers with accurate, useful information about the acquisition of diabetes information and the extent to which the interactive video program contributes to that acquisition. The 40 questions were individually examined. Through this analysis, psychometrically unsound questions were identified and eliminated.

Although the decisions to eliminate questions were subjective, some general guidelines were followed. Questions discriminated between groups at a probability level of $P < 0.1$. If a question did not discriminate at this level, it was only kept when it was thought that the control group possessed the knowledge required to correctly answer the question prior to participation in the study. Items that were difficult for the exposure group (with a difficulty index below 0.50) were not considered acceptable unless they also had relatively high point-biserial correlation coefficient and were able to discriminate between conditions. Questions that were more difficult for the exposure group than for the control group were eliminated. Before discarding any questions, an attempt was made to determine if the questions themselves were problematic or if the information in the program had been presented in a way that was ambiguous or confusing. This was done by examining trends in actual responses (*e.g.,* a, b, c, d or e). If the incorrect responses were evenly distributed among the four distractor alternatives, the item itself was deemed acceptable. In contrast, if one of the incorrect response alternatives was chosen at an unusually high frequency, it was inferred that one of the distractor choices was unacceptably strong and may have been misleading to the subjects.

RESULTS

The readability level for the test instrument was assessed using the Grammatik IV[7] software package. The overall instrument exhibited a Flesch Reading Ease of 79 (considered "fairly easy" to read, generally readable by individuals

Table I. Analysis of variance of group scores by sub-module

Sub-module (q = # of questions)	Control (n=28) Mean (SD)	Exposure (n=40) Mean (SD)	F
General information (q=8)	2.86 (1.28)	6.48 (1.30)	87.07[a]
Drug therapy (q=16)	5.25 (2.13)	11.15 (2.20)	80.96[a]
Exercise (q=6)	2.39 (0.79)	3.48 (1.26)	14.98[a]
Foot care (q=10)	4.17 (1.51)	7.55 (1.75)	45.39[a]

P < 0.001.

who have completed the sixth grade), a Gunning Fog Index of 7 (corresponding to a seventh-grade reading level), and a Flesch-Kincaid grade level of 4.

The scores of the four sub-modules were subjected to a 2 X 2 multivariate analysis of variance (MANOVA) with follow-up univariate analyses of variance (ANOVA) on each module. The purpose of the MANOVA was to determine if the overall test instrument was sensitive enough to discriminate information acquisition between the exposure and control groups (condition) and to determine if there was an effect of gender or the interaction of gender and condition on information acquisition. Results of the MANOVA, using the Hotelling-Lawley algorithm, produced a significant condition main effect $F(4, 61) = 35.29$, $P < 0.0001$. The results of the follow-up ANOVAs are presented in Table I. No significant differences were revealed for the effects of gender or the interaction of gender and condition on information acquisition. The results for each sub-module are redundant with the MANOVA. An additional univariate ANOVA for total scores (sum of the four modules) also revealed a significant difference between conditions $F(1, 64) = 124.80$, $P < 0.0001$.

Item statistics were calculated for each question in the instrument (Table II). The point-biserial correlation coefficients ranged from 0.02 to 9, and the difficulty indices (DI) ranged from 0.18 to 0.95. A frequency distribution, based on condition, was computed to assess the number of subjects correctly answering each item and the number of subjects incorrectly answering each item. Corresponding Chi-square probabilities were calculated to determine differences between the performance of the condition groups. These values ranged from $P = 0.000$ to $P = 0.886$. The purpose of these computations was to demonstrate the ability of the items to discriminate between subjects who viewed the USP-DI Visualized videotape and subjects who did not. Items for the final test instrument were selected based on their difficulty index, point-biserial correlation coefficient, and ability to discriminate between conditions. For example, item #17, which pertained to the cause of ketoacidosis, exhibited a difficulty index of 0.18, a point-biserial correlation coefficient of 0.18 and a *P*-value associated with Chi-square of 0.685. This item was eliminated because it did not significantly discriminate between the control and experimental groups, and it was more difficult than desired.

