Determining the level of comprehension of registered dietitians in South Africa with regard to the glycemic index (GI) used in the treatment of Diabetes Mellitus

by Hildegard Strydom

Thesis presented in partial fulfillment of the requirements for the degree of Master of Nutrition at Stellenbosch University

Study Leader: Dr. R. Blaauw
Study Co-leader: Gabi Steenkamp

December 2009

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained herein is my own, original work, that I am the owner of the copyright hereof (unless otherwise stated) and that I have not previously submitted it in its entirety or in part for obtaining any qualification.

Date: December 2009

ABSTRACT

The glycemic index (GI) has proven to be a valuable nutritional tool in the management and prevention of diabetes and other chronic diseases of lifestyle [1,3,4,5,6,79,12,14,15.] In this quantitative, cross-sectional, observational and descriptive study, the aim was to determine the knowledge and level of comprehension of South African registered dietitians with regard to GI and glycemic load (GL) as well as to determine their ability to use/implement the GI in the treatment of diabetes / insulin resistance. A questionnaire was emailed to 388 registered dietitians for completion. The questionnaire was based on relevant scientific literature and divided into three parts. The first part gathered demographical information about the participants, with special emphasis on where they had acquired their knowledge of GI principles. The second and third parts contained closed-end questions to which the participants were required to answer 'true' or 'false' or were presented with a multiple choice. Twenty-five questions specifically focused on the GI and the other 12 focused on GL. One hundred and fourteen subjects took part in the study. The results showed that most dietitians (54 %) did not learn GI principles at university and that the year that they qualified did not affect test results. The University attended did not seem to affect test results either, with the exception of Medunsa (Medical University of South Africa), where graduates scored on average significantly lower than the rest of the group). The test scores varied between 43% and 97%. The average test score for the group was 71% with those dieticians in private practice scoring the highest average (76%) compared to those working in other practice areas. Although 84% percent of participants reportedly used GI principles in their daily practice with patients, compared to only 33% who reportedly used GL principles, results showed no significant difference between knowledge or comprehension levels of GI and GL or the ability to implement GI or GL principles. To conclude, South African dietitians seem to have a good general knowledge of GI, but there is still room for improvement in order to ensure that dietitians can become experts in the

field. It is recommended that curricula be revised to give this subject more attention during formal university training.

OPSOMMING

Navorsing het bewys dat die Glukemiese Indeks (GI) 'n waardevolle wetenskaplike hulpmiddel is in die voorkoming en bestuur van diabetes en ander chroniese siektes van lewenstyl [1,3,4,5,6,79,12,14,15] . Die doelwit in hierdie kwantitatiewe, dwars-snit, beskrywende studie was om die kennis- en begripsvlak van Suid-Afrikaanse dieetkundiges te toets rakende die GI en glukemiese lading (GL) asook hul vermoëns om hierdie beginsels toe te pas en te gebruik in die behandeling van diabetes en insulienweerstandigheid. 'n Vraelys is aan 388 dieetkundiges gepos. Die vraelys was gebasseer op relevante wetenskaplike literatuur en het uit drie afdelings beslaan. Die eerste afdeling was ten doel om demografiese inligting oor deelnemers te bekom met spesifieke belang by die afkoms van hul kennis oor die GI. Die tweede en derde afdelings het bestaan uit vrae waarop 'waar' of 'vals' gemerk moes word of uit veelvuldige keuse vrae. Vyf-en-twintig vrae het gefokus op die GI en twaalf vrae het gefokus op die GL. Een-honderd-en-veertien persone het deelgeneem aan die studie. Die resultate het getoon dat meerderheid van die deelnemers (54%) nie die beginsels aangaande die GI op universiteit geleer het nie. Die jaar waarop graduasie plaasgevind het, het blykbaar nie 'n invloed op uitkoms gehad nie, en die universiteit waar graduasie plaasgevind het, het ook nie die uitslag beïnvloed nie, uitsluitend Medunsa (waar gegradueerdes aansienlik swakker gevaar het as die res van die groep). Toets uitslae het gewissel tussen 43% en 97%. Die gemiddelde toetspunt was 71%. Dieetkundiges werkend in privaat praktyk het die hoogste gemiddelde toetspunt van 76% behaal in vergelyking met dieetkundiges wat in ander velde praktiseer. Ten spyte daarvan dat 84% deelnemers aangetoon het dat hulle GI beginsels in hulle werksomstandighede toepas, in vergelyking met slegs 33% wat GL beginsels toepas, was daar geen noemenswaardige verskil in uitkomste rakende deelnemers se kennis of begripsvlak van GI of GL, of hul vermoë om verwante beginsels toe te pas nie. Ter opsomming wil dit voorkom of Suid-Afrikaanse dieetkundiges oor 'n goeie vlak van algemene kennis betrekkende die

GI beskik. Daar is wel steeds ruimte vir verbetering om te verseker dat dieetkundiges as ware kenners op die gebied kan optree. Dit word aanbeveel dat universiteite se kurrikulums aangepas word om sodoende voorsiening te maak vir verbeterde voor-graadse opleiding oor die onderwerp.

ACKNOWLEDGEMENTS

A sincere thank you to all the dietitians who took time out of their busy schedules to complete the questionnaire, without their participation the study would not have been possible. Thank you to Gabi Steenkamp, Liesbet Delport and Dr Maretha Opperman for their input to ensure the validity of the questionnaire. To my study leader, Dr Renee Blaauw and study co-leader, Gabi Steenkamp, thank you very much for your guidance throughout my study. A very special thank you to Gabi Steenkamp for patiently teaching me all there is to know about the glycemic index, and for being the most generous and kind teacher imaginable.

LIST OF TABLES

LIST OF FIGURES

LIST OF ADDENDA

LIST OF ABBREVIATIONS

ADSA	Association for Dietetics in South Africa
BMI	body mass index
CHO	carbohydrate
CPD	Continuous Professional Development
g	grams
GI	glycemic index
GL	glycemic load
HbA1c	glycated hemoglobin
HDL	high density lipoproteins
HPCSA	Health Professions Council of South Africa
L	litre
LDL	low density lipoproteins
mg/dl	milligrams per decilitre
mmol	millimol
mmol/L	millimol per litre
NIDDM	non-insulin-dependent diabetes mellitus (currently referred to as type 2 diabetes mellitus)
µU/h	micro units per hour

LIST OF DEFINITIONS

glycemic index	The glycemic index refers to the rate at which food that contains carbohydrates affects blood glucose levels after consumption. Glucose with a GI of 100 is used as the reference food [17]
glycemic load	The glycemic load is the mathematical product of the glycemic index (GI) and grams of carbohydrates in a food product. The GL is an indication of the blood glucose response and insulin demand induced by a serving of food [17].
registered dietitians	A health professional who has obtained a degree in dietetics from a university and is registered with the Health Professions Council of South Africa (HPCSA)
type 1 diabetic	A diabetic dependent on external insulin administration
type 2 diabetic	A diabetic who is not dependent on external insulin administration, thus still depending on exocrine pancreas functioning.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 Introduction

The glycemic index (GI) has proven a very valuable scientific tool in the prevention and treatment of various chronic diseases of lifestyle including type 2 diabetes, insulin resistance, obesity and cardiovascular disease [1-15.] Limited evidence also suggests a preventative role in colon and breast cancer [13].

