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The Glycaemic Index and Glycaemic Load of Snack Foods Consumed by Healthy Adults

Michael Chia*

Physical Education and Sports Science, National Institute of Education, Nanyang Technological University, Singapore

Abstract

The study determined the glycaemic index (GI) and glycaemic load (GL) of foods commonly consumed by Singaporean athletes. 11 Physical Education (PE) student-teachers (6 male and 5 female; age 24.5 ± 1.4 yrs; BMI, 21.6 ± 0.7) volunteered to ingest, in randomised order, either glucose or one of eight foods (mass 52-655 g; 106-347 kcal; protein 4.3-12.3 g; fat 3.7-22.6 g and available CHO 14.0-49.2 g; predicted GI 14-112) after an overnight fast. Capillary whole-blood glucose concentrations were analysed immediately before 15, 30, 45, 60, 90 and 120 minutes after food consumption. Of the 8 foods tested, none was considered as low GI, one was classified as a medium GI food (Curry Puff) while the rest was classified as high GI foods (Nasi Lemak, Mee Goreng, Fried Rice, Mee Siam, Lor Mai Kai, Cheese Bun and Red Bean Pau). Actual-determined GL values of the test foods were different from those predicted from the 2002 International Food Tables, so caution is advised when making predictions of the GL of Singaporean snack foods. These results provide useful information for sport nutritionists and athletes and a good basis further research, discussion and education.

Keywords: Glycaemic response; Snack foods; Adults

Introduction

The Glycaemic Index (GI) of foods was introduced by Jenkins et al. [1] to classify the relative blood glucose response of ingesting a food containing 50 g of digestible carbohydrate compared to the blood glucose response of consuming an equivalent amount of glucose or white bread, expressed as a percentage of that which is ingested by the same subject. The glycaemic load (GL) was introduced as a measure of the overall glycaemic or glucose effect of a meal or a diet. The GL is calculated as the GI value of the food multiplied by the digestible carbohydrate in a usual portion size, divided by 100 [2]. While the GI and GL concepts are supported by the World Health Organisation (WHO), the American Diabetes Association (ADO) and Canadian Diabetes Association (CDA), many health professionals find their usefulness and relevance constrained and too variable for clinical practice [3]. Comparatively, the GI of foods is more researched than the GL of foods and research on the effect of the GL of foods, on exercise performance is at its infancy. Nonetheless, some researchers explain that the GL is a better predictor of glycaemic responses of foods than the GI alone [4].

Wolever [5] reported that the GI of a food, as listed in the Glycaemic Index Table is a significant determinant of glycaemic responses of mixed meals consumed by normal subjects. In a study that involved 14 test meals, in 26 subjects, and compared across two test locations, they reported that the CHO content and the GI together explained more than 90% of the variation in the mean glycaemic response, and with protein and fat having negligible effects.

High GI and GL consumption patterns are associated with diabetes mellitus [2] metabolic syndrome [6], cardiovascular disease [7] and some cancer forms [8]. Low GI and GL diets can ameliorate obesity among adolescents, assist patients in the management of diabetes [9] and reduce coronary heart disease [10]. High GI and GL diets, conversely, if consumed immediately after strenuous exercise, in healthy subjects, can help accelerate recovery [4]. Such information is useful for sport coaches and athletes for training and also when preparing for competitions that are held over several days.

