Subjective Symptoms, Blood Glucose Estimation, and Blood Glucose Concentrations in Adolescents With Diabetes

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Twenty-five adolescent campers with insulin-dependent diabetes mellitus (IDDM) completed a Symptom Rating Checklist and estimated their blood glucose (BG) immediately before having their BG assessed four times daily for 11 days. Consistent relationships between BG and symptoms were not identified when the data were analyzed for the group as a whole. However, when each camper's data were analyzed separately, 23 of the 25 adolescents had at least one significant glycemia-symptom (G-S) correlation. Each camper seemed to have a unique G-S pattern; only one symptom (hungry) was significantly related to BG for more than half of the youngsters studied. Almost all of the significant G-S correlations were indicative of low rather than high BG. However, when asked, few campers were able to accurately identify which symptoms were reliably associated with low or high BG. In this study, different measures of BG estimation error led to different results. The percent of estimates ±20% of the actual BG value (55% in this study) was strongly influenced by the actual BG reading because higher BG values have larger accuracy ranges than lower BG concentrations. When estimated BG was simply subtracted from actual BG, under- and overestimates canceled each other out, resulting in an unusually small estimated error (5 mg/dl in this investigation). The absolute difference score ignores the direction of estimation error, but may more accurately reflect patients' average estimation error (68 mg/dl in this study). When actual and estimated BG values were correlated for the group as a whole, the patients appeared to be highly accurate at estimating BG ($r = .93$, $P < .0001$). However, when the same correlational analysis was conducted for each individual camper, BG estimation accuracy appeared substantially reduced (mean $r = .51$) and varied greatly from camper to camper (range $r = .06–.80$). The type of estimation error was also strongly influenced by the actual BG value. Low (<70 mg/dl) and middle (70–150 mg/dl) range readings were often overestimated, while higher BG values (>150 mg/dl) were frequently underestimated. In the sample studied, campers with lower mean BG were better able to correctly identify hypoglycemic symptoms and made more accurate BG estimates than their more poorly controlled peers. However, BG estimation accuracy was unrelated to G-S patterns and to camper awareness of G-S patterns; this suggests that campers were *not* using internal symptoms to estimate BG. DIABETES CARE 1986; 9:236–43.

For youngsters with diabetes, the goal of treatment is to maintain blood glucose levels as close to normal as possible. Since current treatment methods permit only a crude approximation of normal pancreatic function, imperfect attainment of this goal is to be expected. The detection of symptoms associated with high and low blood glucose concentrations (BG) is an important component of diabetes self-management because symptoms can provide an important signal to act, e.g., to take a BG reading or eat a snack. Consequently, patients with diabetes are taught signs and symptoms that are indicative of abnormally high or low BG levels. However, little is known about patients' actual use of these signs and symptoms to accurately detect hyper- or hypoglycemia.

TABLE 1
Blood glucose–symptom correlations for each camper*

Symptoms	Camper																					
	1	2	3	4	5	6	7	8	9	10	12	14	15	17	18	19	20	21	22	23	24	25	26
Headache												+.35					−.45						
Dizzy		−.34							−.38				−.42							−.39			
Hot face												+.36										−.32	
Trouble talking													−.34										
Hard to concentrate																	−.37		−.39				
Dry eyes, nose, mouth																							
Sweet taste																					+.45		+.33
Mouth watery																							
Thirsty							−.35																−.47
Heart beating fast		−.36		−.54												−.43					−.32		
Pounding heart				−.54																	−.34		
Hard to breathe	−.34																						
Nausea			−.38											−.38		−.44	−.42						
Stomachache									−.34				−.37	−.44		−.48		−.38					
Hungry		−.35	−.35	−.51	−.55	−.36	−.50	−.63				−.38	−.37			−.35		−.52		−.40			−.47
Tired				−.43			−.40	−.36			−.46					−.52	−.43	−.49		−.41			−.33
Shaky		−.40		−.54				−.53				−.44			−.51	−.51	−.42	−.49	−.36	−.46		−.38	−.44
Sleepy							−.37			+.48													
Sweaty																						−.32	
Tense muscles							−.40	−.37															
Bathroom a lot												+.36											
Upset, annoyed																							
Nervous, anxious																							
Multiple R	.33	.50	.44	.68	.55	.36	.65	.63	.40	.48	.47	.73	.54	.45	.51	.63	.71	.61	.41	.57	.58	.46	.71
Multiple R^2	.11	.25	.19	.46	.30	.13	.42	.40	.16	.23	.22	.53	.29	.20	.26	.40	.50	.37	.17	.32	.34	.21	.50

*Only significant correlations ($P < .025$) are included.