If dietitians are equipped to correctly transfer information regarding the use and implementation of the GI, whether through one-on-one consultations, group discussions, talks or magazine articles, it would clearly be beneficial to the general public as well as to the dietetic profession. As the idea of a carbohydrate classification system, according to the effect it has on blood glucose levels, (the GI) was only developed 20 years ago, in the 1980's, it is thus still regarded as a relatively new science [13, 16]. The first GI list, containing 51 foods listed with their GI's, was only published in 1981 by Jenkins and colleagues [13]. It was only about twenty years later, in 2000, that the first South African published book on GI namely *Eating For Sustained Energy 1* (by South African dietitians Liesbet Delport and Gabi Steenkamp) reached our book shops [17]. Two years later in 2002 the first edition of *The South African Glycemic Index Guide* containing GIs of South African food products was published by Steenkamp and Delport [18]. As this means that only a mere nine years ago, the GI was first officially introduced to South African dietitians, the question arises whether this was enough time for South African dietitians to equip themselves with sufficient knowledge on the subject.

1.2 The glycemic index

The glycemic index was first developed to predict post-prandial blood glucose levels in patients and was only later used as a weight management tool for the general population [16]. The GI represents the rate at which glucose is released into the blood stream after consumption of carbohydrate-rich food compared with a reference carbohydrate [16,18]. The GI is calculated by dividing the ratio of the level of blood glucose increase over a two hour period (after consumption of a specific amount of test food) by the level of blood glucose increase over a two hour period, (after consumption of a specific amount of reference food), multiplied by 100 [16,18]. Either white bread or glucose is used as reference food and will be assigned a GI value of 100 (in South Africa we use glucose as reference food [18]). It will then be used as the standard to which other carbohydrates will be compared [16,18]. When using international GI values, it is of importance to determine which reference food was used. If it was white bread, the GI value of any product on that list needs to be multiplied by 0.7 to get a glucose-based GI value in order to compare it with South African tested products [18]. Depending on test results, food will be given a GI value between 0 to 100[18].

Methodology

To test the GI of a specific food, a group of 10-12 volunteers will be fed a 50g portion of available carbohydrate or glycemic carbohydrate (total carbohydrate minus fibre) after an overnight fast [2,16,18]. Blood glucose levels are determined at baseline, as a fasting value, and then every 15 minutes for 2 hours (or 3 hours for diabetic participants) after ingestion of the test food. The same participants will be fed 50g glycemic carbohydrates from the reference food on a separate day to use as a comparison [2,16,18]. Readings for both the test food and reference food are plotted on a graph (blood glucose concentrations against elapsed time). The area under the graph of the test food is calculated and divided by the calculated area under the graph for the reference food and multiplied by 100 to calculate the GI of the test food for that specific individual. The average of all the participants' GIs for the specific test food is calculated to determine the GI of the test food [16,18].

Classification

The food will then be categorized as either high (GI values of 70 and above), releasing glucose fast within 1 hour after consumption, intermediate (GI values between 56 and 69), releasing glucose over 2 hours or low GI (GI values 55 and under) releasing glucose slowly over two and a half to three hours [18].

It is important to note that only carbohydrate-rich foods are tested and categorized according to their GI values. The South African Department of Health's draft regulations of 2006, for the advertising and labeling of food products, determined that only food items that have a carbohydrate content that contributes at least 40% of that food's total energy content (kilojoules); have a maximum protein content contributing no more than 42% of the total energy content and a maximum fat content contributing no more than 30% of total energy, are allowed to make a claim regarding the GI of that food [19].

In South Africa the positive effect of low GI food on diabetes control is so well accepted, that this regulation also states that only food products with a low GI value and reduced fat content will be allowed to be labeled and advertised as products that are suitable for those with diabetes [19].

1.3 The glycemic load

While the glycemic index can predict the effect a single food item containing 50g of carbohydrates may have on blood glucose levels, it cannot predict the effect a meal or diet will have on blood glucose levels [16, 20]. In an attempt to predict the effect an entire day's food intake will have on blood glucose levels, Salmeron et al [21,22] from Harvard University proposed the use of the glycemic load (GL) in 1997.

The glycemic load takes the GI and the amount of carbohydrate (grams) in the portion consumed into account and is calculated as follows [16,18,19,21,22,23].

$$\text{Glycemic load} = \frac{\text{GI of the food} \times \text{carbohydrate content (g) of the food}}{100\text{g}}$$

By adding up the GLs of food items, the GL of a meal and the GL for a whole day can be determined [18]. As a high GL diet can cause high post-prandial blood glucose levels and a high insulin response that can lead to obesity, abnormal lipid profile, insulin resistance and an increase in the severity of diabetes [9,10,14,24] , it is recommended in South Africa that moderately active women of normal weight and overweight men keep their daily GL under 100. Taller, active women of normal weight and moderately active men of normal weight keep their daily GL under 120 and sportsmen and women (exercising more than 2 hours per day) keep their daily GL around 120 [18]. The GL recommendations for specific meals are as follows [18]:

- Breakfast and light meals: 20-25
- Main meals: 25-30
- Snacks: 10-15

The most valuable contribution that the development of the GL added to nutritional sciences was the fact that researchers realised, through using the GL, that all food (even food with a high GI value) can be used safely by those with diabetes as long as the portion sizes are considered [16,18]. Some high GI products (especially fruit and vegetables with high GI values) have low GL values. If one were to consider the GI only, the product would seem to be a bad choice and would be avoided. However since the GL is low, the product is in fact a good and safe choice as long as one exercises portion control[16,18]. For example half a cup of cooked pumpkin has a high GI value of 75, but its GL value is only 5 (this is the case with most vegetables) [18]. This means that one needs to eat 6 times that amount (3 whole cups) before the GL reaches 30 and the product will affect blood glucose levels negatively. On the other hand consuming large amounts of low GI food (and thus consuming large amounts of carbohydrates) will have very negative effects on blood glucose levels and can be potentially dangerous [16,18]. Wolever and Bolognesi [25, 26] tested the extent to which the type and the amount of carbohydrate will effect glycemic response. They found that the amount (grams) of carbohydrate ingested accounted for 57-65% of the variability in glucose response and that the GI of that same carbohydrate accounted for 60% of the variability. This proves that GI and GL contribute equally to changes in blood glucose levels after consumption of carbohydrates. Cumulatively GI and GL account for a total of about 90% variance in blood glucose response [25, 26,]. In support of this idea, Wolever and Mehling [27] showed that reducing the GI of the diet of subjects with impaired glucose tolerance for 4 months reduced postprandial glucose levels over 8 hours by the same amount (0.35 mmol/L) as reducing the amount (grams) of carbohydrate ingestion (GL) over the same period.

Despite its obvious value as a nutritional tool, and although it is endorsed by many health agencies world wide, the GL has not yet been recognized by any governmental or professional entities in the United States of America [23] .. Hopefully ongoing future research will ensure this. A good start-off point, as Ludwig [23] rightfully suggested, is that two modifications in the Food Guide Pyramid are made, namely, by moving highly processed grains and potatoes to the apex and placing non-starchy vegetables, legumes and fruit at the base, as these could result in significant reductions in GL.

