British Journal of Nutrition (2018), **120**, 227–230
doi:10.1017/S0007114518001459

Low 10-year reproducibility of glycaemic index and glycaemic load in a prospective cohort study

Patrick Mullie[1,2,3]*, Benedicte Deforche[2,4], Evelien Mertens[2,5], Ruben Charlier[5], Sara Knaeps[5,6], Johan Lefevre[5] and Peter Clarys[2,3]

[1]*International Prevention Research Institute, 95 Cours Lafayette, 69006 Lyon, France*
[2]*Department of Human Biometrics and Biomechanics, Faculty of Physical Education and Physiotherapy, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium*
[3]*Erasmus University College, Laarbeeklaan 121, 1120 Brussels, Belgium*
[4]*Department of Public Health, Faculty of Medicine and Health Sciences, Ghent University, De Pintelaan 185, 9000 Ghent, Belgium*
[5]*Department of Kinesiology, Faculty of Kinesiology and Rehabilitation Sciences, KU Leuven, Tervuursevest 101, 3001 Leuven, Belgium*
[6]*Department of Movement and Sports Sciences, Ghent University, Watersportlaan 2, 9000 Ghent, Belgium*

(Submitted 20 April 2018 – Accepted 20 April 2018)

Abstract

When relating glycaemic index (GI) and glycaemic load (GL) to health outcomes, many prospective cohort studies assess the nutritional exposure only once in time, that is, at the start of the study, presuming a stability in nutritional consumption during the course of the study. The aim of this study is to investigate the reproducibility of GI and GL. This is a prospective cohort study in which 562 middle-aged Belgian adults noted all foods and drinks consumed during 3 d in 2002 and 2012. GI and GL were calculated after reference tables. The Pearson correlation coefficients between 2002 and 2012 were 0·27 for GI and 0·41 for GL. For GI, 33 % of the participants remained in the same quintile between 2002 and 2012, whereas 31 % moved to a non-adjacent quintile. For GL, this was 34 and 28 %, respectively. The lowest and the highest quintiles of GI were the most stable, with 40 and 44 % of the participants staying in the same quintile. This was only 22 % for the fourth quintile. The same tendency was present for GL – that is, the most extreme quintiles were the most stable. This study shows 10-year correlation coefficients for GI and GL below 0·50. Multiple nutritional assessments and limiting the analysis to the extreme quintiles of GI and GL will limit a possible misclassification in the prospective cohort studies owing to the low reproducibility.

Key words: Glycaemic index: Glycaemic load: Reproducibility: Nutritional assessments

Glycaemic index (GI), developed by Jenkins *et al.*[1], and glycaemic load (GL) have been used as proxy indicators for insulinaemia. The GI represents the postprandial glycaemic increase after consumption of a food with carbohydrates compared with a reference, which is glucose or white bread[2]. The GL was developed to reflect the quality and the quantity of the consumed carbohydrates by multiplying the consumed carbohydrates with their respective GI. The GL is usually considered a better indicator of the postprandial glucose and insulin secretion, because it takes into account the quantities of carbohydrates consumed[3].

Prospective cohort studies usually measure at baseline how often predefined foods are consumed. Using a reference table with GI that were measured for each nutrient during human experiments[2], and with the weighted sum of consumed carbohydrates from the FFQ, the GI and the GL of a dietary pattern can be calculated. However, many prospective cohort studies assess the nutritional exposure only once in time, that is, at the start of the study, presuming a stability in nutritional consumption during the course of the study. Other prospective cohort studies assess nutritional exposure multiple times during the study, presuming instability in nutritional consumption. This difference in nutritional assessment could influence the relation with an outcome. In the prospective cohort study of Sieri *et al.*[4], after 12 years of follow-up the authors found an increased risk of colorectal cancer associated with a high-GI dietary pattern (RR = 1·45; 95 % CI 1·04, 2·03). Nutritional assessment was performed at baseline using FFQ. This is in contrast with the results of Michaud *et al.*[5], who assessed nutritional exposure every 4 years during a prospective study. They found no relation between GI and colorectal cancer.

Abbreviations: GI, glycaemic index; GL, glycaemic load.

* **Corresponding author:** P. Mullie, email patrick.mullie@i-pri.org

The aim of the current study is to investigate the reproducibility of GI and GL. To test this reproducibility, data of a prospective cohort study with two nutritional assessments in 2002 and in 2012 were used.

