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How accurate is glucometer in determining glycemic index?

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Abstract

Incorporation of foods with low and medium glycemic indices (GI) in diets indicates a therapeutic potential in reducing insulin resistance and diabetes. Glucometers are convenient in measuring the postprandial blood glucose concentrations and calculation of GI. The aim of this study was to compare an enzymatic kit method and a glucometer in evaluating fasting, postprandial glucose concentrations and GI of different foods. The Accu-Check Active glucometer and glucose oxidase kit (GOD-PAP) were used to analyze the glycemic response of 16 foods. Healthy individuals (age:20-30 yrs, BMI:24±3 kg/m^2) participated in the study. GI values were calculated using bread as the standard. Fasting glucose concentrations measured by the two methods were significantly different ($p<0.05$). Mean glucometer glucose concentrations (n=10) at each time point for all foods were higher than the enzymatic kit values except for one which was not significant. Peak blood glucose concentrations obtained from the two methods and the GI values of the 15 foods were not significantly different ($p>0.05$). Thus the Accu-Check Active glucometer can be used to determine the GI values of foods.

Introduction

At present there is an epidemic of obesity and type 2 diabetes in both the developed and developing countries (Hossain *et al.*, 2007). The increasing prevalence of diabetes throughout the world is partly related to fast-release nature of the staple carbohydrate foods which are more refined (Chew *et al*., 1988). High and rapid blood sugar levels following consumption of above mentioned foods increase oxidative stress (Hsu *et al*., 2007), protein glycation and the risk of development of type 2 diabetes (Hannah *et al*., 1994; Gavin *et al*., 2001). Thus, the dietary management of diabetes requires a sound knowledge of blood glucose as well as insulin responses to meals as the treatment targets reduction of postprandial hyperglycemia and hyperinsulinemia. The inclusion of low Glycemic Index (GI) foods in type 2 diabetic meals had shown to reduce both the postprandial and 24 hour glucose profiles (Simpson *et al*., 1981). This led to the determination of GI of foods of different parts of the world (Atkinson *et al*., 2008).

Glycemic indices of foods are estimated by either taking capillary blood samples or venous blood samples at different time intervals after consuming the test and the standard food (Jenkins *et al*., 1981). In order to calculate the GI, blood glucose concentrations of these samples are estimated by either using spectrophotometers or auto analyzers (Brouns *et al*., 2005). The glucometers which are mostly used in self monitoring of blood glucose levels had not been conventionally employed for this purpose due to the controversies in its suitability in research purposes (Velangi *et al*., 2005).

However, glucometers will be an ideal tool to estimate blood glucose concentrations when determining GI in circumstances when expert knowledge and other requirements are not available. However, during the past decade several studies have undertaken to evaluate the glucometers for the purpose of determining GI and reported mixed results (Velangi *et al*., 2005). Thus, the aim of this study was to compare an enzymatic kit method (GOD-PAP) and a glucometer (Accu-Check Active) in evaluating i) glucose concentrations at different time intervals (fasting, 30, 45, 60, 90, 120), and ii) GI values of different foods.

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Materials and Methods

Glucometer

Glucometer used for the present study was Accu-Check Active meter (Roche Diagnostics GmbH, Germany). The measuring range was linear between 0.6 mmol/L – 33.3 mmol/L (10-600 mg/dL). The standard (white sliced bread) was given twice to the volunteers. Accu-Check Softclix pricking device and Softclix needles were also from Roche Diagnostics GmbH, Germany. The glucose oxidase kit (GOD-PAP) used for the present study was from BIOLABO (Maizy SA, France).

Food items analyzed

The glycemic responses of 16 food items were analyzed using both methods.The food items included several basic foods, mixed meals and fruits (bananas). The standard (white sliced bread) was given to the volunteers twice.

Subjects and ethical clearance for the study

Healthy, non diabetic individuals (5 males+ 5 females for each food) aged 20-30 years and not under medication with a BMI range of 24 ± 3 kg/m^2 participated in the study. The study was conducted as a random crossover study. Informed written consent was obtained from each individual. Ethical clearance was obtained from the Ethics Committee, Faculty of Medical Sciences, University of Sri Jayewardenepura (USJP), Sri Lanka (Approval No – A 224).