Through this process, seven items were eliminated that did not exhibit desirable psychometric properties. A total of 33 items remained (Appendix A; original numbering retained to facilitate comparison with Table II). It was determined that the elimination of the questions did not significantly jeopardize the content validity of the instrument because remaining questions addressed similar key points

Table II. Summary of item analysis

Question #	DI	r_{pb}	P
1	0.90	0.21	0.002
2	0.93	0.12	0.000
3	0.85	0.47	0.000
4	0.88	0.15	0.000
5	0.65	0.28	0.000
6	0.63	0.25	0.019
7	0.93	0.41	0.000
8	0.73	0.32	0.000
9	0.85	0.39	0.000
10	0.80	0.22	0.000
11	0.93	0.31	0.000
12	0.93	0.67	0.000
13	0.90	0.15	0.048
14	0.85	0.45	0.002
15	0.93	0.02	0.000
16[a]	0.73	0.68	0.188
17[a]	0.18	0.18	0.685
18	0.53	0.17	0.010
19	0.63	0.12	0.000
20[a]	0.50	0.08	0.560
21	0.63	0.23	0.006
22[a]	0.38	0.30	0.649
23[a]	0.20	0.05	0.886
24[a]	0.38	0.17	0.014
25	0.85	0.39	0.753
26	0.80	0.31	0.020
27[a]	0.65	0.39	0.806
28	0.78	0.48	0.038
29	0.70	0.37	0.095
30	0.55	0.49	0.001
31	0.90	0.42	0.318
32	0.75	0.26	0.016
33	0.73	0.30	0.307
34	0.75	0.26	0.003
35	0.48	0.26	0.004
36	0.90	0.06	0.000
37	0.75	0.26	0.016
38	0.73	0.30	0.307
39	0.95	0.35	0.000
40	0.68	0.57	0.245

Difficulty index.

r_{pb}= Point-biserial correlation coefficient.

P = Probability associated with Chi-square.

[a] Eliminated through item analysis.

from the educational program. The estimate of internal consistency of the final test instrument, using data from the experimental group only, was 0.72 using the Kuder Richardson 20 formula.

DISCUSSION

Numerous test instruments have been developed over the years to test for diabetes-related knowledge in patients with diabetes. However, only five studies were identified that reported psychometric data. Two previous articles on the psychometric analysis of a diabetes test instrument report conducting a readability analysis. Hess and Davis(4) reported a readability level of 8th to 9th grade, but did not indicate which formula(e) were used. Garrard and others(6), using the Dale-Chall formula, reported an average readability level of 7th to 8th grade with a range of 5th to 12th grade. Readability is a critical factor that must be considered because not all subjects have the same reading ability. With over 40 existing formulae for measuring readability (9), difficulty arises in deciding which formula(e) to use. Because considerable variance exists between the different formulae(10), it is suggested that the reliability of assessments improves by utilizing three or more tests concurrently(11). In the analysis of the current instrument, readability was assessed using the Grammatik IV(7) software package for the Flesch Reading Ease score, the Flesch-Kincaid score, and the Gunning Fog Index. Although the three formulae used in the current study may not perfectly correlate with those used in previous studies, a general interpretation of the current test instrument's readability level can be made comparatively. The instrument achieved a readability level comparable to, or lower than, the levels attained by previous tests. While the instrument was designed for the evaluation of the program, it is important to note that this readability analysis pertains only to subjects who complete the written test.

The final test instrument consisted of 33 questions and exhibited an internal consistency estimate (KR20) of 0.72. While this value is lower than those reported in previous studies(3-6), it is predicted that when new questions from the remaining modules of the program are added to the instrument and it is administered to a more heterogenous population, the internal consistency estimate will increase(12). While it is often suggested that instruments should exceed a minimum level of 0.70(12, 13), the acceptable level of error should be determined with respect to the hypothesis being tested and its corresponding level of power to detect a treatment effect. It also should be recognized that the estimate is highly dependent on the total number of the items(12).