Methods

Subjects

The Flemish Policy Research Centre Sport, Physical Activity and Health collected all the data[6]. One aim of the Research Centre was to investigate the relationship between nutritional behaviour, physical health, mental health and physical fitness in an adult population. For this purpose, forty-six Flemish municipalities were selected by clustered random sampling. Within these municipalities, a random sample of men and women between 18 and 75 years of age was selected and invited to participate. Detailed establishment and description of this sample have been given elsewhere[7]. Subjects were asked to visit the central test laboratory to have anthropometric measurements taken and to complete questionnaires. A 3-d food record was sent about 2 weeks before their visit to the laboratory, and subjects were requested to bring their completed record on the day of their appointment. The first visit to the laboratory took place in 2002, and the second visit took place in 2012. Of the original 1569 participants in 2002, 562 (36 %) returned for participation in 2012. In general, men and women from the follow-up study had a lower adiposity than the drop-outs[8]. The Ethical and Medical committee of the Catholic University of Leuven (Belgium) approved the study. All participants signed an informed consent form and received information about the tests and measurements.

Dietary assessment

Participants noted all foods and drinks consumed during 2 non-consecutive weekdays and 1 weekend day. The participants were instructed to weigh the amount of foods and drinks consumed. If weighing was not possible, the participants were instructed to estimate the amount of the foods and drinks they consumed by using standard household measures (e.g. a spoon, glass, cup and so on). All information about the food record was included in the 3-d record booklet. Diet records were analysed using the Becel Nutrition software (Unilever Co.). Total energy intake and macronutrients were calculated using quantities of foods and beverages consumed.

The GI of foods was obtained from international tables using white bread as reference[2]. We calculated daily GI by multiplying the GI value of each food item with its carbohydrate content and frequency of consumption, and dividing the sum of these values over all food items by the total amount of carbohydrate consumed. Daily GL was calculated in the same manner but without dividing by the total amount of carbohydrate consumed.

Anthropometric measurements

Anthropometric measurements were performed by trained staff using standardised techniques and equipment according to the International Society for the Advancement of Kinanthropometry[9]. Participants were measured barefoot and in minimal clothing. Body weight was recorded to the nearest 0·1 kg with a digital balance (Seca 841; Seca GmbH) and body height with a Holtain stadiometer (Holtain) to the nearest 0·1 cm. BMI was calculated using the following formula: BMI = body weight (kg)/(height (m))^2.

Statistical analysis

SPSS 21.0 (SPSS Inc.) statistics software was used for data analysis. Mean values and standard deviations were used to describe the characteristics of the participants in 2002 and 2012. Reproducibility and cross-classification between quintiles between the two measurement periods were tested with Pearson's correlation coefficient for GI and GL. A two-sided 0·05 level of significance was defined. $P_{\text{for trend}}$ across the quintiles of GI and GL were estimated by ANOVA.

Results

Characteristics in function of quintiles of GI are presented in Table 1. Means of GI were 63·6 (SD 7·4) and 80·2 (SD 2·9) ($P < 0·001$) for the lowest and highest quintiles in 2002 and 63·7 (SD 3·6) and 79·1 (SD 2·3) ($P < 0·001$) in 2012, respectively. There was no statistically significant difference in age and BMI between the GI quintiles. For both periods, intake of energy was higher for the highest quintile of GI ($P < 0·001$). Energy-adjusted intake of proteins and added sugar was lower for the highest quintiles of GI ($P < 0·001$). For both periods, energy-adjusted intakes of SFA were higher in the highest quintiles of GI ($P < 0·01$).

Table 2 presents the Pearson correlation coefficients for GI and GL between 2002 and 2012. The correlation coefficients were 0·27 for GI and 0·41 for GL.

Table 3 presents the cross-classification between 2002 and 2012 for GI and GL. For GI, 33 % of the participants were in the same quintile between 2002 and 2012, and 31 % moved to a non-adjacent quintile. For GL, this was 34 and 28 %, respectively. The lowest and the highest quintiles of GI were the most stable, with 40 and 44 % of the participants staying in the same quintile. This was only 22 % for the fourth quintile. The same tendency was present for GL – that is, the most extreme quintiles were the most stable.

Discussion

This study shows a low 10-year reproducibility of GI and GL, with correlation coefficients below 0·50 and a cross-classification between quintiles, with only one out of three participants staying in the same quintile. This cross-classification was higher for the most extreme quintiles of consumption, that is, the first and fifth quintiles, with more than 40 % of participants correctly classified. This low 10-year reproducibility should be taken into account in prospective cohort studies with only one nutritional assessment at baseline. Many prospective cohort studies do not consider changes in food intake during the observation period, thus assuming that nutritional intakes

British Journal of Nutrition

Table 1. Characteristics of the 562 participants across quintiles of glycaemic index calculated from 3-d food records in 2002 and 2012 (Mean values and standard deviations)