Estimation of serum glucose concentrations using enzymatic kit method

Volunteers were requested to undergo an overnight fast of 10–12 hours. Fasting blood samples (50 -100 µl) were collected into tubes containing NaF. Standard (white sliced bread) containing 50 g available carbohydrate was given with 250 mL of water. Volunteers consumed the meals within 15 min and further blood samples were obtained at 30, 45, 60, 90 and 120 min intervals after taking the first bite. Standards and test foods were given on separate mornings. Serum glucose concentrations were estimated using an enzymatic kit (GOD-PAP).

Estimation of whole blood glucose concentrations using the glucometer

As mentioned earlier, fingertips were pricked using the Softclix lancet device following fasting. The first drop of blood was placed onto the strip and a reading was taken (within 5-10 sec) and recorded. The meal was given as stated earlier and further blood glucose readings at 30, 45, 60, 90 and 120 min intervals after taking the first bite were recorded.

Calculation of GI

The Incremental areas under curves (IAUC) of test foods and standard of each individual were calculated with both sets of readings, i.e., kit method and glucometer. The GI was calculated as a ratio between IAUC of test to that with the standard of the same individual (modified FAO/WHO., 1998). The results were analyzed using students't-test by Microsoft Excel and Minitab (version 14) at 95% confidence interval.

Results

A total of 2280 blood glucose samples were analyzed in the present study (Table 1). The mean incremental serum and whole blood glucose responses of 16 foods tested by the kit and glucometer are shown in Figure 1. Measuring of glucose concentrations with the glucometer was linear within the tested range, 50-300 mg/dL (R^2= 0.9966) and with the kit was from the tested range, 50-200 mg/dL (R^2= 0.9960). The coefficients of variation (CV) for repeatability of glucometer and the kit were 1.6 and 1.4 respectively. The CV of reproducibility of glucometer and kit were 1.2 and 1.1. Both values for glucometer compared with the values given.

The CV of fasting glucose concentrations of foods with glucometer were 3.2-9.0% and with kit were 3.0-10.0%. Average fasting glucose concentrations ranged from 4.1-4.8 mmol/L and 4.7-5.3 mmol/L with the kit method and the glucometer respectively. The fasting glucose concentrations of the two methods were significantly different from each other ($p<0.05$). The mean glucose concentrations (n=10 individuals) of the meter at every time point for all foods were always higher than the kit values except for wholemeal bread which elicited more than 0.1 mmol/L increase from 30-90 minutes with the kit. The glucose concentrations which were significantly different ($p<0.05$) with the two methods are depicted at the legend of each food (Table 1). However, 47% of glucose concentrations at the six time intervals were not significantly different with the two methods. The peak serum/whole blood glucose concentrations of each food with the two methods were not significantly different ($p>0.05$). Correlations of the average blood glucose values of the two methods for each food were (R^2) 0.826-0.953. Among the 16 foods analyzed 68% of the correlations (R^2) were >0.900.

Glucose concentrations obtained from the kit method and the glucometer were used to calculate incremental area under curves (IAUC) for test foods and standards. IAUC values of the two methods

Table 1 . Average glucose concentrations (mmol/L) of foods (n=10) determined using enzymatic kit and glucometer