1.4 The effect of a low GI diet on health status

1.4.1 Diabetes Mellitus

Type 2 Diabetes Mellitus is a chronic disease of lifestyle that affects an increasing number of people worldwide. Since the 1960's, investigators noticed a sharp rise in the prevalence of type 2 diabetes accompanied by an increase in the number of obese people [3,16,28,29]. In America from 1990 to 2001 the prevalence of self-reported diabetes, within the age group 30-39 years, almost doubled and the age group 40-49 years showed an 83% increase compared to that of previous decades [3]. Scientists have linked this phenomenon to dietary changes that occurred during the same time. Since the 1960's Americans are eating less fat (the percentage of calories derived from fat decreased from 42% to 34%) and the lower fat intake has made way for a higher intake of carbohydrates [29]. One would expect that this change would decrease the prevalence of obesity and not increase it [28]. However, in the western diet the major sources of carbohydrates are found in the upper GI range [1, 16] and as high GI foods have been proven to be more insulinogenic and can be implicated in the development of insulin resistance and type 2 diabetes [1,3,4,16,28,29], the natural conclusion is that the world-wide increase in the prevalence of type 2 diabetes is in part due to the high GI, high GL western diet, and therefore predominantly related to lifestyle. In support of this idea, Willet et al [30] showed that women who followed a high GL diet had a 40% higher risk of developing diabetes than women who followed a low GL diet. Those whose diets regularly consisted of (high GI) white bread, potatoes and carbonated drinks had the greatest risk of developing diabetes [30]. Between 1986 and 1992, Salmeron et al [21, 22] conducted two large prospective studies on 42 759 healthy men and 65 173 healthy women respectively. Adjustments were made for age, BMI, activity level, daily energy intake, smoking and alcohol consumption. They found that for both groups, the GI of their diets was the best indicator for risk of developing type 2 diabetes compared to other factors such as the type or amount of fat or the amount of carbohydrate present in the diet. The results also showed that a diet with a high GL and low fibre content increased the risk for developing type 2 diabetes in both groups, compared to a high fibre diet with a low GL.

A large body of evidence supports the therapeutic potential of food with a low glycemic index (GI) in the treatment of diabetes and prevention of developing non-insulin-dependent diabetes mellitus (NIDDM) [1,3, 4,5,6,7]. Reducing the GI of the diet has resulted in reductions in blood glucose levels of subjects with diabetes (insulin dependent and non-insulin dependent) and in subjects without diabetes [2]. Improved insulin sensitivity and glucose tolerance has also been linked to low GI diets [1, 4, 8]. A study by Rizkalla et al [9] showed that type 2 diabetics who followed a low GI diet showed an improvement in fasting glycemia, HbA1c levels, peripheral insulin sensitivity and whole-body glucose utilization within 4 weeks. Other studies have also shown a decrease in HbA1c when subjects were on a low GI diet [1,4,9,10,16,30,31]. Salwa et al [9] showed a decline in HbA1c that was twice as much on a low GI diet, compared to a high GI diet and Burani et al [10] showed a mean drop of 1.5 units in HbA1c on a low GI diet. In a study by Willet et al [30] on diabetics, HbA1c levels were reduced from 8% to 7.2%, translating into a 10% lower risk of developing diabetic complications. Brand et al [31] conducted a twelve week study on overweight but well-controlled type 2 diabetics and showed an 11% mean reduction in HbA1c on a low GI diet.

1.4.2. Obesity

As insulin resistance is classed as the most prevalent abnormality of abdominal and visceral obesity, it is important that those with diabetes maintain normal weight and have a normal body fat percentage in order to reduce insulin resistance and risk for cardiovascular disease[11]. Consumption of low GI foods is associated with weight reduction and a decrease in body mass index (BMI) [1,10,12,13,14]. Low GI foods seem to promote satiety, minimize postprandial insulin secretion and increase fat oxidation. In contrast, consumption of high GI foods is associated with lower satiety and reduced fat oxidation[13,32].

In America, one in two adults and one in four children are overweight, indicating a 50% increase of overweight people since the 1960's. Investigations showed that the American diet consists mainly of high GI foods such as sugar-containing foods and refined starches and grains [16]. This link between the increase of body weight and consumption of high GI food is explained by Ludwig et al [32] in terms of hormonal changes that occur during three post-prandial stages. In the first stage, referred to as the early post-prandial event which lasts up to two hours after eating a high GI meal, blood glucose levels can be twice as high as they would have been after eating a low GI meal containing the same number of kilojoules. Increased amounts of insulin are released to bring down the elevated blood glucose levels, thus favouring anabolism and storage of all incoming energy substrates, especially fat and glucose. As blood glucose levels drop, hunger occurs. A constant exposure to high GI meals can (and probably will) result in insulin resistance and continuous hyperinsulinemia that will in turn lead to promotion of glycogenesis and thus an increased amount of glycogen stored in the liver and muscle; lipogenesis that causes increased fat storage in the adipocytes; suppression of glycolysis due to decreased glucagon secretion and suppression of lipolysis by the inhibition of lipoprotein lipase in the adipose tissue. All of these result in an increased anabolism and an increase in fat storage. In the second stage, referred to as the middle post-prandial period (2-4 hours after eating a high GI meal), the high insulin/glucagon ratio will remain even though most nutrients will be completely absorbed from the gastrointestinal tract. The imbalance of the insulin and glucagon will cause blood glucose levels to continuously drop, often to a hypoglycemic state. As the brain uses only glucose for fuel, this hypoglycemic state will cause intense hunger. As explained in the first stage, the body's other major fuel source, namely free fatty acids, are also suppressed by the high insulin levels, resulting in the simulation of a fast as the body cannot access any of its major fuel sources. In the final stage or the late post-prandial period (4-6 hours after consuming a high GI meal), when circulating glucose and free fatty acid levels are very low, the release of glucagon, epinephrine, cortisol and growth hormone is stimulated. Glucagon will stimulate the breakdown of glycogen to glucose through glycogenolysis and cortisol stimulates gluconeogenesis in which glucose is produced from amino acids in the liver. This will restore glucose concentrations. Epinephrine and growth hormone will restore fatty acid concentrations by stimulating fat mobilization from the adipocytes. However, if insulin levels are constantly high, all of these actions (especially those of glucagon and growth hormone) will be inhibited. In this stage an intense hunger will be experienced that can only be satisfied by over consumption of high kilojoule meals. Contrary to this, no dramatic hormonal shifts occur after consumption of low GI meals. As it takes longer to digest low GI meals, hyperglycemia and hyperinsulinemia do not occur and glucose release (from the liver via gluconeogenesis and glycogenolysis) will not be inhibited. Therefore hypoglycemia and extreme hunger will not result. To support this hypothesis, two randomized, prospective, crossover studies found that subjects were less hungry and consumed 25% fewer calories on a low GI diet than on a high GI diet [33]. This higher satiety level, linked with consumption of low GI food, can also be enhanced by the slower rate of digestion and absorption of low GI food Nutrient receptors in the small intestine will be stimulated over a longer period (compared to high GI food), leading to an increase in the length of stimulation of the brain's satiety center [34].

1.4.3 Cardiovascular disease

The development of cardiovascular disease is part of the risk profile for those with diabetes and treatment should include treatment or prevention of heart disease.

Long-term studies have shown that low GI diets can reduce triglycerides, low-density lipoproteins (LDL) cholesterol and total cholesterol to high-density lipoproteins (HDL) ratio [9,12,14,15]. In a randomized, prospective, crossover study, subjects on a high GI diet showed a 28% increase in their triglyceride levels and a 10% decrease in their HDL levels within 6 days. In contrast, subjects who followed a eucaloric low GI diet showed a 35% decrease in their triglyceride levels within 6 days, while their HDL levels were unchanged during this period [33]. This positive effect on blood lipids suggests that a low GI diet can be protective against development of cardiovascular disease or can be used to manage existing cardiovascular diseases [14]. A 10-year, multi-centre clinical trial suggested that following a low GI, high fibre diet early in life can be protective against development of cardiovascular disease later in life, as participants on a long-term low GI, high fibre diet had lower weight, a lower waist-to-hip ratio, lower fasting insulin levels, higher HDL, lower blood pressure and lower levels of triglycerides and LDL than subjects following a high GI diet for most of their lives [35]. Bell and Sears [16] suggested that a low GI diet can reduce the risk of cardiovascular disease in three ways:

1. By promoting weight loss;
2. By the reduction of hyperinsulinemia and insulin resistance that mediates risk for blood pressure, serum lipids and inflammatory mediators and
3. By the reduction of free fatty acids, and thereby the suppression of inflammatory cytokine release from the adipose tissue.