		2002					2012				
		Quintile 1 glycaemic index		Quintile 5 glycaemic index			Quintile 1 glycaemic index		Quintile 5 glycaemic index		
	Unit	Mean	SD	Mean	SD	P_{trend}*	Mean	SD	Mean	SD	P_{trend}*
Glycaemic index		63·6	7·4	80·2	2·9	<0·001	63·7	3·6	79·1	2·3	<0·001
Glycaemic load		159·2	63·8	223·1	137·9	<0·001	156·4	57·7	181·9	72·9	<0·001
Age	years	47·9	10·4	46·0	9·1	0·394	57·2	10·1	55·8	9·6	0·630
BMI	kg/m^2	24·9	3·1	24·8	3·2	0·827	25·1	3·1	25·4	3·5	0·757
Energy	kJ	8774	2519	10 598	2828	<0·001	8293	2205	10 134	2858	<0·001
Energy	kcal	2097	602	2533	676		1982	527	2422	683	<0·001
Proteins	G	88·7	26·6	96·8	26·5	0·127	83·2	21·4	91·2	24·9	0·082
	energy percent	17·3	3·9	15·6	3·2	<0·001	17·2	3·8	15·5	3·7	<0·001
Carbohydrates	G	244·4	86·1	272·8	88·1	<0·001	220·0	69·4	271·6	92·9	<0·001
	energy percent	46·5	8·0	44·9	6·6	0·008	44·4	7·5	44·7	7·9	0·845
Sugar	G	84·6	46·7	75·9	42·6	0·261	73·8	38·1	72·4	47·5	0·450
	energy percent	16·0	6·6	11·7	5·1	<0·001	15·0	6·3	11·6	5·8	<0·001
Fat	G	74·8	28·6	100·8	33·8	<0·001	74·4	26·7	94·7	35·5	<0·001
	energy percent	31·8	7·4·2	35·6	5·8	<0·001	33·4	6·9	34·7	6·1	0·216
Saturated fat	G	29·4	11·8	40·1	13·7	<0·001	28·4	11·4	37·6	14·2	<0·001
	energy percent	12·5	3·4	14·1	2·7	<0·001	12·7	3·4	13·8	2·8	0·043
Alcohol	G	13·0	14·1	14·1	15·6	0·779	14·4	14·8	17·2	18·4	0·194
	energy percent	4·4	4·6	4·1	4·7	0·941	4·6	5·5	4·1	4·3	0·755

* P_{trend} (ANOVA).

Table 2. Reproducibility of glycaemic index and glycaemic load in 562 middle-aged Belgian adults*

	Dietary glycaemic index 2002	Dietary glycaemic load 2002	Dietary glycaemic index 2012	Dietary glycaemic load 2012
Dietary glycaemic index 2002	–	0·26	0·27	0·34
Dietary glycaemic load 2002	0·26	–	0·34	0·41

* All Pearson's correlation coefficients were significantly different from zero ($P<0·05$).

Table 3. Cross-classification of glycaemic index and glycaemic load for 562 middle-aged Belgian adults (Numbers and percentages)

	Same quintile between 2002 and 2012		Adjacent quintile between 2002 and 2012		Non-adjacent quintile between 2002 and 2012	
	n	%	*n*	%	*n*	%
Dietary glycaemic index						
All quintiles	184	33	200	36	178	31
Lowest quintile 2002	45	40	22	20	45	40
Second quintile 2002	35	31	47	42	30	27
Third quintile 2002	29	26	48	43	35	31
Fourth quintile 2002	25	22	53	47	34	31
Highest quintile 2002	50	44	30	26	34	30
Dietary glycaemic load						
All quintiles	193	34	214	38	155	28
Lowest quintile 2002	59	53	25	22	28	25
Second quintile 2002	29	26	51	46	19	28
Third quintile 2002	26	23	55	49	31	28
Fourth quintile 2002	31	28	52	47	29	25
Highest quintile 2002	48	42	31	27	35	31

are stable during follow-up. Our results show that changes in intakes during follow-up do not necessarily depend on amounts consumed at baseline. Relating a specific outcome after 10 years to baseline nutritional assessment can underestimate a possible underlying true relationship between quintiles of GI, GL and the outcome under study, and this is owing to occurring misclassification between quintiles. Multiple nutritional assessments and limiting the analysis to the extreme quintiles of GI and GL will attenuate this misclassification.

Comparing our observed reproducibility of GI and GL with other studies is not evident, because very few studies assess the reproducibility during a long period. Assessing the nutritional exposure with FFQ, Du *et al.*[10] studied the reproducibility of GI and GL on 134 subjects out of 960 invited. They found a crude Pearson's correlation coefficient of 0·69 for GI and of 0·83 for GL after 6 months. Levitan *et al.*[11] found between two FFQ a crude correlation of 0·67 for GL and GI after 6 months among 141 participants out of 790 invited. Murakami *et al.*[12], using dietary records on 184 Japanese participants, found a crude correlation between 0·59 and 0·65 for GI and 0·47–0·66 for GL after 1 year. In both studies, with follow-up periods of 6 months to 1 year, the crude correlation coefficients were higher than

those observed in our study after 10 years – that is, 0·27 for GI and 0·41 for GL. In our study, nutrition was assessed with dietary records. It can be hypothesised that the nutritional assessment method can influence the reproducibility of GI and GL. However, the correlation coefficients of Levitan *et al.*[11] with FFQ and Murakami *et al.*[12] with dietary records are comparable. In this study, nutrition was recorded with dietary records, and this is because this assessment tool has a better estimate of dietary intake than the FFQ[13].