Most patients will describe symptoms that they believe are indicative of high or low BG. However, the symptoms vary greatly from patient to patient and are not always consistent with physician-selected symptoms of hypo- or hyperglycemia.[1] Studies that have correlated symptoms with BG have found little support for a relationship between the two when data are analyzed for groups of patients as a whole.[1,2] However, Pennebaker, Cox, and colleagues explored glycemia-symptom (G-S) patterns in adult patients using a within-subject analysis and found strong evidence that such patterns do exist, but are unique to the individuals.[2,3]

The purpose of the present investigation was to examine G-S relationships in an adolescent population and to evaluate adolescents' ability to estimate their own BG.

METHODS

Subjects and setting. Participants were 14 male and 11 female volunteers, 12–15 yr old, attending a 2-wk summer camp for youngsters with diabetes (Florida Camp for Children and Youth with Diabetes, Inc.). Their diabetes was of 6 mo to 13 yr duration, with a median of 2.3 yr.

Instruments. Using symptoms identified in two previous investigations,[1,2] a 23-item Symptom Rating Checklist was developed with symptoms organized by body part, e.g., symptoms associated with the stomach. The camper was instructed to concentrate on how his whole body felt by focusing on each part separately and then to indicate the degree to which each symptom was experienced on a 7-point scale (from 0 = not all to 6 = a whole lot). A space was also provided for the patients' estimates of their current BG levels and for the actual BG reading, which was obtained using Dextrostix read by a Glucometer (Ames, Elkhart, IN).

Procedures. Each camper completed a pretest consisting of two Symptom Rating Checklists. On one checklist, the camper was asked to imagine that he/she was having a hypoglycemic episode and to rate each symptom accordingly. On the other checklist, the camper was asked to rate each symptom in a fashion that was congruent with his/her experience of hyperglycemia.

The campers then had BG assessed four times daily for 11 days by trained technicians using Glucometers. Immediately before each BG assessment, the camper completed a Symptom Rating Checklist and estimated current BG. The Glucometer reading was then recorded by the technician and the camper told the result. Hurried or careless checklist completion was discouraged, while careful checklist completion was praised. A contest between the boys and the girls was also held to help maintain campers' interest and motivation. The winning team for each day was the team that estimated their BG most accurately. Individual campers with the best estimations were rewarded with paper medals, which could be traded for sugar-free drinks.

At the end of the study, each camper was again asked to complete one Symptom Rating Checklist in a manner that was descriptive of the camper's hypoglycemic episodes and one Symptom Rating Checklist that was descriptive of the camper's hyperglycemic experiences.

Following completion of the data analysis, each participant was sent the following information by mail: *1*) the camper's G-S pattern; *2*) the camper's average BG during the study; and *3*) the camper's BG estimation accuracy.

TABLE 2
Percent of hypoglycemic symptoms correctly identified by campers

		Camper's mean BG	
	Test sample* (N = 22)	Low (<246 mg/dl) (N = 11)	High (>246 mg/dl) (N = 11)
Pretest	41%	49%	33%
Posttest†	40%	64%	15%

*Only subjects with significant hypoglycemia-symptom correlations were included.
†Campers with low vs. high mean BG were significantly different, $P < .003$.

RESULTS

G-S relationships: between-subjects analyses. Possible G-S associations were first examined for the group as a whole. The mean symptom report and mean BG level were computed for each camper and were then correlated. This resulted in 23 G-S correlations. A positive correlation coefficient indicates that the symptom was characteristic of high BG and a negative correlation coefficient indicates that the symptom was characteristic of low BG. Due to the large number of correlations involved in the analysis, the significance level was set at $P < .025$. Two G-S correlations were statistically significant for the group as a whole: dizzy ($r = -.35$, $P < .001$) and pounding heart ($r = -.36$, $P < .001$). Both related to low BG; none of the symptoms was related to high BG. Of course, the use of each camper's mean BG reading may have resulted in BG readings primarily in the middle, asymptomatic range, obscuring possible relationships between symptoms and BG extremes.