On the other hand, many studies linked post-prandial hyperglycemia to cardiovascular mortality in the normal population, as a high blood glucose concentration seems to be damaging to the endothelium by increasing protein glycation, oxidative stress and impaired functioning of the endothelium [13]. It is of importance to note that post-prandial hyperglycemia is caused not only by the GI of the food item or meal, but also by the GL [9,13]. High glucose levels are also associated with an increase in the thickness of the carotid intima media (a known predictor of coronary infarct) and impaired vasodilatation through inhibiting nitrous oxide synthase and thus reducing the production of nitrous oxide [13]. Studies also implicated insulin resistance and compensatory hyperinsulinemia in the development of risk factors for coronary heart disease such as hypertension, impaired fibrinolysis and dyslipidemia (high triglycerides and low HDL) [13].

1.5 Factors influencing the GI

1.5.1 Food processing

The way in which food is processed during food preparation can influence the GI value of the meal. Starch is present in carbohydrates in the form of granules. Amylose and amylopectin become available for hydrolysis when the granules are disrupted. Disruption of the granules occurs through mashing, milling, grinding, chewing or other processing methods and will increase the digestibility of the product and result in an increase in the GI value of the food item [36 37]. Mashing a 1-inch cube of potato will increase the GI of the potato by 25% [37]. Similarly a flatter glucose response was observed when apples were ingested compared to apple puree and apple juice [36, 37] and cooked whole rice resulted in a flatter glucose response than cooked ground rice [36].

Jenkins et al [36] examined the effect processing has on blood glucose responses and found that bread containing whole wheat grains produced less of a glucose response compared to bread containing flour milled from whole wheat grains and therefore suggests that a clear distinction should be made between ‘whole grain’ and ‘whole meal’ products.

1.5.2 Structure of the starch

Dietitians are often faced with the dilemma of explaining to patients why different types of the same food can have different GI values. For example jasmine rice has a high GI value, basmati rice has an intermediate GI value and Tastic rice has a low GI value [18]. Similarly baby potatoes have an intermediate GI value, while large potatoes have a high GI value [18].

Different GI values of the same food can be attributed to the difference in proportions of amylose and amylopectin present in the type of food. Amylose is a single strand molecule in which linear D-glucose units are linked in a α 1-4 manner. Amylopectin is a branched structure that consists of both α 1-4 and α 1-6 linkages. Amylose is more resistant to hydrolysis in the gut than branched chain amylopectin due to its single strand structure [37]. The types of food that have lower GI values (e.g. baby potatoes) will therefore contain more amylose in their structure than their high GI counterparts (e.g. large potatoes) where the starch structure consists of more amylopectin [37].

1.5.3 Gelatinization

The GI value of food will also be increased when the granular structure of the starch is destroyed by gelatinization, a process in which starch is subjected to water and heat [38]. When gelatinization occurs, the starch granules absorb water in the presence of heat and swell to a point where they rupture and individual starch molecules are exposed, thereby increasing the product's susceptibility to be hydrolyzed in the gut, and thus the starch becomes easily digestible. The degree of gelatinization is dependent on the amount of available water, temperature, cooking time and pressure present during cooking [37, 38]. Ross et al [38] showed that food like puffed wheat and puffed crisp bread with a high prebaking water : flour ratio, baked at high temperatures and high pressure where a high degree of gelatinization occurred, also had high GI values. On the other hand, biscuits with a low prebaking water : flour ratio, baked at moderate temperatures that resulted in low levels of gelatinization, had lower GI values. It was therefore concluded that the level of starch gelatinization correlates to the level of digestibility and the GI value [38].

It is of interest to note that the gelatinization process can also be reversed by cooling the product down, whereby the starch will regain increased resistance to hydrolysis [37]. For example, uncooked potatoes are very hard to digest, but once the potatoes are cooked and the starch granules are completely gelatinized, the potatoes become easily digestible. If the potatoes are then cooled down, gelatinization is reversed and 12% of the potato starch will again become resistant to hydrolysis and will not be able to be absorbed [37]. These changes in the level of gelatinization also affect the GI value of the product as illustrated in the *South African Glycemic Index and Load Guide* (Steenkamp and Delport) [18] where GI testing revealed that hot mealiemeal porridge has a high GI value of 74 whereas cooled mealiemeal porridge has a low GI value of only 50. This is valuable information for any dietitian practicing in South Africa where mealiemeal porridge is the staple food of many ethnic groups.

1.5.4 Acidity

The acidity of a meal affects the GI level [37,39,40]. An increase in the amount of acetic acid (vinegar) or organic acid (sourdough bread) can lower the GI of a meal by decreasing the gastric emptying rate [37].

In a study by Liljeberg and Björck [39] ten healthy volunteers were given a white bread reference meal and a meal supplemented with vinegar (on separate days) after an overnight fast. Both meals contained the same amount of carbohydrate, protein and fat. Paracetamol was ingested with the meal to act as a marker of the gastric emptying rate. Post-prandial blood samples of glucose, insulin and paracetamol were taken. The researchers found that compared to the reference meal, the addition of vinegar significantly reduced post-prandial glucose and insulin levels. Post-prandial paracetamol levels were also significantly lower when vinegar was present in the meal, suggesting that vinegar causes delayed gastric emptying resulting in delayed absorption of nutrients and an overall lower GI level of the meal.

Östman et al [40] found similar results when they tested the potential of acetic acid to lower post-prandial glucose and insulin levels and increase satiety. Twelve healthy volunteers were given 18, 23 or 28 mmol vinegar portions served with white bread containing 50 g glycemic carbohydrate after an overnight fast. An equal amount of bread without vinegar was used as reference food. Blood glucose and insulin levels were tested every 15 minutes post-prandially and satiety was measured with a subjective rating scale. A significant decrease in blood glucose and insulin responses was seen between 15 and 90 minutes for all doses of vinegar. No significant difference in GI or insulin indices between the test and reference meals were seen at 120 minutes. The level of satiety was directly related to the portion of vinegar.

These results confirm the GI lowering potential of fermented and pickled products containing acetic or organic acid.

1.6 The effect of protein and fat on the GI of a meal

As carbohydrates are not eaten alone in a balanced meal, one needs to consider the effect that the presence of protein and fat will have on the overall GI value of the meal.

It is known that protein intake stimulates insulin secretion in normal and diabetic subjects [37,41,42,43,44,45]. Karamanlis et al [46] suggested that protein is also associated with a slower gastric emptying rate due to its ability to stimulate the release of cholecystokinin. Both these effects can result in reduced post-prandial glycemic response. Gulliford et al [42] tested this hypothesis by administering 25g portions of either low GI spaghetti or high GI potato to type 2 diabetics. Blood glucose and insulin levels were tested for 4 hours post-prandially. Meals were repeated and either 25g of protein or 25g protein and 25g of fat were added. Blood tests were repeated. The results showed that the addition of protein greatly increased the insulin response to both low and high GI meals, although the difference in insulin levels between the two meals was maintained. Nuttall et al [43] investigated the effect protein ingestion has on post-prandial glucose and insulin levels when taken with an oral glucose load. Nine diabetic males were given meals containing 50g protein, 50g of glucose and 50g of protein with 50g of glucose over five hours. They found that insulin responses were only moderately higher for the glucose meal compared to the protein meal (97 ± 35, 83 ± 19 µU.h/ml, respectively). The meal that contained both protein and glucose showed a significantly higher insulin response (247 ± 33 µU.h/ml). After administering a second meal containing protein and glucose, the blood glucose levels were only

7% of the value they were after the first protein and glucose meal (after administering a second glucose meal, blood glucose levels were 33% lower than after the first meal). This indicates that protein has the ability to reduce blood glucose levels when given in large amounts.

