Does cheap equal bad? System accuracy of a blood glucose monitoring system for personal use

Matthes Kenning*[1], Anselm Puchert [1], Eckhard Salzsieder [1]

Author Affiliation: [1]Institute for Diabetes Karlsburg, Germany, Greifswalder Str. 11E, 17495 Karlsburg, Germany

***corresponding author contact:** mkenning@diabetes-karlsburg.de

Abbreviations: -

Keywords: diabetes mellitus, BGMS, accuracy, precision

Graphics count: 2 tables, 1 figure

Acknowledgements: The authors would like to thank the personnel of the IDK for providing technical help, intellectual input and feedback in conducting the studies, and preparing the manuscript.

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The author(s) declare the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: All authors are employees of the Institute of Diabetes Karlsburg GmbH, Germany, which carries out studies evaluating blood glucose meter systems proactively as well as on behalf of various clients.

Introduction

Directive ISO 15197 is an internationally accepted standard that harmonizes the performance evaluation procedures of, and defines minimum acceptance requirements for Blood Glucose Monitoring Systems (BGMS). Regarding the system's accuracy (i.e. *system accuracy*), in its current revision ISO 15197:2015 [1] stipulates that at least 95% of measurements must not have deviations to the results of a reference greater than 15 mg/dL at glucose concentrations < 100 mg/dL, and 15 % at glucose concentrations ≥ 100 mg/dL, respectively. The directive thus leaves a certain degree of leeway in which *quality* can be defined and further categorized. Along these lines, we assessed the system accuracy of "low price discounter" BGMS for personal use following amended test procedures specified in ISO 15197:2015, and by using two established comparison measurement methods.

Material, Methods and Procedure

The study was conducted between September and October 2021 at the Institut for Diabetes Karlsburg in compliance with the German Medical Devices Act. The study was reviewed and approved by the responsible human subjects ethical review board under the approval number BB106-21, and registered under the clinicaltrials.gov-ID NCT05031000. Initially, five BGMSs purchased from local pharmacies and/or health centers were evaluated using a single test strip lot each. Data and results on four devices, however, were excluded from this article on request of the respective manufacturer. All meters displayed plasma-equivalent blood glucose values in mg/dL.

Table 1 *Blood Glucose Monitoring System, Test Strip Enzyme and Lot, and control solutions used in the evaluation.*

BGM	Manufacturer/ Distributor	enzyme	Calibration	LOT	LOT exp	CS	CS exp
1 adia	OSANG Healthcare Co., Ltd., Korea	GDH-FDA	plasma	Z21A215F1	01/23	CLXWA07 CNXWB01 CHXWB15	01/23 01/23 02/23

A total of 122 subjects with a clinical indication for blood glucose measurements were included to obtain 100 evaluable data sets. All tests with the device were performed on the same capillary blood samples from these subjects after a study physician reviewed the subject's anamnesis and checked the inclusion and exclusion criteria

for study participation. For unaltered samples, measurements were performed directly from the fingertip. For blood glucose concentrations < 80 mg/dL and > 300 mg/dL, the glucose concentration of the sample was adjusted by either glucose supplementation or glycolysis. The hematocrit value was checked for each subject with on an alignment chart with an accuracy of ±1 % to comply with the BGMS's specifications. Reference method measurements were performed with a glucose oxidase system (YSI 2300 STAT Plus glucose analyzer; YSI Inc.) and a hexokinase (Cobas c111 analyzer; Roche) method in duplicate, prior to and after BGM testing. Compliance with ISO 15197:2015 accuracy criteria was determined by calculating the percentage of results within ±15 mg/dL or ±15 % of the comparison method measurements for glucose concentrations at and above, or below 100 mg/dL, respectively, and by calculating the percentage of results within zones A and B of a consensus error grid. Data were excluded from the analysis in case of a handling error, a technical error, incomplete data set (missing reference value, missing or incompatible hematocrit), oversampling of a glucose range, environmental conditions outside prescribed parameters, and/or a drift of reference measurements greater 4 mg/dL or 4 %, respectively.

Results

The system accuracy was assessed with samples ranging between 37.4 mg/dL and 528 mg/dL. A total of 200 measurements were obtained from 100 subjects using a single test strip lot. The results are summarized in Table 2 and Figure 1. The minimum acceptance criteria of ISO 15197:2015 were fulfilled by the system with both reference measurement methods, showing a mean total compliance of 95.5–99% of BGM measurement results, residing within ±15 mg/dL or ±15%, respectively, and with 100 % of measurements residing n zone A and B of the CEG. In glucose concentrations <100 mg/dL, 100% of measurements reside within ±15 mg/dL for the GOD and the hexokinase method. In glucose concentrations ≥100 mg/dL, 98.7% of measurements reside within ± 15% for the GOD reference measurement method. Using the alternative method, the tested system narrowly misses to reach the acceptance criteria at 94.2% (Fig.1). The relative bias of the tested BGMS was consistently positive when evaluated against the GOD comparison method (+1.4%). Against the hexokinase method, relative bias was consistently negative (-2.4%). The

difference is mirrored in an average deviation between the two reference methods of 3.8% (±2.1, n= 100, ranging from -1.4% to 8.6%).