A limitation of this study is that, of the original 1569 participants in 2002, 36 % returned for participation in 2012. However, this participation rate is comparable to the proportions of cohort subjects included in statistical analyses of major prospective studies. For instance, Pan *et al.*[14] included in their analyses 40–45 % of the participants of the Nurses' Health Studies and the Health Professional Follow-up Study. The aim of our study was not statistical inference of our results to the general population, but to examine the consequences of the variability in ways exposure data are reported and analysed. For this reason, the representativeness of the used sample is of less priority. A strong point of this study is the long follow-up period and the number of participants.

In conclusion, this study shows 10-year correlation coefficients below 0·50. Multiple nutritional assessments and limiting the analysis to the extreme quintiles of GI and GL will limit a possible misclassification owing to the low reproducibility.

Acknowledgements

The authors thank the participants of the study.

This research is accomplished at the Policy Research Centre Sport and funded by the Flemish government. The study funder had no role in the study design; in the collection, analyses and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

B. D., J. L. and P. C. worked on the original idea for the study. P. M. analysed the data, and drafted the first version of the manuscript, corrected by P. C. All authors read and approved the final version of the manuscript. P. M. is the guarantor. All authors had full access to all data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

The authors declare that there are no conflicts of interest.

References

1. Jenkins DJ, Wolever TM, Taylor RH, *et al.* (1981) Glycemic index of foods: a physiological basis for carbohydrate exchange. *Am J Clin Nutr* **34**, 362–366.
2. Foster-Powell K, Holt SA & Brand-Miller JC (2002) International table of glycemic index and glycemic load values: 2002. *Am J Clin Nutr* **76**, 5–56.
3. Salmeron J, Manson JE, Stampfer MJ, *et al.* (1997) Dietary fiber, glycemic load, and risk of non-insulin-dependent diabetes mellitus in women. *JAMA* **277**, 472–477.
4. Sieri S, Pala V, Brighenti F, *et al.* (2007) Dietary glycemic index, glycemic load, and the risk of breast cancer in an Italian prospective cohort study. *Am J Clin Nutr* **86**, 1160–1166.
5. Michaud DS, Fuchs C, Liu S, *et al.* (2005) Dietary glycemic load, carbohydrate, sugar, and colorectal cancer risk in men and women. *Cancer Epidemiol Biomarkers Prev* **14**, 138–143.
6. Duvigneaud N, Wijndaele K, Matton L, *et al.* (2007) Socio-economic and lifestyle factors associated with overweight in Flemish adult men and women. *BMC Public Health* **7**, 23.
7. Duvigneaud N, Wijndaele K, Matton L, *et al.* (2006) Prevalence of overweight, obesity and abdominal obesity in Flemish adults. *Arch Public Health* **64**, 123–142.
8. Mertens E, Deforche B, Mullie P, *et al.* (2015) Longitudinal study on the association between three dietary indices, anthropometric parameters and blood lipids. *Nutr Metab* **12**, 47.
9. Stewart A, Marfell-Jones M, Olds T, *et al.* (2001) *International Standards for Anthropometric Assessment*. Underdale, SA, Australia: The University of South Australia.
10. Du H, van der AD, van Bakel MM, *et al.* (2009) Reproducibility and relative validity of dietary glycaemic index and glycaemic load assessed by the food-frequency questionnaire used in the Dutch cohorts of the European Prospective Investigation into Cancer and Nutrition. *Br J Nutr* **102**, 601–604.
11. Levitan EB, Westgren CW, Liu S, *et al.* (2007) Reproducibility and validity of dietary glycemic index, dietary glycemic load, and total carbohydrate intake in 141 Swedish men. *Am J Clin Nutr* **85**, 548–553.
12. Murakami K, Sasaki S, Takahashi Y, *et al.* (2008) Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. *Br J Nutr* **99**, 639–648.
13. Park Y, Dodd KW, Kipnis V, *et al.* (2018) Comparison of self-reported dietary intakes from the automated self-administered 24-h recall, 4-d food records, and food-frequency questionnaires against recovery biomarkers. *Am J Clin Nutr* **107**, 80–93.
14. Pan A, Malik VS, Hao T, *et al.* (2013) Changes in water and beverage intake and long-term weight changes: results from three prospective cohort studies. *Int J Obes (Lond)* **37**, 1378–1385.