The ability of protein to affect glycemic responses seems to be amount-specific. In a study by Jenkins et al [41] no effect on blood glucose levels or GI was seen when cottage cheese was added to whole meal bread. Nuttall et al [43], however, found that a meal containing a protein to carbohydrate ratio of 40 g : 60 g could significantly reduce glucose responses after the second or third meal containing this ratio, when meals were given 4 hours apart. Spiller et al [44] added 16 g of protein to a test meal containing 58 g of carbohydrates from sugars and found that the inclusion of that amount of protein reduced the glucose response by 40%, while the insulin response was doubled. When they increased the added protein amount to 50 g, the glucose response was reduced to 40%, but the insulin response stayed the same when 16 g protein was added. Karamanlis et al [46] found a reduced blood glucose response when 30 g of gelatin (protein) was ingested with 50 g of glucose. In most studies a protein to carbohydrate ratio of 1:1.5 (30 g : 50 g) seemed to have a reducing effect on blood glucose levels [43,46].

Fat (especially vegetable fat) [45] slows gastric emptying rate [41,42] thus reducing carbohydrate absorption and insulin release [45.] It also reduces jejunal motility and post-prandial flow rate in the upper small intestine [42] thereby delaying post-prandial glucose response [44]. Gulliford et al [42] gave six type 1 diabetics test meals containing 25 g of either potato or spaghetti. Blood glucose and insulin responses were tested 4 hours post-prandially and results were compared to the results from meals where 25 g of protein or 25 g of protein and 25 g of fat were added. They found a lower glycemic response to the potato meal when fat was added, compared to when the potato was eaten alone or eaten with protein, suggesting that the decreased gastrointestinal motility limited the glycemic response of this meal. However, the addition of fat had no effect on the glycemic response of the spaghetti meal. As spaghetti already has a low GI value [18, 42] and the carbohydrate structure of pasta is associated with high resistance to starch hydrolysis, the researchers suggested that the glycemic response to fat is not limited to decreased gastrointestinal motility but also dependent on factors like resistance to starch hydrolysis [42]. Collier and O'Dea [47] examined the effect the addition of 50 g of fat (butter) to 50 g of carbohydrate (potato) will have on blood glucose and insulin responses. They found that the inclusion of fat significantly lowered post-prandial blood glucose response, however insulin response was not reduced. This implies that using fat to lower glycemic responses of high GI carbohydrates over a long term is not safe, as it can have negative effects on insulin sensitivity in the diabetic and normal population [47].

As was the case with protein, the ability of fat to lower blood glucose levels seems to be amount specific. Most of the studies only showed a blood glucose lowering effect when fat was used in a 1:1 ratio with carbohydrates, thus 1 g of fat ingested with every 1 g of carbohydrate[42,45,47].

Some researchers like Estrich et al [45] showed that ingestion of fat and protein simultaneously affects the GI of carbohydrates. In their study, ingestion of 50 g of carbohydrate with 40 g of fat and 30 g of protein resulted in a much lower post-prandial blood glucose level than when glucose was ingested with only protein or fat. They attributed this to the increased insulin release and a modification in glucose absorption. They also found that insulin levels stayed elevated for longer periods and that free fatty acid decrease was lowest with ingestion of both protein and fat with glucose, than when glucose was ingested alone or with only protein or fat. Gannon et al [48] put eight untreated type 2 diabetics on a 5 week diet with a carbohydrate : protein : fat ratio of 20:30:50. A control diet with a 55:15:30 ratio was followed after a 5 week washout period. Results showed the integrated mean 24 hour serum glucose to be 198 mg/dl for the control and 126mg/dl for the test diet. Glycohemoglobin was 9.8 $\pm$ 0.5 % for the control and 7.6 $\pm$ 0.3 % for the test diet. Serum insulin was also decreased and plasma glucagon increased on the test diet compared to the control diet.

The test methods described above are not practical in the sense that they are not representative of normal balanced meals. For instance when 25-50g of protein is added to 50g of carbohydrate, 33-50% of that meal's total energy is provided by protein. The recommended energy contribution of protein in a meal is only 12-20%. Similarly 25-50g of fat added to 50g of carbohydrate means 53-69% of the total energy is provided by fat, which is twice the recommended intake of 30-35% of fat. Even in the very high fat North American diets only 35-40% fat is consumed [44]. Before commercial insulin was available to diabetics, diets in which 50% of the energy was derived from fat were commonly used to manage diabetes [45] and clearly the addition of large amounts of fat and protein seem to lower the GI of a meal through decreased absorption rate and increased insulin availability, but because such large amounts of fat and protein need to be added to lower the glucose response, it is not really a practical or healthy way to improve glycemic control in those with diabetes.

1.7 The mixed meal effect

It has been established that the GI of a meal consisting of two equal proportions of carbohydrates with different GI values, will approximate the average of the GI values of the two products [49]. However, what occurs when there are more than two carbohydrates with varying proportions present in a meal?

Wolever and Jenkins [49] formulated a calculation to determine the GI of a meal consisting of multiple carbohydrates with different GI values present in different proportions. Below is an example of how to calculate the GI of a mixed meal.

Let's assume there are three carbohydrates (to be referred to as C1, C2 and C3) present in the meal, the GI of the meal will be calculated as follows:

Step 1: Determine the total amount (grams) of carbohydrate (g) present in the meal by adding up the grams of each carbohydrate present.

$$g = g_{C1} + g_{C2} + g_{C3}$$

Step 2: Determine the proportion (P) that each carbohydrate represents in the meal by dividing the grams of a particular carbohydrate with the total amount (g) of carbohydrate present in the meal.

$$P_{C1} = g_{C1} / g$$

Step 3: Determine the meal GI contribution (MGI) for each carbohydrate by multiplying the proportion carbohydrate present (P) with the GI value for that carbohydrate (GI).

$$MGI_{C1} = P_{C1} \times GI_{C1}$$

Step 4: Determine the total GI of the meal by adding the GI contribution of each carbohydrate (MCI).

$$\text{Total MGI} = MGI_{C1} + MGI_{C2} + MGI_{C3}$$

The above method is a valuable tool to calculate the GI value of a recipe or to evaluate food records of patients.

For example, if the carbohydrates in a recipe are:

1 cup of cake flour (105.4 g CHO, GI = 70),
4 teaspoons of apricot jam (32 g CHO, GI=49)

1 cup of full cream milk (11.8 g CHO, GI=27), the GI of the recipe will be calculated as follows:

Step 1: Determine total amount of carbohydrates present

105.4 + 32 + 11.8 = 149.2 g

Step 2: Determine the proportion each carbohydrate represents

Portion of flour = 105.4 / 149.2 = 0.71

Portion of jam = 32 / 149.2 = 0.21

Portion of milk = 11.8 / 149.2 = 0.08

Step 3: Determine the GI contribution of each carbohydrate

Flour = 0.71 x 70 = 49.7

Jam = 0.21 x 49 = 10.29

Milk = 0.08 x 27 = 2.16

Step 4: Determine the total GI

49.7 + 10.9 + 2.16 = 62.15

Therefore the GI of the recipe is intermediate.

1.8 The role of GI in exercise

In the past it was often recommended that athletes avoid eating carbohydrates 1 hour before exercise due to fear of rebound hypoglycemia that occurs shortly after exercise begins as a result of increased insulin production leading to increased muscle carbohydrate oxidation and a fall in blood glucose levels [50].