For this reason, all of the campers' BG readings were reentered into the analysis and permitted to correlate with each symptom rating. No significant correlations emerged greater than or equal to $r = \pm.30$. Next, only those campers with BG readings ≤100 mg/dl were included in the analysis (N = 20). The mean of each of these campers' BG readings ≤100 mg/dl was correlated with their associated symptom ratings, resulting in 23 correlations. Only two correlations were stronger than $r = -.30$ (headache, $r = -.31$; dizzy, $r = -.37$), but neither was statistically significant ($P > .025$). A similar analysis was done with BG readings ≥100 mg/dl in an attempt to elucidate G-S associations for hyperglycemia; none was found. Finally, t tests for correlated means were used to explore possible differences in symptom ratings by the 19 campers who experienced both low (≤70 mg/dl) and high

TABLE 3
BG estimation accuracy

Accuracy measure	Total sample (N = 25)		Camper's mean BG: Low (<246 mg/dl) (N = 13)		Camper's mean BG: High (>246 mg/dl) (N = 12)	
	Mean	Range	Mean	Range	Mean	Range
Estimated/actual BG correlation*	.51	(.06–.80)	.61	(.06–.69)	.40	(.13–.80)
Actual − estimated BG difference score (mg/dl)	5	(−61–42)	6	(−14–21)	4	(−61–42)
Absolute value of difference score (mg/dl)*	68	(34–101)	61	(34–86)	76	(54–101)
% Estimations within ±20% of actual BG*	55	(42–70)	52	(42–60)	58	(50–70)

*On these measures, campers with low mean BG were significantly different from campers with high mean BG, $P < .03$.

(≥150 mg/dl) BG values. On the 7-point rating scale, only three symptoms showed significant differences of at least one scale point between ratings that were made when the camper was experiencing low as compared with high BG levels: hungry ($t = -5.09$, $P < .001$), tired ($t = -4.12$, $P < .0006$), and shaky ($t = -6.13$, $P < .0001$). With all three symptoms, low BG was associated with higher symptom ratings.

Overall, the between-subjects analysis yielded little evidence of consistent G-S associations across subjects.

G-S relationships: within-subject analyses. For the within-subject analysis, correlation coefficients were computed for each camper between the 23 symptoms and all BG readings across the 11 days of the study. Table 1 shows each camper's statistically significant G-S correlations. As in the between-subjects analysis, a positive correlation coefficient indicates that the symptom was characteristic of high BG and a negative correlation coefficient indicates that the symptom was characteristic of low BG. Two of the 25 campers had no significant correlations; their data are excluded from the table. Multiple regression[4] was used to calculate the multiple correlation between each camper's symptoms and BG readings (see the R and R^2 statistics in Table 1). Only symptoms that showed significant relationships to BG were included in this analysis. By comparing the R statistic to each camper's individual G-S correlations, possible overlap between symptoms can be assessed. For example, camper no. 8 had four symptoms that were significantly correlated with low BG (hungry, tired, shaky, and tense muscles). Using all of these symptoms did not yield greater prediction accuracy ($R = -.63$) than using the symptom, hungry, alone ($r = -.63$). For this patient, attending to one symptom as a method of detecting low BG would be as effective as attending to multiple symptoms. In contrast, the R statistic ($R = .71$) of camper no. 20 is substantially greater than any one of her five significant G-S correlations, which ranged from $r = -.37$ to $-.45$. In this case, use of several symptoms to detect low BG offered better prediction than any symptom alone. This patient might function best if she attended to several different symptoms rather than focusing on one symptom to the exclusion of all others.

While each camper seemed to have a unique G-S pattern, some symptoms (dry eyes, nose, mouth; mouth watering; upset, annoyed; nervous, anxious) did not significantly correlate with BG for any camper. Other symptoms (hungry, shaky, tired) were associated with BG for many youngsters. However, only one of these symptoms (hungry) was reported by more than half of the sample (54%). Almost all of the significant G-S correlations were indicative of low rather than high BG.