The clinical and practical useful and relevance of the GI and the GL are contentious because of the scarcity of GI and GL food tables with food lists that emanate from Asia. For instance, in an updated 2008 international list of tables of GI and GL values, out of the 2487 separate entries [3], South East Asian foods are grossly under-represented with only seven food types from Thailand. No food types from Singapore, Malaysia or Indonesia are represented. Previous research on the effects of GI and GL in Asian subjects, were invariably reliant on 'guesswork' from experts in the field or were based on best estimates that were drawn from the international tables where similar but not necessarily identical GI foods were listed. As a consequence, differences were noted between the estimated GI values and the actual GI values [11]. Relevant GI tables are necessary for continued research and resolution of the GI and GL debate. South East Asia is home to many ethnic races- Malay, Chinese, Indian and Eurasians- South East Asian foods are therefore unique and can be quite different from those that are reported in the International GI Food Tables. The need to expand the food lists is important since the incidence of type 2 diabetes, especially for the developing countries in the region is increasing disproportionately. Yoon and colleagues [12] reported that people in Asia tend to develop diabetes with a lesser degree of obesity at younger ages, suffer longer with complications of diabetes, and die sooner than people in other regions. They recommend urgent action and advocacy for lifestyle changes as the cost of inaction is clear and unacceptable.

Active participation in regular exercise and sport, defined as performing exercise at least once a week, among adult Singaporeans increased from 10% in 2001 to 48% in 2005. It was reported that 25% exercised at least 3 times a week and that adult Singaporeans were participating in a greater variety of sports [13]. To encourage research on the GI and GL of foods in the region and to advise healthy

***Corresponding author:** Michael Chia, Office of Faculty Affairs, National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637 616, Tel: +65-6790 3081; Fax: +65-6896 9125; E-mail: michael.chia@nie.edu.sg

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Singaporeans on their diets, the present study was undertaken with the aim of determining the GI and GL of eight foods commonly consumed by athletes in Singapore. These data provide the catalyst for greater research activity on the postprandial responses of healthy adults on other Singaporean foods.

Materials and Methods

Subjects

Volunteers for the study were 11 healthy Physical Education Student teachers (six male and five female; age 24.5 ± 1.4 yrs; BMI, 21.6 ± 0.7). All subjects passed a medical screening test which verified no history of diabetes or other ailments and all female subjects were not pregnant and were not lactating. All subjects provided written informed consent and the study was granted institutional ethics clearance.

Procedures

The choice of the eight snack foods tested was previously derived from an in-house survey conducted by the Singapore Sports Council (SSC) among Singaporean athletes (unpublished personal communication with a sport nutritionist from the SSC).

The GI and GL of the 8 Singaporean snack foods were determined using the Food and Agriculture Organisation recommended methods [14], albeit with each test food, and reference food, tested twice for practical considerations as Wolever et al. [15] reported no significant difference in results in testing each food twice versus testing three times. Subjects were instructed to consume a normal balanced diet the night before the test and also to refrain from smoking, alcohol, caffeine consumption and vigorous physical activity 24 hrs before the test. After a 12-14 hour overnight fast, subjects arrived at the laboratory between 0800 and 0900 hours. A capillary whole blood sample was obtained from the subject by finger prick (Accu-Chek Advantage System, Roche Diagnostics Ltd, UK) after a 15 minute rest.

Subjects consumed either a reference (glucose solution providing 50 g of carbohydrate) or a test food containing an equivalent 50 g of digestible carbohydrate based on the Food Composition Guide Tables of the Health Promotion Board of Singapore [16]. The reference food and the test foods were tested twice for each subject and the interval between the two test occasions was at least four days. The test food for each subject was randomised and was consumed within 10 minutes. A 250 ml cup of water was provided for each test food to facilitate eating. The equivalent of 50 g of CHO of each of the 8 test foods was consumed by each of the 11 subjects.

Capillary whole blood samples were obtained at 15, 30, 45, 60, 90 and 120 minutes after eating began. Whole-blood glucose was analysed using a YSI glucose analyser (YSI 1500, USA). The use of capillary blood sampling for whole blood glucose using the YSI glucose analyser is in accordance to that reported in other associated studies, which are reported elsewhere [17]. In the present study, the intra-coefficients of variation for fasted blood glucose and 2-hour postprandial whole-blood glucose levels were established as 2.3% and 3.6%, respectively. Moreover, researchers reported that the CV and IAUC values were significantly lower for capillary than for venous blood glucose values [15], therefore in the present study, capillary blood samples were used to determine the GI and the GL of the snack foods consumed.