Research has since shown that not all carbohydrates will have this effect. Foster et al [51] showed that ingestion of high GI glucose 15-60 minutes before exercise caused a rapid raise in blood glucose and insulin levels. The high levels of insulin inhibited free fatty acid release leading to an increased usage of glycogen. As glycogen stores are then depleted faster, endurance decreases.

Both Thomas et al [51] and DeMarco et al[52] showed that ingestion of low GI carbohydrates before exercise enhanced endurance. Thomas et al gave 8 cyclists a pre-exercise meal consisting of low GI lentils. On a separate day the cyclist were given a pre-exercise meal consisting of an equal amount of carbohydrates but this time coming from high GI potatoes. The time they could ride before fatigue set in was measured for both days and compared. They found that with the low GI meal (compared to the high GI meal) the cyclists had:

1. Increased endurance;
2. Blood glucose and insulin levels were lower before exercise and overall blood glucose control was better during exercise;
3. Free fatty acid concentrations were higher during exercise;
4. Plasma lactate levels were lower before and during exercise;
5. Average respiratory exchange ratios were lower and
6. Lower carbohydrate oxidation during the first 90 minutes of exercise suggesting increased sparing of muscle glycogen (although not tested in this study, it was suggested by other researchers e.g. Bergstorm et al in 1967 and Jansson et al in 1980).

In the study by DeMarco et al [52] 10 cyclists were asked to perform a cycling routine consisting of 2 hours of cycling at 70% maximal oxygen uptake and thereafter to cycle to exhaustion at 100% maximal oxygen uptake. The cyclist were fed a pre-exercise meal 30 minutes before exercise started consisting of 1.5 g / kg body mass of either a low or high GI carbohydrate meal. They found that on the low GI meal (compared to the high GI meal) the cyclists had:

1. An exhaustion time that was prolonged by 59%;

2. Plasma insulin levels were significantly lower;
3. Plasma glucose levels were higher;
4. Lower respiratory exchange ratio's (this was thought to support a higher rate of fat oxidation and an increase in the availiblity of free fatty acids as energy source)
5. An improved maximal performace ability.

In studies by Wee et al [53], and Thomas et al [54] no difference in outcome in terms of endurance could be found when a low GI pre-exercise meal was taken compared to a high Gi pre-exercise meal, but in both cases blood glucose levels and the concentration free fatty acids were higher when the low GI meal was consumed compared to the hig GI meal.

During exercise it is recommended that athletes consume high GI carbohydrates [51]. As the glucose uptake of skeletal muscles increases during exercise, readily available high GI carbohydrates are needed to maintain glucose levels and prevent premature fatigue and muscle glycogen depletion [51].

Researchers suggested that athletes and diabetics, in particular, refill their muscle glycogen stores by consuming high GI carbohydrates directly after exercise to ensure optimum glycogen availability for the next training session or sports event, as the readily available high GI carbohydrates will prevent post-exercise hypoglycemia [55].

It is important to note that not only the GI values of the pre-, during- and after-exercise meals need to be considered, but also the amounts of carbohydrate in these meals. Factors like weight, height, sex and health status of the athletes (are they diabetic?) as well as activity level and exercise duration all need to be considered before a carbohydrate portion for any part of the training can be ascertained [56]. It is therefore of the utmost importance that dietitians are well informed before giving advice in this regard, especially when dealing with diabetic athletes.

1.9 Perceived dietary misconceptions about the diabetic diet

Before the GI was developed, there were certain 'rules' that made up the diabetic diet. For example, a person with diabetes was not allowed any sugar. Many of these 'rules' have been proven to be misconceptions by GI research, and dietitians are often faced with the challenge to explain to patients why some of these 'rules' are no longer valid. This study not only examined the knowledge level of South African dietitians on GI and GL but also their ability to interpret their knowledge. If they were successful in doing so, they would be able to pinpoint and explain such misconceptions to patients. Below are previously believed misconceptions about the diabetic diet (tested in the questionnaire):

1.9.1 Perceived misconception 1: The complexity of the carbohydrate structure determines its effect on blood glucose levels.

Carbohydrates used to be classified mainly on the grounds of their structure and polymeric chain length. Simple carbohydrates consisting of mainly mono-,di- and oligosaccharides were thought to be low in nutrient value and fibre, and it was suggested that these simple carbohydrates had a more profound effect on blood glucose levels than complex carbohydrates consisting of polysaccharides and starches and thought to be higher in fibre and nutrient value [57]. This misconception was based upon an experiment that Frederick N. Allen conducted in 1910 on pancreatectomized diabetic dogs. The dogs were given sucrose and starch respectively and their blood glucose levels were tested after ingestion of each. Their blood glucose levels rose after ingestion of sucrose and not after ingestion of starch, and so it was assumed that simple carbohydrates (like sucrose) affect post-prandial blood glucose levels to a greater extent than complex carbohydrates (starch). However, the reason why the dogs' blood glucose levels did not rise after ingestion of the starch is because they had no exocrine pancreas to aid them in the digestion of the starch and could therefore not absorb significant amounts of carbohydrates from the starch in order to evoke a blood glucose response [57].

Proof that complex carbohydrates will not affect blood glucose levels to a lesser degree than simple carbohydrates can be found in the *South African Glycemic Index and Load Guide* (Steenkamp and Delport) [18]. In the high GI category many starchy or 'complex' carbohydrates like bread and potatoes can be found, and despite their long polymeric chain length (and even high fibre content, like whole wheat bread), they will effect blood glucose levels more profoundly than fructose, for example,, which is a 'simple' sugar with a low GI value. Even more detrimental to Frederick Allen's claims is the fact that both 'complex carbohydrate' baby potatoes and 'simple carbohydrate' sucrose have almost identical GI values (baby potatoes have a GI value of 62 and sucrose has a GI value of 65) and therefore, regardless of the complexity of their structure, will have the same effect on blood glucose levels (providing the portion of each contains the same amount of glycemic carbohydrate) [18]. Studies have supported this hypothesis, for example in 1987 Jenkins et al [58] compared the glycemic responses of maltodextrin to corn syrup. Maltodextrin, a cornstarch hydrolysate consisting of 22 glucose units showed no significant difference in glycemic response compared to corn syrup which contains polymers of only six glucose units. Again providing proof that the complexity of the carbohydrate structure cannot predict the effect that a carbohydrate will have on blood glucose levels but GI can, since maltodextrin and corn syrup had similar GI values (maltodextrin has a GI value of 109 ± 11 and corn syrup has a GI value of 113 ± 7). The GI, and not the chain length, therefore seems to be the predicting factor for glucose response [58]**.** Other studies have also shown that foods containing the same amount of carbohydrate, and therefore with the same length of polymeric chain,have different effects on blood glucose
levels.[57]

The only way in which the structure of carbohydrates can be used to predict their ability to effect blood glucose levels is when one refers to resistant starches [1]. A high-resistant starch content seems to be correlated to low GI foods. In a study by Akerberg et al [1] resistant starches were found to be existing as B-type resistant starch, retrograded starch or physically inaccessible starch. Resistant starches have lower GI values due to their resistance to digestion by amylase via retro-gradation of the amylose component or encapsulation with an indigestible botanical structure causing more indigested carbohydrates to reach the colon.

Dietitians used carbohydrate exchange lists for over 30 years to help those with diabetes to plan their diets, but since we now have proof that one carbohydrate cannot simply be exchanged for another with the same carbohydrate content, dietitians are challenged to adapt those lists to accommodate not only GI but also GL in a way that can be practically implemented by those with diabetes [41,57].