The relationships of various patient characteristics to G-S patterns were explored using t tests. Male and female patients were compared and sample medians were used to create contrasting groups based on age (median 14.4 yr), duration of diabetes (median 2.3 yr), average BG values at camp (median 257 mg/dl), and BG variability at camp (median BG standard deviation 89 mg/dl). In all analyses the camper's multiple R, best G-S correlation, and frequency of significant G-S correlations served as the dependent measures. None of the patient characteristics studied showed a statistically significant relationship to any of the dependent measures.

G-S relationships: camper awareness. A pretest and a posttest were used to assess camper awareness of G-S relationships. Each camper completed a Symptom Rating Checklist in a manner that was consistent with his/her experience of hypoglycemia. The camper then completed a second checklist to reflect his/her experience with hyperglycemia. Each symptom rating on the checklist was then correlated with the camper's actual G-S correlations. If the camper was accurate about his/her G-S relationships, one could expect a significant negative correlation by use of the Symptom Rating Checklist for hypoglycemia in the analysis and a significant positive correlation by use of the Symptom Rating Checklist for hyperglycemia in the analysis. At pretest, five campers

TABLE 4
Estimation accuracy for low, middle, and high BG readings*

Accuracy measure	BG readings		
	Low (<70 mg/dl)	Middle (70–150 mg/dl)	High (>150 mg/dl)
Actual BG (mg/dl)	55	110	275
Estimated BG (mg/dl)	115	170	240
% Estimates within ±20% of actual BG†	19	21	48
% Estimates >20% of actual BG†	77	65	12
Actual − estimated BG difference score (mg/dl)†	−57	−61	34
Absolute value of difference score (mg/dl)	59	75	68

*N = 19.
†On these measures, high BG readings were significantly different from low and middle BG readings, $P < .0003$.

showed accurate symptom identification for low BG ($r \leq -.48$, $P < .025$), and none correctly identified their hyperglycemic symptoms. At posttest, seven campers showed accurate identification of hypoglycemic symptoms ($r \leq -.48$, $P < .025$), and three showed accurate identification of hyperglycemic symptoms ($r \geq .48$, $P < .025$). Campers who correctly selected hypoglycemic symptoms at pretest were equally or more accurate at selecting these symptoms at posttest.

In a second approach to assessing camper awareness of G-S associations, a symptom was categorized as related or not related to hypoglycemia based on each camper's G-S correlations. This categorization was done only for hypoglycemia-symptom associations because so few significant hyperglycemia-symptom correlations were found. The 22 campers who had significant G-S associations indicative of low BG were used in this analysis. For each camper, those symptoms that correlated with BG $\leq -.30$ were categorized as positive symptoms of hypoglycemia. Those symptoms that correlated with BG $> -.30$ were categorized as negative symptoms of hypoglycemia, i.e., not indicative of low BG. Each camper's pre- and posttest symptom ratings of a hypoglycemic episode were then compared with the youngster's actual hypoglycemia-symptom pattern. If a camper gave a 3 or greater rating to a symptom actually associated with low BG ($r \leq -.30$), this was considered a correct identification of a G-S association, or a positive hit. If a camper gave a 0, 1, or 2 rating to a symptom not associated with hypoglycemia ($r > -.30$), this was considered a correct identification of a symptom *not* associated with hypoglycemia, or a negative hit. Each camper's positive hit rate (the percent of symptoms actually associated with low BG correctly identified by the camper) and negative hit rate (the percent of symptoms *not* associated with low BG correctly identified by the camper) were then calculated and compared. At pretest, campers correctly identified 41% of hypoglycemic symptoms and 74% of symptoms *not* associated with low BG. At posttest, similar results were obtained: a 40% positive hit rate and an 82% negative hit rate. Campers were clearly better at identifying those symptoms that were *not* associated with low BG than they were at selecting symptoms that were associated with low BG. This difference was statistically significant at both pretest ($t = -3.11$, $P < .005$) and posttest ($t = -3.81$, $P < .001$). Campers did not improve their correct identification of symptoms associated with hypoglycemia over the course of the study.

A variety of patient characteristics were analyzed by use of t tests for possible association to campers' positive hit rates for hypoglycemic symptoms. Male and female patients were compared and, as described previously, sample medians were used to create contrasting groups based on age, disease duration, average BG values at camp, and BG variability at camp. Only the camper's average BG level at camp showed a significant relationship to the camper's positive hit rate for hypoglycemic symptoms. Youngsters with lower mean BG values (<246 mg/dl) during camp had higher positive hit rates at pre- and posttests than youngsters with higher mean BG levels (>246 mg/dl). This difference was statistically significant at posttest (see Table 2).