Table 2 *System accuracy results are calculated within ± 5, ± 10, and ±15 mg/dL and % of the respective reference measurement method at blood glucose concentrations of < 100 mg/dL and ≥ 100 mg/dL, respectively.*

BGMS	Reference method	within limits (±15 mg/dL / ±15%)		blood glucose < 100 mg/dL			blood glucose ≥ 100 mg/dL			Bias
				±5 mg/dL	±10 mg/dL	±15 mg/dL	±5 %	±10 %	±15 %	
		n	%	%	%	%	%	%	%	%
adia	HK	191/200	95.5	65.2	100	100	46.7	70.1	94.2	-2.4
	GOD	198/200	99.0	50	91.7	100	52.6	82.9	98.7	1.4

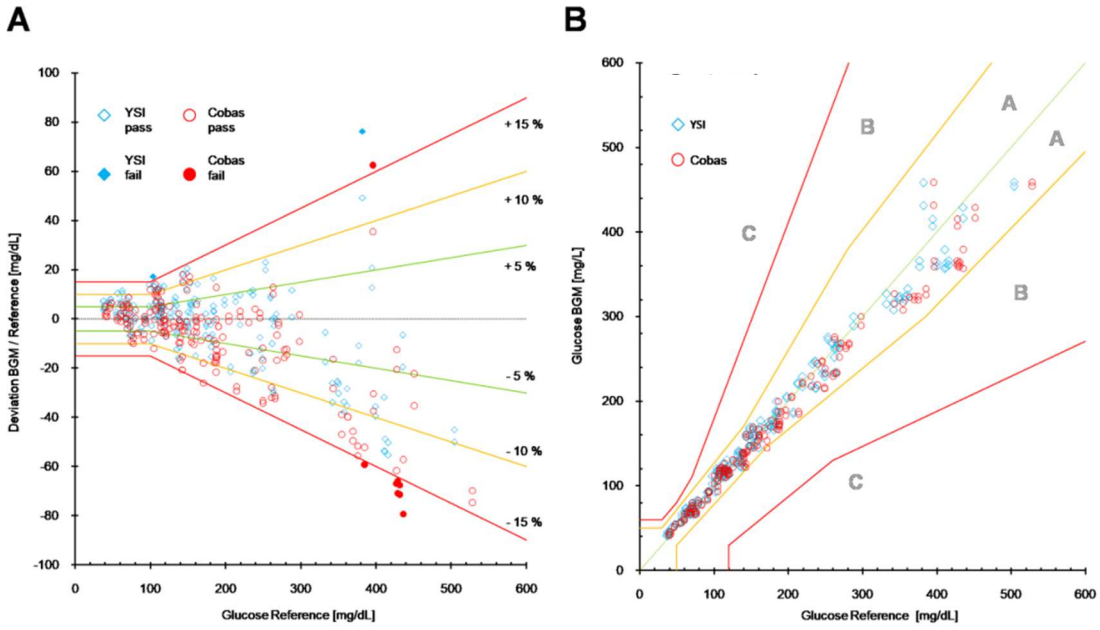

Figure 1 *System accuracy. (A) Bland Altman plot showing the relative deviation of BGM measurements to both reference method GOD (YSI, cyan) and Hexokinase (Cobas, red). Open symbols indicate measurements met minimum acceptance criteria, solid symbols indicate failed measurements. Accuracy levels of ± 5%, ± 10%, and ± 15% indicated by green, yellow, and red line, respectively. (B) consensus error grid with minimum acceptability zones A and B indicated by yellow and red line, respectively.*

Discussion

The "accuracy" of blood glucose measurements of BGM is estimated by comparison with two validated reference methods. In dependence of the actual deviation of BGM

and reference values, system accuracy achieves a relevance with regard to therapeutic decision making, medication and therapy that should not be underestimated. In this study the acceptability requirements were satisfactorily met with 95.5 % to 99 % of measurements within the specified acceptance limits of ± 15 mg/dL / ± 15 %, based on the respective reference method. However as demonstrated, the choice of reference method in the performance evaluation is equally important.

Although in the light of the retracted data we refrain from a cost-benefit assessment, it has to be noted that the system tested is one of the most cost-effective systems, as well as one of the best selling BGMS on established online market places. Therefore the saying *quality has its price* is not readily transferred to blood glucose monitoring systems without further ado, when in terms of BGM performance quality is translated to accuracy.

References

[1] International Organization for Standardization. *In vitro diagnostic test systems—requirements for blood-glucose monitoring systems for self-testing in managing diabetes mellitus*. ISO 15197:2015-12.