1.9.2 Perceived misconception 2: Diabetics are not allowed any sugar

Sugars (in the form of added sugar and/or naturally-occurring sugars like those found in fruit or milk) play an important role in diets in developed countries and make up about 20% of total daily energy consumption and about half the energy of total carbohydrate intake [59]. They play a role in sports performance, satiety and treatment of hypoglycemia [59].

For many years the biggest misconception about the diabetic diet has been the one surrounding sugar. The first thing newly-diagnosed diabetics were often told was to eliminate all sugar (specifically table sugar or sucrose) from their diets. When scientists started testing the GI value of food items, they found that sugar had an intermediate GI value of 65 and thereby provided proof that the assumption that sugar and sugar containing foods have a more profound effect on blood glucose levels than starchy food did not have scientific back-up[18, 59]. In a study by Brand Miller et al [59] where blood glucose responses of food containing naturally-occurring sugars were compared to those of food containing added sugars, they found the following:

1. The median GI of food containing added sugars was similar to food containing naturally-occurring sugar (GI= 58 and 53 respectively, P=0.08)
2. There was no evidence of rebound hypoglycemia after ingestion of food containing added sugar.
3. More than 80% of 'sugary' foods tested had a GI value lower than 70 (ranking in the intermediate category) and thus having lower GI values than most refined starchy foods.

Studies like these showed that it was a misconception that diabetics had to stick to 'sugar-free' diets, but, as with any products, the amount used in one meal is of importance. How much sugar can a person with diabetes then use safely? The glycemic load of two heaped teaspoons of sugar is 6 and therefore it is safe to use this amount in a low GI meal [18, 59]. Chantelau et al [60] suggested that up to 40g of sucrose per day is safe to use for those with diabetes and Anderson [61] found that ingestion of a diet, where refined sugar made up 10-12% of total energy had no effect on insulin sensitivity.

As not all sugars have equal GI values and thus not all sugars will have the same effect on blood glucose levels [18,57], it is advisable for dietitians to classify sugars according to their GI values instead of commanding a 'sugar ban' from their diabetic patients.. Sugars like maltodextrin and maltose, with GI values above 100 and glucose with a GI value of 100, should be avoided or used with extreme caution when they are represented in the first 3 ingredients of a product [18]. Sucrose recommendations can be similar to those of healthy individuals [57, 59], and those with diabetes can also use sucrose (in controlled amounts) in food preparations or baking, as the inclusion of sucrose can help reduce the overall GI of a meal [59,61]. Polydextrose, fructose and sugar alcohols (e.g. sorbitol, xylitol, lactitol, maltitol) all have low GI values [18].

In support of these scientific findings surrounding sugar, draft regulations for the advertising and labeling of foods of the Department of Health's Directorate of Food Control now state that a product will not be allowed to carry the claims "sugar free" or "contains no added sugar" if the product contains high GI sweeteners, and in the case of a product advertising these claims, a compulsory listing of the GI range of the product has to appear on the product [19].

1.9.3 Perceived misconception 3: An increase in any type of fibre will lower blood glucose response to the meal

Recommendations for fibre intake are the same for diabetics as they are for the general public (20-35g /day) [14,62]. Studies have shown that consumption of 2.7 daily servings of whole-grain products decreased the risk of developing diabetes by 27% [30].

In the past, those with diabetes were often encouraged to make high fibre or whole wheat choices always, as fibre was believed to cause a lower blood glucose response. As the tested products on the GI lists increased, the idea that any fibre has a blood glucose lowering effect was proven to be wrong. For example, testing revealed that whole wheat bread and nutty wheat bread (previously advised diabetic choices) have similar GI values to white bread (GI=70 and 72 respectively) [18]. Those with diabetes were also often advised to choose brown rice or whole wheat pasta instead of white rice or normal pasta, but both white and brown rice have similar GI values (54 and 55 respectively) and so do normal and whole wheat pasta [18].

Research has revealed that soluble fibre (e.g. oat bran, legumes, barley, etc.) are more beneficial in glycemic control than insoluble fibre and therefore all fibre will not affect blood glucose levels in the same way [14,57,,62,63]. Soluble fibre, like cellulose, lignin and many hemicelluloses found in the cell wall of cereals and vegetables, acts as a bulking agent and decreases intestinal transit time. Water-soluble pectins, gums, mucilages, algal polysaccharides, some hemicelluloses and some storage polysaccharides have high water-holding capacities and become highly viscous in a solution [62]. Soluble fibre (mixed with food or consumed in the same meal) increases the viscosity of the bolus in the stomach and small intestine, causing the bolus to resist intestinal contractions, resulting in a slower rate of nutrient absorption. The increased viscosity also inhibits glucose transport through the increased resistance to mucosal diffusion and results in decreased glucose and insulin peaks [62].

The beneficial effect of soluble fibre on GI was demonstrated by research in which diets rich in guar gums (found in legumes) have been used to decrease urinary glucose loss in diabetics.. Diets containing generous daily amounts of beans allowed those with diabetes (using less than 30 units of insulin per day) to terminate their insulin usage [64]. Meals high in soya beans and lentils raised blood glucose levels by only 30%, the percentage it was raised when the same amount of carbohydrate in the form of wholemeal bread (containing insoluble fibre) was ingested [65]. In a study by Jenkins et al [64] subjects were given a 50g portion of carbohydrates. The effect on blood glucose levels of eight varieties of dried legumes was compared to 24 other carbohydrates like grains, cereals and vegetables. Both the glucose peak and mean area under the curve were at least 45% lower with consumption of dried legumes compared to other carbohydrates. Tapola et al [24] tested the ability of oat bran (high in ß-glucan, a soluble gum) to decrease the glycemic response of an oral glucose load. They found that ingesting 30 g of oat bran flour with 25 g of glucose decreased the blood glucose peak by 1.5 mmol/L compared to ingesting glucose alone. In a breakfast containing 35 g glycemic carbohydrates, oat cereals (containing 4 g ß-glucan) provided a 1.2 mmol/L lower blood glucose peak compared to a continental breakfast. In healthy subjects the consumption of 7.2 g and 14.5 g of oat gum with 50 g glucose reduced blood glucose peaks with 1.2 and 1.1 mmol/L respectively [24].

Although insoluble fibre is not scientifically implicated in lowering blood glucose levels in the same way as soluble fibre is, it plays an important role in digestion and colon health and should not be excluded from the diabetic diet [14, 57].

1.10 Study outcomes

From the results of many scientific research projects and evidence mentioned above, it becomes clear that diabetes can be managed and prevented by a diet that consists mainly of lower GI carbohydrates in controlled portions. The evidence presented in this introduction however highlights the complexity and variability of the GI. Since the glycemic index is used as a nutritional tool in dietary manipulation by dietitians in South Africa, this study hopes to elucidate whether it is in fact understood correctly; and secondly implemented correctly within the scope of practice of South African dieticians. In the process, this study also hopes to pinpoint areas where improvement may be needed with respect to the understanding and implementation of the glycemic index in South African nutrition circles.

The study will be presented as a thesis that forms part of a master's degree in nutrition through the University of Stellenbosch and a copy will be kept at the library of the University of Stellenbosch. The manuscript will also be made available for publication in peer reviewed journals.

CHAPTER 2

METHODOLOGY

2.1 Aims and Objectives

The aim of the study was to investigate the level of knowledge of registered dietitians in South Africa regarding the use of the glycemic index (GI) in the treatment of diabetes.

Three specific objectives were formulated, namely:

To determine the:

1. Knowledge of registered dietitians regarding GI and GL
2. Level of comprehension of registered dietitians regarding GI and GL
3. Use/implementation of GI in treatment of diabetes / insulin resistance.