The test foods, which are common snack foods consumed by athletes before training, (Singapore Sports Council sport nutritionist, personal communication) were: Malay-style Fried Rice (rice stir-fried with egg, mixed vegetables, chilli and tomato sauce), Nasi Lemak (rice cooked in coconut milk served with fried egg and chilli sauce), Mee Goreng (yellow noodle fried with mixed vegetables, and egg in tomato and chilli sauce), Mee Siam (thin, white rice noodles, hard boiled egg and dried bean curd, served in a tangy gravy), Lor Mai Kai (steamed glutinous rice with chicken), Red Bean Pau (steamed bun filled with sweetened red bean paste), Chicken Curry Puff (deep fried pastry filled with chicken and potato curry) and Cheese Bun (bun filled with cheese). The foods were prepared and collected on the morning of the test. These food types were prepared using the usual standard cooking methods as those reported in the 2003 Food Composition Guide [16]. The detailed nutritional information of the eight test foods (per 100 g) are outlined in table 1.

Statistical analysis

The GI for each test food was calculated geometrically using the trapezoid rule, by expressing the incremental area under the curve (IAUC) for each test food, as a percentage of each subject's average IAUC for the reference food (glucose). The IAUC did not include the area beneath the fasting level [14]. The GI of each of the test food was computed as the mean value across all the subjects who consumed the test food.

GI = (incremental area under the curve for glucose response in the test food) ÷ (incremental area under the curve for glucose response for the reference food) × 100.

The actual GL values of the test foods were calculated by multiplying the GI values of the test foods, divided by 100, and the available CHO (g) of a usual portion size of the snack foods tested. The usual portion sizes of the snack foods were derived from food tables published by the Health Promotion Board of Singapore [16].

Actual GL of the test food = GI for the test food/100 × available CHO in a usual portion size of the test food.

The predicted GL value was based on the GI of the food/100 (e.g. best or nearest descriptor that was available from the existing 2008

Test food	Portion (g)	Energy (kcal)	CHO (g)	Sugar (g)	Protein (g)	Fat (g)	Fibre (g)
MFR	377	197	27.3	0.0	5.7	7.2	1.1
NL	210	235	38.1	0.6	6.1	6.5	3.1
MG	309	162	19.7	2.4	5.9	6.6	1.4
MS	655	106	14.0	10.0	4.3	3.7	1.4
LMK	149	216	37.0	0.0	6.0	4.9	4.5
RBP	67	306	49.2	22.7	6.0	9.5	3.2
CCP	71	347	28.7	1.8	7.3	22.6	2.9
CB	52	324	45.4	0.0	12.3	10.3	1.8

MFR=Malay-style Fried Rice; NL=Nasi Lemak; MG=Mee Goreng; MS=Mee Siam; LMK=Loi Mai Kai; RBP=Red Bean Pau; CCP=Chicken Curry Puff & CB=Cheese Bun

Table 1: Nutrient information of test foods (per 100 g basis), which is adapted from the Food Composition Guide, Heath Promotion Board Singapore [16].

International (Table 3) × available CHO in a usual portion size of the test food).

Independent t-tests were used to compare the differences in IAUC, GI and GL values between male and female subjects. Repeated tests for the reference and the test foods were for IAUC, GI and GL and these were compared using paired-sample t-tests. All results were analysed using the PASW Statistics 18. The level of statistical significance was set at $p<0.05$ and values are described as Mean ± SD.

Results

There was 100% accomplishment of the research tasks by all the subjects. The GI and GL of the test foods are summarised in table 2.