Food	Fasting glucose concentration		30 min glucose concentration		45 min glucose concentration		60 min glucose concentration		90 min glucose concentration		120 min glucose concentration	
	Kit	Meter	Kit	Meter	Kit	Meter	Kit	Meter	Kit	Meter	Kit	Meter
White sliced bread 1	*4.50	*4.94	*6.07	*6.32	*6.65	*6.95	6.82	7.02	*6.09	*6.40	5.76	5.88
White sliced bread 2	*4.72	*5.14	*6.38	*6.82	*6.95	*7.40	*6.95	*7.17	*6.05	*6.39	*6.05	*6.21
White sliced bread 3	4.56	4.83	6.16	6.12	6.81	6.84	6.22	6.53	*5.62	*6.35	5.39	6.12
White sliced bread 4	4.58	5.00	6.12	6.71	6.79	7.14	6.51	6.65	5.92	6.29	5.67	5.85
Wholemeal bread	*4.68	*4.70	*6.43	*6.24	*6.69	*6.43	*6.77	*6.51	*6.29	*6.13	*5.57	*5.41
Ordinary bakery bread	*4.61	*5.04	*6.80	*7.29	*7.12	*7.43	*6.75	*6.95	*5.79	*6.14	*5.89	*6.19
wholemeal bread & lentil curry	*4.56	*5.16	*6.06	*6.79	*6.25	*7.07	*6.19	*6.68	*5.81	*6.38	*5.33	*5.82
Red rice & coconut gravy	*4.54	*5.06	*7.17	*7.67	*7.02	*7.70	6.35	6.93	5.24	5.55	5.34	5.49
Red rice meal 1	4.75	5.32	*6.42	*7.22	*6.20	*7.16	5.58	6.52	*5.21	*6.14	5.14	5.71
Red rice meal 2	4.76	4.98	6.94	6.84	6.60	6.57	5.99	5.92	4.90	5.20	5.18	5.30
Red rice meal 3	4.62	5.12	6.82	7.17	6.49	6.88	5.43	5.72	4.85	5.13	4.98	5.24
String hopper meal (wheat)	*4.54	*5.21	*6.47	*7.29	*6.47	*6.91	*6.20	*6.38	*6.14	*6.13	*5.58	*5.79
String hopper meal (rice)	4.68	5.30	*6.63	*7.40	*6.52	*7.20	*6.40	*6.90	6.17	6.70	5.92	6.20
Manihot esculenta meal	4.80	5.30	7.54	7.90	7.33	7.90	6.56	7.20	6.17	5.70	5.77	5.90
Artocarpus heterophyllus meal	4.59	5.02	*6.95	*7.03	*6.47	*6.69	*5.90	*6.13	5.16	5.72	*4.95	*5.29
Banana 1	*4.74	*5.07	*6.55	*6.83	6.32	6.41	5.80	5.87	*5.10	*5.22	*4.66	*4.70
Banana 2	*4.60	*4.77	*6.94	*7.28	6.34	6.53	*5.49	*5.72	*4.74	*5.05	*4.65	*4.90
Banana 3	*4.66	*5.00	*6.81	*7.15	6.02	6.38	5.67	5.91	*4.84	*5.39	*4.46	*4.83
Banana 4	4.68	5.07	7.83	8.25	7.50	7.81	6.53	6.83	5.91	6.24	5.47	5.98

* Significantly different ($p<0.05$) glucose values with the two methods.

(Table 2) were significantly different ($p<0.05$) from each other. The percentage difference between the IAUC of two methods was -13 to +5%. We further calculated the area under curve (AUC) for test foods and standard and these values were also significantly different ($p<0.05$) from each other.

GI were calculated as a ratio by using IAUC of test and standard of both sets of values (Table 2). GI obtained with kit method elicited -8 to + 1% difference compared with the glucometer values. Despite the significant differences ($p<0.05$) in glucose concentrations and IAUC, the GI values calculated with enzymatic kit method and glucometer were not significantly different ($p>0.05$).

Discussion

The predicted percentage increase of prevalence of diabetes by year 2025 in the developed and developing countries will be 42% and 170% respectively (Wild *et al*., 2004; Hossain *et al*., 2007). In developed countries the oldest age group (≥65) includes the largest number of people with diabetes while in developing countries it is the 45-60 age group who are still in the productive years of their lives (Wild *et al*., 2004).