BG estimation accuracy. Campers' ability to accurately estimate BG levels was evaluated using four measures *1*) each camper's estimated/actual BG correlation; 2) the mean of each camper's difference scores (actual BG − estimated BG); 3) the mean of each camper's absolute difference scores (absolute value of: actual BG − estimated BG); and 4) the percent of each camper's estimates that were within ±20% of the actual BG value. These data are presented in Table 3. The average estimated/actual BG correlation was in the moderate range ($r = .51$) and over half of the campers' estimates were within ±20% of the actual BG value. The average difference between estimated and actual BG values was small (5 mg/dl). The average absolute difference score was substantially higher (68 mg/dl). The range data presented in

Table 3 highlight the large individual differences in estimation accuracy. Some campers evidenced little ability to estimate BG values while others were remarkably accurate.

A number of camper characteristics, e.g., sex, age, duration of diabetes, average BG values, and BG variability at camp, were assessed for possible relationships to BG estimation accuracy by use of *t* tests. The adolescent's average BG values at camp showed the most significant relationship to estimation accuracy (see Table 3). Campers in better control (mean BG < 246 mg/dl) had significantly higher estimated/actual BG correlations and lower absolute difference scores than campers in poorer diabetes control (mean BG > 246 mg/dl). In contrast, campers in poorer control had a higher percentage of estimates within ±20% of actual BG values. However, this measure is strongly influenced by the size of the actual BG value, i.e., for lower BG values, the ±20% range is smaller than for higher BG values. For example, any BG estimate from 240 to 360 mg/dl (a range of 120 mg/dl) would be considered an "accurate" estimate for a 300-mg/dl BG value. In contrast, the estimation accuracy range for a 100-mg/dl BG value is only 40 mg/dl, from 80 to 120 mg/dl. Since youngsters in poorer diabetes control have higher BG values, they may seem more accurate using this measure than youngsters who typically experience lower BG levels. The correlation and absolute difference score measures, which are not influenced by the size of the actual BG value, suggest that youngsters in better diabetes control are more accurate at predicting BG levels. Youngsters with lower BG variability at camp (BG standard deviation <89.4 mg/dl) also had lower absolute difference scores than their more variable peers (60 vs 77 mg/dl; $t = 3.0$, $P < .007$). Girls had lower actual − estimated BG difference scores than boys (−5.8 mg/dl vs 13.7 mg/dl, $t = 2.13$, $P < .05$). However, significant sex effects were not found for any of the other accuracy measures.

The influence of the actual BG value on estimation accuracy was explored by comparing estimation accuracy measures at low (70 mg/dl), middle (70–150 mg/dl), and high (>150 mg/dl) BG ranges. These data are provided in Table 4. Only subjects who had values in all three ranges were used in the analysis. Campers clearly overestimated BG values when BG levels were in the low and middle ranges and underestimated them when BG levels were high.

Correlated *t* tests were used to make comparisons between BG ranges for each of the four accuracy measures listed in Table 4. Estimates in the low and middle BG ranges were consistently different from those in the high BG range. Fewer estimates in the low and middle ranges were within ±20% of the actual BG value and 65–77% were higher than actual BG values by >20%. The actual − estimated BG difference score also reflects the campers' overestimation of BG values in the low and middle ranges and their underestimation in the high ranges. The absolute value of the difference score was not significantly different across BG ranges because this measure is insensitive to the direction of actual − estimated BG differences.

Improvement in estimation accuracy over the 11 days of the study was assessed by use of a repeated-measures analysis of variance in which the campers' estimation accuracy at the beginning, middle, and end of the study was compared. The campers' absolute difference scores were used as the dependent measure in the analysis ($F = 4.09$, $P < .025$). Campers' absolute difference scores at the end of camp (62 mg/dl) were significantly lower than their scores during the middle of camp (75 mg/dl), but were not significantly different from their scores at the beginning of camp (68 mg/dl). Overall, there was little evidence that campers' estimation accuracy improved in any meaningful way over the course of the study.