As sex differences for resting blood glucose for the reference (male 5.17 ± 0.36 vs. female 4.86 ± 0.15 mmol/L; p>.05) and for the IAUC for the reference food (male 726.34 ± 75.40 vs. female 752.85 ± 73.61 mmol/min/L) and test foods (male 5.08 ± 0.16 vs. female 4.86 ± 0.26 mmol/L) were not significantly different (all F-ratios; p>0.05), the data were pooled for subsequent analysis. Results showed that the_resting blood glucose for the reference food and for test food occasions were similar (5.03 ± 0.31 vs. 4.98 ± 0.23 mmol/L; p>0.5).

None of the test foods were considered as low GL foods. Consuming 50 g of available carbohydrate in Chicken Curry Puff produced a GL of 18 which is considered as having an intermediate glycaemic response in the subjects tested (Table 3).

Discussion

Paucity of associated data

This is apparently the first study of its kind in Singapore and represents an important step forward in encouraging further research on the GI and GL of popular mixed foods consumed by active and healthy adults. Researchers are dependent on reliable GI values of different foods as more people are involved in sport training and more are also becoming more health conscious. Reliable GI and GL values of mixed foods are also important sources of information for patients living with type 2 diabetes, and for the management of the disease in daily living. International tables of GI and GL [14], including recently updated lists are available, but foods from South East Asia, with the exception of seven foods types from Thailand, are glaringly absent.

The paucity of these data has curtailed research in the GI and GL of foods from South East Asia. Mixed foods in Singapore are a juxtaposition of racial influences of the Chinese, Malays, Indian and Others. Unlike Western cooking where the recipes are adhered to like laboratory instructions, Singaporean cooking are a blend of ethnic influences, which allows for creativity and experimentation, like the creation of 'fusion foods'. Moreover, the wide-ranging and often subtle factors (like processing, preparation, cooking methods used, the physical form of the food, the type of sugars and starch present in the food, the presence of other macro-nutrients or food additives in the food) which influence the GI of a particular food, make it impossible to predict the GL of a particular mixed food with certainty and confidence, from a published GI values for the constituents of foods of similar descriptions.

This could also be one reason why South East Asian foods are under-represented in the international GI and GL food tables. The majority of adult Singaporeans aged between 18 and 69 years eat hawker foods almost on a daily basis (breakfast-21%; lunch-and dinner-22%) [18] providing education about the GI and the GL of the hawker snack foods consumed on a daily basis is important as this helps Singaporeans to be more selective of the foods in their diets for sporting purposes and also for the promotion of healthy lifestyles.

Sex differences

No sex difference was detected in the mean IAUC for the test foods and consequently, there was also no sex difference in the mean GI for the test foods. This finding is also affirmed previously by others [15].

Predicted GL versus actual GL

The GL predicted from the International Table for Glycaemic Index and Glycaemic Loads were, with the exception of Loi Mai Kai (steamed glutinous rice with chicken), was not accurate and deviated for the other seven tests foods. From (Table 2) the actual GL for Malay-style Fried Rice was 60% that of the GL predicted from the International (Table 3). For the rest of the test foods, the actual GL values were 128% (Chicken Curry Puff) to 309% (Nasi Lemak) of the predicted GL values, based upon the existing international tables. These results compare favourably with similar studies conducted elsewhere which examined the meal glycaemic load of normal and overweight Hong Kong children [19]. This affirms the need to have precise GI of Asian foods that are evidence-based using internationally agreed standard protocols and adding on to the international food lists rather than relying on 'best estimates' from experts.

The wide difference between the published GI values for foods of similar description, from that determined in the present study could be plausibly explained by real differences between the foods and/or differences in food factors, which can influence the GI. Some of these include the processing, preparation and cooking methods, the physical form of the food, the type of sugars and starch in the food, the presence of other macronutrients and the ripeness or maturity of the food [11]. Caution is therefore advised when relying on the existing international