The underling factors responsible for this health issue have been recognized as life style changes that lead to reduced physical activity and foods with rapid release carbohydrates and excess calorie intake. When considering the diet, intake of high GI foods are reported to be associated with development of insulin sensitivity (Smith, 1994), insulin resistance and increase in the risk of development of type 2 diabetes and coronary heart disease (Hannah *et al*., 1994; Gavin *et al*., 2001). The GI values of many commonly eaten foods from around the world are available (Atkinson *et al*., 2008) and the available data are being used by the medical practitioners when modulating diets of high risk individuals. Glucometers which are mostly used for self monitoring of blood glucose concentrations by type 2 diabetic patients (Ajala *et al*., 2003; Kirk *et al*., 2010) are not conventionally used for research purposes in determining GI. However, glucometers have several attractive features over the other methods, i.e., easy to use, takes less time to give readings, portable and can be used under any condition. During the past two decades the glucometers have been improved to provide more reproducible and accurate readings (Bohme *et al*., 2003).

Thus, the present study compared an enzymatic kit (GOD-PAP) values and readings obtained from a glucometer (Accu-Check Active glucometer, Roche Diagnostics GmbH, Germany) in estimating serum/ blood glucose concentrations following ingestion of foods to calculate GI. GI values calculated using two methods were not significantly different ($p>0.05$) and the percentage difference of GI is within the accepted range (±10%). The percentage difference between

Table 2 . IAUC, GI values against bread with enzymatic kit method and glucometer

Food	Enzymatic kit		Glucometer	
	IAUC	GI	IAUC	GI
[1]White sliced bread	181 ± 18	100	167 ± 14	100
Wholemeal bread	179 ± 13	103 ± 11	173 ± 17	108 ± 10
Ordinary bakery bread	189 ± 19	114 ± 9	181 ± 21	115 ± 9
Wholmeal read (64% starch) Lentil curry (36% starch)	145 ± 14	87 ± 6	146 ± 16	92 ± 7
Red rice & coconut gravy meal *Boiled red rice* *Coconut gravy*	184 ± 29	99 ± 10	159 ± 22	92 ± 9
Red rice meal 1 (82% starch) Boiled red rice Lentil curry (18% starch) Egg *Centella asiatica* salad *Coconut gravy*	97 ± 16	60 ± 5	85 ± 14	55 ± 8
Red rice meal 2 (82% starch) Boiled red rice Lentil curry (18% starch) Egg *Centella asaitica* salad *Lasia spinosa* salad *Coconut gravy*	119 ±17	57 ± 5	108 ±14	55 ±4
Red rice meal 3 (82% starch) Boiled red rice Lentil curry (18% starch) Egg *Centella asaitica* salad *Trichosanthes cucumerina* (snake gourd) salad *Coconut gravy*	128 ± 19	61 ± 5	121 ±17	56 ±6
String hopper (wheat rice) Egg *Coconut gravy* Coconut salad	168 ± 15	104 ± 7	176 ± 32	99 ± 12
String hopper (red rice) Egg *Coconut gravy* Coconut salad	186 ± 18	103 ± 11	168 ± 17	110 ± 10
Manihot esculenta (manioc) meal Boiled manioc Coconut salad	206 ± 21	120 ± 9	181 ± 15	118 ± 12
Artocarpus heterophyllus (Jackfruit) *meal* Boiled Jack flesh Boiled jack seeds Coconut scrapings Onion sambol	132 ± 19	75 ± 11	122 ± 22	79 ± 12
Banana 1 (Silk AAB- Kolikuttu)	88 ± 11	61 ± 5	79 ± 13	66 ± 8
Banana 2 (Mysore AAB – Ambul)	107 ± 12	61 ± 5	102 ± 18	67 ± 9
Banana 3 (Anamalu - Gros Michel AAA)	119 ± 16	67 ± 7	115 ± 19	73 ± 11
Banana 4 (*Seeni kesel* - Pisang Awak ABB)	123 ± 19	69 ± 9	117 ± 11	67 ± 10

[1]n= 10 x 4; other foods n=10; Values are given as mean ± SEM (Standard Error of Mean)