G-S associations, BG estimations, and BG concentrations. Pearson product moment correlations were used to assess the relationships among G-S associations, BG estimation accuracy, and BG concentrations. The camper's mean BG at camp was significantly related to both camper awareness of G-S associations and camper BG estimation accuracy (see Table 5). It was not related to actual G-S patterns. These findings are consistent with the *t* test results presented previously.

Because actual BG values were significantly related to measures of BG estimation accuracy and measures of camper awareness of G-S patterns, partial correlations were used to assess the relationship between G-S associations and BG estimation accuracy, i.e., the effect of mean BG at camp was partialled out. By use of this analysis, there was evidence that G-S associations were related to camper awareness of G-S patterns. The camper's pretest positive hit rate was significantly related to the camper's multiple R^2 ($r = .47$, $P < .03$), and the camper's posttest negative hit rate was significantly associated with his best single G-S correlation ($r = .51$, $P < .02$). Partial correlations between measures of G-S as-

TABLE 5
The relationship of mean BG to G-S associations, camper awareness of G-S associations, and BG estimation accuracy

	Mean BG	
	r	*P*
G-S associations		
Best G-S correlation	−.24	NS
Multiple *R*	−.14	NS
Camper awareness of G-S associations*		
Pretest: % positive hits	−.15	NS
Pretest: % negative hits	−.55	<.009
Posttest: % positive hits	−.57	<.006
Posttest: % negative hits	.21	NS
Estimation accuracy		
Estimation/actual BG correlation	−.51	<.009
Actual − estimated BG difference score	.05	NS
Absolute value of difference score	.49	<.01
% Estimates within ±20% of actual BG	.54	<.005

*For hypoglycemia only.

sociations and BG estimation accuracy were not significant. Partial correlations between measures of camper awareness of G-S patterns and BG estimation accuracy were also not significant.

DISCUSSION

The results of this investigation suggest that there is a reliable relationship between subjective symptoms and BG in some individuals with IDDM. However, the nature of this G-S association differs from person to person. The traditional between-subjects approach to studying G-S patterns is inappropriate because it assumes that all patients respond to abnormal BG in a subjectively similar manner. In this study and in previous investigations,[1-3] between-subjects analyses yielded few or no consistent relationships between subjective symptoms and BG. In contrast, within-subject analyses are sensitive to possible differences between individuals. Replicating previous work by Pennebaker et al.[2] and Cox et al.[3] with adults, the present study found that most of its adolescent participants (92%) had one or more symptoms that were predictive of low or high BG. Not only did G-S associations differ from individual to individual, but the utility of single versus multiple symptoms as predictors of BG varied from camper to camper.

While the importance of individual differences in how people experience various glycemic states cannot be overemphasized, certain G-S relationships were more common than others. In this investigation, only one symptom—hunger—significantly correlated with low BG in more than half of the sample (54%). Other symptoms often associated with hypoglycemia were shaky (46% of the sample) and tired, weak, no energy (31%). These were the three symptoms most commonly associated with hypoglycemia in the Eastman et al.[1] and Pennebaker et al.[2] studies as well. This suggests that while there are no "classic" symptoms of hypoglycemia that are accurate for all individuals, certain symptoms may be more commonly experienced than others. In our study and in the Pennebaker et al. investigation, relationships between subjective symptoms and BG were much more reliable for hypothan for hyperglycemic states. Hyperglycemia does not appear to be as subjectively discernible as hypoglycemia.

Camper awareness of G-S patterns was less than ideal. By use of a correlational analysis, we found only five campers showed evidence of accurate identification of hypoglycemic symptoms at pretest; this number increased to seven at posttest. Campers were better able to exclude symptoms than select symptoms associated with hypoglycemia. On the average, campers correctly identified only 40–41% of symptoms actually associated with hypoglycemia. In contrast, they were able to accurately exclude 74–82% of symptoms *not* associated with hypoglycemia. Youngsters with lower mean BG levels at camp were better able to accurately identify hypoglycemic symptoms than their peers with higher than usual BG levels. Better controlled campers may have had more frequent experiences with hypoglycemic episodes, enabling them to be more aware of internal sensations associated with low BG.