Test food With 50 g of available CHO	IAUC (mmol/min/L)	IAUC 95% confidence intervals	GI	GI 95% CI	Available CHO (g per serving)	GL (actual/predicted) (per serving)
MFR	728 ± 37	701-753	99 ± 7	94-104	67.6	67 (112)
NL	735 ± 64	692-778	100 ± 14	91-110	99	99 (32)
MG	668 ± 55	631-705	91 ± 9	85-97	76.9	70 (38)
MS	645 ± 62	603-686	88 ± 11	81-95	80.7	71 (50)
LMK	696 ± 83	641-752	94 ± 9	87-100	28.7	27 (28)
RBP	672 ± 70	625-719	91 ± 6	87-95	34.1	31 (23)
CCP	678 ± 55	641-715	92 ± 8	87-97	19.6	18 (14)
CB	695 ± 46	664-726	95 ± 9	89-100	25.26	24 (15)

MFR=Malay-style Fried Rice; NL=Nasi Lemak; MG=Mee Goreng; MS=Mee Siam; LMK=Loi Mai Kai; RBP=Red Bean Pau; CCP=Chicken Curry Puff & CB=Cheese Bun

Table 2: Glycaemic index and glycaemic load of the eight test foods IAUC=Incremental Area under Curve; GI=Glycaemic Index; GL=Glyacemic Load.

Categorization	Glycaemic Index (GI)	Glycaemic Load (GL)
Low	54 or less	10 or less
Intermediate	55-69	11-19
High	70 or greater	20 or greater

Table 3: Categorization of Glycaemic Index and Glycaemic Load- adapted from International Table of Glycaemic Index and Glycaemic Load [3].

tables to make predictions of GL of mixed meals as they may differ significantly from the actual values.

Foods with a higher GI break down the faster during digestion and produce more rapid rises in blood glucose. High GI foods are useful for sport athletes, who need a fast supply of glucose for muscle contraction during training or competition. In the present study, all the snack foods tested were classified as High GI foods and these foods are excellent recovery foods for the muscles and the liver to replenish their depleted glycogen stores. This is especially important when there is a limited time to recover for the next training session or for the next competition. As the test foods consumed are popular among Singaporean athletes as a 'before training' snack, they may negatively affect sports performance when they are eaten 1-2 hours before the training session [4,20].

The present study has some limitations, which should be noted. Even though the GI is based on 50 g of available CHO in the test foods, fibre is consumed along with the CHO, and soluble fibre (Table 1) is known to delay gastric emptying and glucose absorption and therefore lower the GI of the food [1]. While the GI is thought to be a better measure of the quality of the available CHO (minus fibre), the GL values of mixed foods is a combination of the GI and the CHO quantity in the portion sizes of the foods.

The present study has several limitations. For instance, a high GL value of a mixed meal could be the result of consuming a large amount of refined grain (high GI) and a sugar-based beverage (high GI) or one that includes a variety of whole-grain nutrient-dense CHOs, insoluble fibre that are high in CHOs and still moderately high in GI, therefore, the GL values of mixed meals, are in themselves, not very informative. Another limitation is that the subjects were healthy adults and the glycaemic responses of the snack foods of adults living with conditions such as obesity, in the context of the present study are not known. Therefore the results are only applicable to healthy adults and not those living with diseases, and future research should also focus on this adult segment of the Singaporean population. The debate about the usefulness of the GI and the GL of foods continues and the potential clinical and public health significance of the GI and the GL in healthy and diseased populations have yet to be fully elucidated. Therefore further research in the area is warranted.

Conclusions

The GI and the GL of 8 common foods consumed by healthy adult Singaporeans were reported. All the snack foods are classified as High GI foods and consuming them elicited high GL responses, with the exception of curried chicken curry puff, which produced an intermediate GL response. The predicted GL values, with one exception, were markedly different from the actual-determined GL values. These data provide an important reference for a further expansion of the GI and GL database of snack foods of Singapore, and possibility to foods commonly consumed by healthy adults in the South East Asian region.

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Declaration

The submitted manuscript is original research and has not been submitted elsewhere and no part of the present research has been previously published.

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