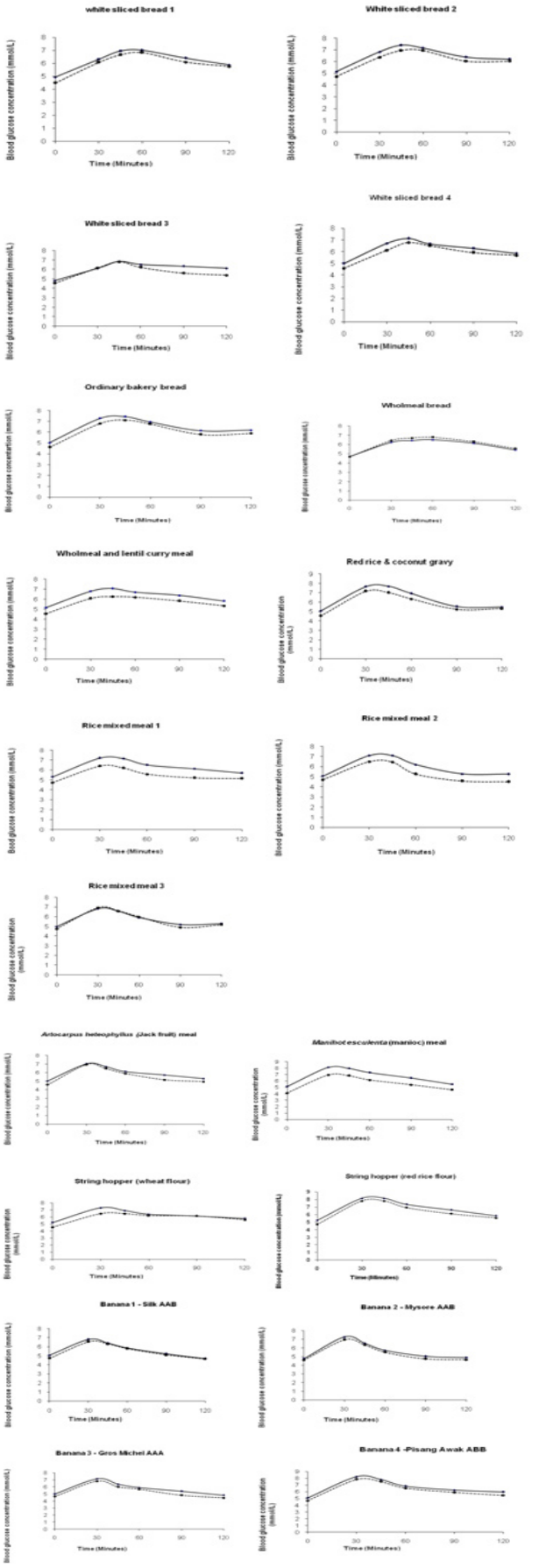

Figure 1. Mean glucose concentrations (n=10) of test foods (n=15) and standards
[——— Glucometer; ------- Kit]

the IAUC of two methods was -13 to +5%. As the percentage difference of IAUC is higher, it can be stated that the expected differences between two methods still exist when estimating only the blood glucose concentrations.

Since GI is calculated as a ratio of IAUC of test and the standard, Accu-Check Active glucometer can be used to determine GI values of foods. Thus, this particular glucometer instead of the enzymatic method can be recommended for determining GI especially when trained personnel and facilities are not available for the enzymatic assays. A study carried out to compare the GI values obtained with a glucometer (Elite, Japan) and a glucose analyzer also indicates possibility in using that particular glucometer in determining GI values (Wong *et al*., 2009). This study also highlights the observation that the mean glucose concentrations of the meter were higher than the values obtained with the enzymatic kit. The delay in separating serum when using the kit to estimate glucose concentrations leads to reduction of glucose levels by 10 mg/dl per hour by the glycolysis procedure even with the addition of NaF as certain duration is taken for the action of NaF (Schrot *et al*., 2007). The higher mean glucose concentrations of the meter compared to the kit might be due to this reason.

Although the GI values of most foods in the world are available giving an opportunity for the medical practitioners and nutritionists to plan a variety of meals for type 2 diabetic patients, inter individual variations to the same foods (Bornet *et al*., 1997) hinder this process. This leads to different categorization of foods especially when these are in the borderlines of low-medium and medium-high GI with different individuals. The use of glucometer thus, provides an opportunity for the type 2 diabetic patients to monitor the fluctuations in blood glucose concentrations following ingestion of established low and medium GI foods. This aspect will further improve the best food choices for different individuals and improve the diet control programme. However, this approach has to be followed after educating the patients on ingestion of correct portion sizes (50 g or 25 g available carbohydrate portions) and the specific time intervals to check blood glucose concentrations. Similarly there should be an available system implemented to carry out a continuous check up on the status of the meters.