Camper's ability to accurately estimate BG was measured in several different ways. First, actual and estimated BG were correlated for each camper. These correlations ranged from $r = .06$ to $r = .80$, with a mean of $r = .51$. Eighteen campers had a statistically significant correlation ($r > .40$, $P < .01$) indicating some ability to accurately estimate BG. Nevertheless, accuracy varied from camper to camper. Wing et al.[5] reported an actual/estimated BG correlation of $r = .75$ ($P < .001$) for their sample of 37 adult patients with non-insulin-dependent diabetes mellitus (NIDDM). However, Wing et al.[5] used a between-subjects analysis in which each patient estimated BG on a single occasion, and the correlation was calculated for the group as a whole. In contrast, we used a within-subject analysis in which an actual/estimated BG correlation was calculated for each subject. To make our study and the Wing et al.[5] study more comparable, we used a between-subjects analysis in which each subject's mean BG and mean BG estimate were correlated for the group as a whole. A correlation of $r = .93$ ($P < .0001$) resulted. In other words, when data were analyzed for the group as a whole, BG estimation appeared to be highly accurate. When the data were analyzed for each camper separately, BG estimation appeared to be less accurate and varied greatly from individual to individual.

In this study, the actual − estimated BG score averaged 5 mg/dl, similar to the 2 mg/dl reported by Wing et al. for adult patients. However, by use of this measure, underestimates and overestimates cancel each other out, offering a somewhat misleading picture of patients' accuracy. The absolute difference score measures the difference between actual and estimated BG without regard to under- or overestimations. On the average, campers' estimates differed by 68 mg/dl from the actual BG reading. The discrepancy between these two measures of BG estimation accuracy (the actual − estimated BG difference score and the absolute difference score) highlights the misleading results that may be obtained if only the actual − estimated BG difference score is used.

Probably the most common measure of BG estimation accuracy is the percent of estimates within ±20% of the actual BG value. In the present study, ~55% of a youngster's estimates were within this range. This is slightly lower but comparable to the 65% figure reported by Wing et al. for adult patients with NIDDM. However, this measure is strongly influenced by the actual BG value. Higher BG values result in larger accuracy ranges than lower BG values. Consequently, patients with higher BG levels may appear to be more accurate at BG estimation than their better controlled peers. In our study, measures not affected by the actual BG value (the actual/estimated BG correlation and the absolute difference score) indicated that better controlled campers were actually more accurate.

The type of estimation error made was strongly influenced by the actual BG value. Low (<70 mg/dl) and middle (70–

150 mg/dl) range BG readings were often overestimated, whereas higher BG values (>150 mg/dl) were frequently underestimated. The overestimation of BG values <70 mg/dl is especially problematic. In this study, 77% of these readings were overestimated by more than 20% of the actual BG value. On the average, youngsters overestimated low BG (<70 mg/dl) by 57 mg/dl. This suggests that hypoglycemic states were often undetected by the campers.

Estimation accuracy for BG did not improve over the 11 days of the study. Others[6,7] have reported improved BG estimation with feedback when BG estimates were compared with a no-feedback condition. However, in these earlier studies, improvement did not appear to occur in BG estimation accuracy during the feedback condition, consistent with the findings reported here.

The camper's diabetes control at camp was related to both awareness of hypoglycemia-symptom associations and BG estimation accuracy. Youngsters with lower mean BG levels at camp were better able to identify symptoms of hypoglycemia and were better BG estimators. Their better control may have made them more sensitive to hypoglycemic symptoms as they may have experienced hypoglycemic episodes more frequently than their more poorly controlled peers. Similarly, youngsters in better control may pay better attention to or be more knowledgeable about factors that influence BG, making them better at BG estimation. Of course, the correlational nature of the data does not permit us to assess whether good diabetes control results in increased sensitivity to hypoglycemic symptoms and increased BG estimation accuracy, or whether the accurate identification of hypoglycemic symptoms and the ability to accurately estimate BG leads to good diabetes control. Further research is needed to tease out the casual nature of the relationships described here.

While camper awareness of hypoglycemic symptomatology was related to the strength of G-S patterns, BG estimation accuracy was unrelated to G-S patterns and to camper awareness of these G-S patterns. This suggests that campers were *not* using internal symptoms to estimate BG. Instead, they were probably using other information, e.g., quantity and timing of last meal or duration and type of exercise, to make their estimates. Of course, camper awareness of G-S associations was less than ideal. Whether improving patient knowledge of their unique G-S pattern could enhance BG estimation accuracy remains to be seen.

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