

Blood Glucose Awareness Training Delivered Over the Internet

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OBJECTIVE— Blood glucose awareness training (BGAT), a psycho-educational intervention, trains individuals with type 1 diabetes to 1) detect/interpret internal cues to better detect extreme blood glucose levels, e.g., neurogenic and neuroglycopenic symptoms; and 2) interpret external cues to detect current and anticipate future extreme blood glucose levels, e.g., insulin timing/dose and recent self-monitoring of blood glucose results. Although outcome studies using BGAT are significant, limitations include the requirement of eight weekly meetings and limited professionals trained to deliver BGAT.

RESEARCH DESIGN AND METHODS— Due to the limitations mentioned above, BGAT was converted for web-based delivery. The internet allows BGAT delivery to be dynamic, engaging, convenient, and personalized. Efficacy was evaluated using a 2 (BGAThome, $n = 20$, vs. control, $n = 20$) \times 2 (pre/post) design.

RESULTS— BGAThome was judged as useful and easy to use, was completed by 94% of the participants, and resulted in significant clinical improvements ($P < 0.05$).

CONCLUSIONS— The internet may be an efficient and effective means of delivering diabetes interventions like BGAT.

Diabetes Care 31:1527–1528, 2008

Thirteen U.S. and European studies have documented the benefits of blood glucose awareness training (BGAT) (1). These benefits include improvements in detecting and reducing the occurrences of extreme blood glucose levels and their sequelae, e.g., reducing occurrence of ketoacidosis, severe hypoglycemia, hypoglycemia-related driving mishaps, and fear of hypoglycemia. We hypothesized that an internet version of BGAT would be perceived as useful, be completed efficiently, and produce greater clinical benefits compared with a wait-list control group.

RESEARCH DESIGN AND METHODS

A notice in *Diabetes Forecast* inviting participants to evaluate BGAThome.com resulted in 210 individuals completing an online screening in 10 days. Participants were

the first 40 individuals who, by telephone interviews, met the following inclusion criteria: type 1 diabetes, routinely measuring blood glucose levels more than twice a day, and willingness to devote 1–2 h/week for 8–10 weeks to completing BGAThome. Of 108 responders telephoned, 38 were unreachable, 14 were ineligible, and 10 declined participation (Table 1).

After signing institutional review board–approved informed consent, participants were mailed a handheld computer (HHC) and a LifeScan One-Touch meter with supplies for one month's use. Participants were instructed to 1) activate the HHC before performing routine self monitoring of blood glucose (SMBG); 2) enter an estimate of their current blood glucose level; 3) based on this estimate, indicate whether they should then eat fast-acting carbohydrates, engage in vig-

orous exercise, or drive; and 4) perform SMBG and record their actual blood glucose levels. After returning the HHC, participants completed online a demographic questionnaire, the Diabetes Knowledge Scale, and the Hypoglycemia Fear Survey (2). The HHC and questionnaire data were collected again 12 weeks later, along with Likert-scale items assessing BGAThome's benefits and usability.

Users were given 12 weeks to complete BGAThome's units, detailed elsewhere (1). Central to BGAT is completing daily blood glucose diaries, in which participants 1) record relevant blood glucose information and symptoms, 2) estimate their current blood glucose, 3) receive feedback on their estimate accuracy by performing and recording SMBG, 4) interpret the clinical significance of their accuracy with the error grid (2), and 5) anticipate their blood glucose level 1 h later. To encourage use of blood glucose diaries, participants were only given access to the next unit 7 days following completion of the previous unit.

With internet delivery to a heterogeneous sample, individuals would be expected to pursue BGAT for various reasons. Thus, the primary outcome variable would need to incorporate a variety of possible desired outcomes. Consequently, our Improved Functioning Score (IFS) is a composite score where assessment-dependent variables are converted to Z scores. Assessment 2 performance was converted to Z scores based on assessment 1's mean and SD. Z scores for each outcome variable were totaled, where zero reflects average baseline functioning for all variables and +1 reflects performance across all variables one SD above the sample's baseline mean (3). It incorporated the following variables from questionnaires: Diabetes Knowledge Scale (percent correct) and Hypoglycemic Fear Survey (sum of Worry subscale). It also incorporated the following variables from the HHC: percent SMBG readings within target range (3.9–10.0 mmol/l), number of undetected blood glucose readings <3.9 mmol/l, overall blood glucose estimation accuracy (Accuracy Index) (4), when blood glucose levels

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Received 9 October 2007 and accepted 9 May 2008.