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References

Ajala, M.O., Oladipo, O.O., Fasanmade, O. and Adewole, T.A. 2003. Laboratory assessment of three glucometers. African Journal of Medicine and Medical Sciences 32: 279-282.

Atkinson, F., Foster-Powell, K. and Brand-Miller, J. 2008. International tables of glycemic index and glycemic load values: 2008. Diabetes Care 31: 2281-2283.

Bohme, P., Floriot, M., Sirveaux, M.A., Durain, D., Ziegler, O., Droun, P. and Guerci, B. 2003. Evolution of analytical performance in portable glucose meters in the last decade. Diabetes care 26: 1170-1175.

Bornet, F.R.J., Billaux, M.S. and Messing, B. 1997. Glycaemic index concept and metabolic diseases. International Journal of Biological Macromolecules 21: 207-219.

Brouns, F., Bjorck, K., Frayn, N., Gibs, A.L., Lang, V., Slama, G. and Wolever, T.M.S. 2005. Glycaemic index methodology. Nutrition Research Reviews 18: 145-171.

Chew, I., Brand, J.C., Thorburn, A. and Truswell, A. 1988. Application of glycemic index to mixed meals. American Journal of Clinical Nutrition 47: 53-56.

FAO/WHO. 1998. Carbohydrates in human nutrition: report of a joint FAO/WHO expert consultation. FAO Food and Nutrition 66: 1-140.

Gavin, J. 2001. Pathophysiologic mechanisms of postprandial hyperglycemia. American Journal of Cardiology 88: 4-8.

Hannah, J. and Howard, B. 1994. Dietary fats, insulin resistance and diabetes. Journal of Cardiovascular Risk 1: 31-37.

Hossain, P., Kawar, B. and Nahas, M. 2007. Obesity and diabetes in the developing world a growing challenge. New England Journal of Medicine 356: 213-215.

Hsu, I.R., Kim, S.P., Kabir, M. and Bergman, N. 2007. Metabolic syndrome, hyperinsulinemia and cancer. American Journal of Clinical Nutrition 86: S867-S871.

Jenkins, D.J.A., Wolever, T.M.S., Taylor, R.H., Barker, H., Fielden, S.R.D.H., Baldwin, J.M., Bowling, A.C., Newman, H.C., Jenkins, A.L. and Goff, D.V. 1981. Glycaemic index of foods: a physiological basis for carbohydrate exchange. American Journal of Clinical Nutrition 34: 362-366.

Kirk, J.K. and Stegner, J. 2010. Self-monitoring of blood glucose: practical aspects. Journal of Diabetes Science and Technology 4: 435-439.

Schrot, R.J., Patel, K.T. and Foulis, P. 2007. Evaluation of inaccuracies in the measurement of glycemia in the laboratory by glucose meters and through measurement

of hemoglobin A1c. Clinical Diabetes 25: 43-49.
Simpson, H.C.R., Lousley, S., Geekie, M., Simpson, R.W., Carter, R.D., Hockaday, T.D.R. and Mann, J.I. 1981. A high carbohydrate (leguminous fibre) diet improves all aspects of diabetic control. Lancet 317: 1-5.
Smith, U. 1994. Carbohydrates, fat, and insulin action. American Journal of Clinical Nutrition 59: S686-S689.
Velangi, A., Fernandes, G. and Wolever, T.M.S. 2005. Evaluation of a glucose meter for determining the glycaemic responses of foods. Clinical Chimica Acta 356: 191-198.
Wild, S., Roglic, G., Green, A., Sicree, R.,and King, H. 2004. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. Diabetes Care 27: 1047-1053.
Wong, S.H.S., Fenghua, S., Yajun, C. and Yajun, H. 2009. Determination of the glycemic index of selected Chinese traditional foods using different glucose analyzers. Medicine and science in sports and exercise 41: S444-445.