The multivariate and univariate analyses of variance revealed significant differences between conditions. It is important for the developers of "About Your Diabetes" to know that significant information acquisition occurs as a result of viewing the modules, but more important to the objectives of this study is the fact that the test instrument is sensitive enough to detect these changes. Had the results of the multivariate and univariate analyses of variance revealed no significant differences, then one would conclude that either information acquisition did not occur as a result of viewing the program, or the test instrument was unable to detect the changes. Suggestions for future research regarding the current test instrument include the development of additional questions for the remainder of the program and the evaluation of the interactive video program for its effectiveness in patient education as compared to more traditional methods of teaching. It also would be of interest to reproduce this study in a population of patients with diabetes to empirically test the appropriateness of the decision to use student volunteers as our study population. If it is confirmed that the results are generalizable across populations, considerable burden could be removed from patients in the future by employing student volunteers for this type of study.

In relation to diabetes education, it is important for the diabetes educator or health care provider to make correct assessments of patient knowledge. Without psychometrically sound measures of patient knowledge, it is difficult for educators to accurately interpret a patient's level of knowledge. This can lead to ineffectively managed patient care. Valid and reliable methods of measurement can be used to determine the effectiveness of an educational program and

to examine relationships between patient knowledge and adherence or outcomes of therapy. If a positive relationship is demonstrated, a concerted effort of health care providers toward educating patients with diabetes will be warranted, and the need for educational programs such as USP-DI Visualized "About YOUT Diabetes" may be increased.

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APPENDIX A. FINAL TEST INSTRUMENT OF REVISED ITEMS (Original numbering retained)

DIRECTIONS: Read each item and decide which answer best completes the statement or answers the question. Mark your answer by circling the appropriate letter. There is only one answer per question. Please answer all questions.

(1) Insulin is made by:
  a. the adrenal gland.
  b. the pituitary.
  c. the pancreas.
  d. the thyroid.
  e. the liver.
(2) Ninety percent of patients with diabetes have:
  a. type I diabetes.
  b. type II diabetes.
  c. juvenile-onset diabetes.
  d. gestational diabetes.
  e. both type I and type II diabetes.
(3) The normal amount of blood sugar when fasting (not eating) is:
  a. 0-50 mg/dl.
  b.. 50-70 mg/dl.
  c.. 70-115 mg/dl.
  d.. 115-140 mg/dl.
  e.. 140-200 mg/dl.
(4) The pancreas:
  a. makes glucose.
  b. makes glucose go out in the urine.
  c. makes ketones.
  d. makes insulin.
  e. helps food be absorbed from the stomach.
(5) Diabetes is NOT caused by:
  a. genetics (inherited factors).
  b. obesity (being very overweight).
  c. high blood pressure.
  d. environmental factors.
  e. insulin resistance.
(6) Having diabetes for a long time may lead to all of the following problems EXCEPT:
  a. heart and circulation problems.
  b. kidney problems.
  c. stomach ulcers.
  d. eye problems.
  e. a stroke.
(7) In type II diabetes:
  a. medications may be obtained without a prescription.
  b. oral medications may be used.
  c. exercise and weight control are not important.
  d. chocolate is a good source of sugar when blood sugar is low.
  e. sugar in the diet must be increased.
(8) A symptom of high blood sugar is:
  a. less urination.
  b. weakness.
  c. less thirst.
  d. weight gain.
  e. high blood pressure.
(9) Medicines for type II diabetes.
  a. are taken by mouth.
  b. may also help someone with type I diabetes.
  c. may substitute for exercise.
  d. are injected into the vein.
  e. can be bought without a prescription.
(10) Some oral anti-diabetes medicines work to lower blood sugar by:
  a. causing the pancreas to release more insulin.
  b. causing more sugar loss in the urine.
  c. decreasing sugar absorption from the stomach.
  d. decreasing hunger.
  e. lowering blood pressure.
(11) Oral anti-diabetes medicines do NOT work as well if you:
  a. have high blood pressure.
  b. have arthritis.
  c. are over 40 years old.
  d. are underweight (very thin).
  e. are obese (very overweight).
(12) Which is NOT a good source of sugar to use when blood sugar is low?
  a. chocolate
  b. honey
  c. hard candy
  d. Coca Cola
  e. fruit juice
(13) Another word for low blood sugar is:
  a. hyperglycemia

b. hypotension
c. hypokalemia
d. hypoglycemia
e. hypertension

(14) Fat breakdown in the body can lead to:
a. high blood pressure.
b. fever.
c. weight gain.
d. cold feet.
e. ketones in the urine.