Published ahead of print at <http://care.diabetesjournals.org> on 13 May 2008. DOI: 10.2337/dc07-1956.

Clinical trial reg. no. NCT00327210, clinicaltrials.gov.

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Table 1—Demographics of participants in the waiting-list control and BGAThome groups

	Waiting-list control group	BGAThome.com group	Comparison values
Demographics			
Sample size (n)	18	17	
Age (years)	52.7 ± 13.96	43.7 ± 14.06	F(1,33) = 3.79, P < 0.07
Sex (% female)	56	59	$\chi^2 = 0.04$, P < 0.85
Race (% white)	100	100	
Years of education	15.3 ± 1.71	16.1 ± 1.93	F(1,33) = 1.86, P < 0.19
Married	78	71	$\chi^2 = 1.13$, P < 0.57
Age at diagnosis (years)	26.3 ± 16.24	18.9 ± 8.86	F(1,33) = 2.79, P < 0.11
Height (in)	66.6 ± 13.73	67.6 ± 4.15	F(1,33) = 0.54, P < 0.47
Weight (lbs)	163.2 ± 30.99	178.3 ± 47.32	F(1,33) = 1.26, P < 0.28
Dependent variables pre- to posttreatment			
Decisions to eat fast-acting carbohydrates when blood glucose is <3.9 mmol/l (%)	35 (25.4) to 25 (30.7)	36 (25.0) to 45 (30.9)	F(1,24) = 3.73, P < 0.07
Decisions not to drive when blood glucose is <3.9 mmol/l (%)	57 (28.2) to 52 (36.5)	45 (32.6) to 59 (34.1)	F(1,24) = 2.46, P = 0.13
IFS	0.46 (3.8) to 0.60 (4.0)	-0.49 (4.0) to 1.87 (4.1)	F(1,33) = 4.20, P < 0.05

Data are means ± SD or percent.

are <3.9 mmol/l, number of risky decisions to drive, not eat fast-acting carbohydrates, and exercise.

RESULTS— Two wait-list control group participants and one BGAThome participant dropped out during the treatment period. Two BGAThome participants dropped out during assessment 1.

ANOVA demonstrated that BGAThome resulted in greater improvement in IFS: interaction F(1,33) = 4.20; P = 0.048 (Table 1). On a scale of 1–5 in which 1 = Not at all and 5 = Very, treatment participants rated BGAThome as beneficial, easy to use, and enjoyable (3.8 ± 1.17, 3.9 ± 0.73, and 3.8 ± 1.04, respectively).

On average, participants completed BGAThome in 11 weeks, logged onto BGAThome.com 30.4 ± 16.51 times, and spent 26.4 ± 16.3 min on each unit. These measures of use indicate trends toward a relationship between more website use and increased benefits. More time spent on units was associated with greater IFS improvement ($r = -0.36$, $P = 0.10$). More frequent log-ons were associated with greater improvement in knowledge ($r = 0.49$, $P = 0.03$) and lower blood glucose levels <50 mg/dl ($r = -0.54$, $P = 0.02$). Age was not correlated with IFS improvement; however, education tended to be associated with improved IFS ($r = 0.45$, $P = 0.07$).

CONCLUSIONS— BGAThome was found to be beneficial, easy to use, and enjoyable. This is the first time BGAT was made available to individuals with various goals, needs, diabetes regimens, and re-

sources. Despite this heterogeneity, BGAThome improved performance, summed across all eight dependent variables an average of 2.37 SDs.

Greater BGAThome use appeared to yield improved benefits. Engagement might be further enhanced by 1) incorporating a chat room where users share experiences and support; 2) employing a group context, led by a diabetes educator (5); 3) undergoing an initial motivational interview (6); 4) fiscally investing in training; and 5) having a pressing personal goal, such as achieving tight metabolic control because of pregnancy without increasing risk of severe hypoglycemia (7) or following a costly hypoglycemia-related driving mishap.

While our final participant sample came from 35 different U.S. cities and 21 different states, allowing greater external validity, the sample size and its demographic composition (white, middle-aged, educated individuals) was a limitation of this study. A larger, more representative sample would also allow investigation into the role of socioeconomic status, race, and education.

Nevertheless, this study indicates the possible benefits of disseminating BGAThome over the internet in a personalized and self-directed format, serving a large number of individuals in a cost-effective manner.

Acknowledgments— This study was supported by the American Diabetes Association; the National Institutes of Health Grant DK28288; LifeScan, Inc.; and contributions by post-doctoral fellow Kushal Patel.

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