(15) Many people with type II diabetes:
a. do not have to follow a meal plan.
b. can control their diabetes with exercise and diet alone.
c. are less than 20 years old.
d. inject insulin into the veins.
e. do not have a pancreas.

(18) A type of drug which masks (hides) the signs of low blood sugar is:
a. a blood thinner.
b. aspirin.
c. sulfur medicine.
d. tylenol.
e. beta-blockers.

(19) In regard to oral anti-diabetes medicines:
a. they cannot be used together with injected insulin.
b. if you miss a dose, double the next dose.
c. they are generally sensitive to heat and moisture.
d. they are commonly used in people with type I diabetes.
e. meal planning is not important.

(21) A sign of low blood sugar is:
a. burning urination.
b. frequent bowel movements.
c. rapid pulse.
d. hot, flushed face.
e. muscle cramps.

(25) Hypoglycemia means:
a. extremely high blood sugar.
b. high blood sugar.
c. normal blood sugar.
d. low blood sugar.
e. no blood sugar.

(26) A regular exercise program may:
a. lower the need for diabetes medicine.
b. cure diabetes.
c. cause diabetes.
d. decrease cholesterol levels.
e. increase sugar loss in the urine.

(28) People with type II diabetes should:
a. not exercise.
b. not drink a lot of water when exercising.
c. keep hard candy or other source of sugar with them when exercising.
d. not exercise if their blood sugar level is over 150mg/dl.
e. inject insulin before exercising.

(29) A patient with type II diabetes may raise levels of "good" cholesterol by:
a. taking more oral antidiabetes medicine.
b. lowering alcohol intake.
c. exercising more.
d. drinking more water.
e. taking less oral antidiabetes medicine.

(30) Persons with diabetes should not exercise if glucose levels go over:
a. 50 mg/dl.

b. 70 mg/dl.
c. 100 mg/dl.
d. 150 mg/dl.
e. 250 mg/dl.

(31) The main cause of foot problems in patients with diabetes is:
a. varicose veins.
b. corns and calluses.
c. poor circulation.
d. fallen arches.
e. big feet.

(32) A sign of poor circulation in the feet is:
a. leg pain when dangling feet.
b. thin toenails.
c. lower back pain.
d. weak leg muscles.
e. cold feet.

(33) Intermittent claudication is:
a. lower back pain.
b. foot ulcers.
c. ketones in the urine.
d. a fungus infection.
e. pain in the calf.

(34) When trimming toenails:
a. trim nails straight across.
b. apply hand lotion on nails and between toes when done.
c. do not trim nails too short.
d. trim closely into the corners.
e. do NOT use an emery board or nailfile.

(35) A sign of nerve damage in the feet is:
a. cold feet.
b. slow healing of cuts and scratches.
c. leg pain at night.
d. weak leg muscles.
e. lower back pain.

(36) As part of your daily foot care routine:
a. wash feet with very hot water.
b. wash feet with a strong soap.
c. allow feet to air dry.
d. apply hand lotion between toes when done.
e. inspect feet for injuries.

37) When caring for your feet:
a. shoes made of man-made fabrics are better than leather.
b. wear nylon socks if possible.
c. do not go barefoot when at home.
d. do not wear tennis shoes.
e. it is best to wear sandals.

(38) Intermittent claudication may be caused by:
a. low blood sugar.
b. loss of appetite.
c. ketones in the urine.
d. high blood pressure.
e. poor circulation.

(39) When caring for your feet, you should:
a. use chemicals to remove corns and calluses yourself.
b. use a heating pad or hot water bottle on your feet.
c. put lotion between your toes.
d. pull off loose pieces of skin.
e. avoid sitting with your legs crossed.

(40) A change in the shape of the foot can mean you have:
a. lower back pain.
b. ketoacidosis.
c. low blood sugar.
d. kidney infection.
e. nerve damage