2.2 Hypothesis

The following hypothesis was formulated for the study:

Dietitians do not have adequate knowledge about the principles of the GI.
No hypothesis could be generated for objectives 2 and 3.

2.3 Study Design

2.3.1 Type of study

The study was a quantitative, cross-sectional, observational, descriptive study.

2.3.2 Ethics

The study was submitted to the Committee of Human Research, Faculty of Health Sciences, University of Stellenbosch, for approval. Each participant received an explanation of the purpose of the study and a summary of details of participation. Confidentiality was ensured for all participants. Participation was voluntary and agreement to participate acted as informed consent. The ethical approval number for this project is: N08/01/024.

2.3.3 Budget

The researcher covered all costs involved in the study.

2.4 Sampling

2.4.1 Study population

The study population comprised registered dietitians practicing in South Africa. The Association for Dietetics in South Africa (ADSA) was contacted to provide a database with registered dietitians. From this database a sub sample was selected. Although not all registered dietitians are ADSA members, most actively practicing dietitians are which is why the ADSA database was used for the purposes of the study.

2.4.2 Sample selection

The study group was selected via systematic sampling. A list with the names of registered dietitians who appear in alphabetical order on the ADSA website was used. Every third person was selected by hand and phoned. Three attempts were made (on different days) to reach the selected candidate. If the candidate could not be reached by the third attempt, the person whose name appeared next on the list was chosen as a candidate and was contacted .

2.4.3 Sample size

At the time of the study, there were 1095 dietitians registered with ADSA. To ensure a good representation of the population, the questionnaire was sent out to

388 dietitians. The sample size was determined by using a confidence interval of 95% and precision (Cp) of 4%.

2.4.4 Selection criteria

2.4.4.1 Inclusion criteria

The following were the inclusion criteria for the study:

- Registration at the Health Professions Council of South Africa (HPCSA) (dietitians need to have a registration number provided by the HPCSA to be able to join ADSA, thus ADSA membership is proof of registration);
- Graduated from a South African university.

2.4.4.2 Exclusion criteria

The following were the exclusion criteria for the study:

- Dietitians who are not currently practicing dietetics and are not registered with the HPCSA.
- Registered dietitians residing outside South Africa

2.5 The Questionnaire

2.5.1 Questionnaire description

The researcher set up a questionnaire based on relevant scientific literature (see Addendum 1).

The questionnaire was divided into three parts. The first part contained 7 questions about the participant’s training, date of graduation, degrees, courses completed and university attended. The aim was to find out where the participant acquired their knowledge of the GI principals and if he/she used these principles in his/her practice and if this academic training was adequate to equip the dietitian to put these principals into practice.

The second part contained 20 questions to which the participant had to answer 'true' or 'false' and the third part contained 17 multiple-choice questions. Twenty-five questions specifically focused on the GI and the other 12 focused on GL. The questions were aimed at testing participants' general knowledge on GI and GL (14 questions), their level of comprehension regarding the GI and GL (17 questions) and their ability to implement the principles in the treatment of diabetes (6 questions). The latter was of specific interest to the researcher because a person with specialized knowledge on the GI should be able to explain it in a practical way to his/her clients and should be able to teach them to put it into practice with ease. Because all the questions were closed-ended, the questionnaire was designed in such a way that most concepts would be covered in more than one question, therefore ensuring that the participant did not score good results by chance. To encourage participation and in consideration of the participants time, the questionnaire was designed so as not to take longer than 20 minutes to complete, which is why only closed-ended questions were included.

2.5.2 Questionnaire Validity

As the questionnaire was developed by the researcher, there was no evidence of its validity. The questionnaire was set up by the researcher with input from the Study Co-leader, Gabi Steenkamp RD(SA), (who is a leader in the field of the GI).

Content validity was measured by the evaluation of the questionnaire by Gabi Steenkamp, Liesbet Delport, and Dr Maretha Opperman, dietetic leaders in the field of the GI. As they are among the most knowledgeable people on the subject, they were asked to judge if the questionnaire measured what it was supposed to measure. Their suggestions were incorporated to ensure that the questionnaire tested extensive knowledge of the subject and evaluated comprehensive understanding of the glycemic index. The questionnaire tested ‘must know’ facts as well as more advanced aspects of using the glycemic index.

Face validity was measured by circulating the questionnaire to a sub-section of the final population (consisting of 4 registered dietitians with a good knowledge of the glycemic index and the treatment of diabetes) as well as 4 non-dietitians (occupational therapists) with 4-year degrees, who also work in the paramedic field, for completion. The non-dietitians scored an average of 46% for the questionnaire. This mark is significantly lower than the average scored by the dietitians (they scored an average of 91%), and this therefore acts as proof that good test results cannot be scored by guessing, but that the questionnaire indeed tested true knowledge and understanding of the subject matter.

2.6 Methods of data collection

Selected participants were contacted by telephone. The purpose of the study was explained and if the selected participant agreed to take part in the study, a questionnaire was emailed to the participant. Three hundred and eighty-eight participants were contacted. All of them agreed to take part in the study. Participants had 4 weeks to complete the questionnaire. Two reminders of the final date by which the completed questionnaire needed to be emailed back to the researcher were emailed to participants. On the receipt of a completed questionnaire, the researcher allocated a number to the questionnaire (the number was not linked to any personal details of the participant). From that point onwards only the number was used in data analysis and the information was therefore kept completely anonymous.

2.7 Data analysis

In this cross-sectional study, descriptive statistics were employed to summarize the findings, i.e. for categorical data use was made of frequencies and percentages while for continuous data mean, standard deviation and 95% confidence intervals were used.

The totals scored by participants were compared to the year of graduation, the university attended and the field of practice to ascertain factors that could be linked to patterns of performance. Questions in the questionnaire were divided into those concerning GI and those concerning GL and each question was also allocated to one of three groups. Results for the groups were analysed separately for these groups. The first group covered all questions that tested knowledge on GI or GL, the second group tested level of comprehension regarding GI or GL and the last group tested ability to implement knowledge of GI or GL. Grouping of the questions in the questionnaire was as follows:

1. Questions regarding GI: 2.1-2.7, 2.10, 2.12-2.14, 2.17, 2.18, 2.20, 3.1-3.3, 3.8-3.11, 3.14-3.17.
2. Questions regarding GL: 2.8, 2.9, 2.11, 2.15, 2.16, 2.19, 3.4-3.7, 3.12, 3.13.
3. Questions testing knowledge: 2.1, 2.8- 2.11, 2.19, 2.20, 3.5-3.8, 3.13, 3.16.
4. Questions testing comprehension: 2.2-2.7, 2.14, 2.16-2.18, 3.1, 3.2, 3.4, 3.10, 3.12, 3.14, 3.15.
5. Questions testing ability to implement knowledge: 2.13, 2.15, 3.3, 3.9, 3.11, 3.17.

In this study a set passing rate or an acceptable score was not allocated, the study simply set out to determine the level of knowledge of participants. Because the study set out to test specialized knowledge, scoring 100% (or very close to full marks) is seen as optimal and an indication that the hypothesis for this study can be rejected.

CHAPTER 3

RESULTS

3.1 Demographical information of the participants

Questionnaires were sent out to 388 participants. One hundred and fourteen participants completed the questionnaire. Therefore the response rate was 29%. Some participants did not fill in all of the demographical information, resulting in the numbers in some demographic fields not adding up to 114.

Figure 3.1 shows the area of practice of participants. Most of the participants (50%) worked in private practice, 26% worked in hospitals, 4% in community clinics and 20% worked in other environments such as food service departments, regional offices, corporate companies or as company representatives.

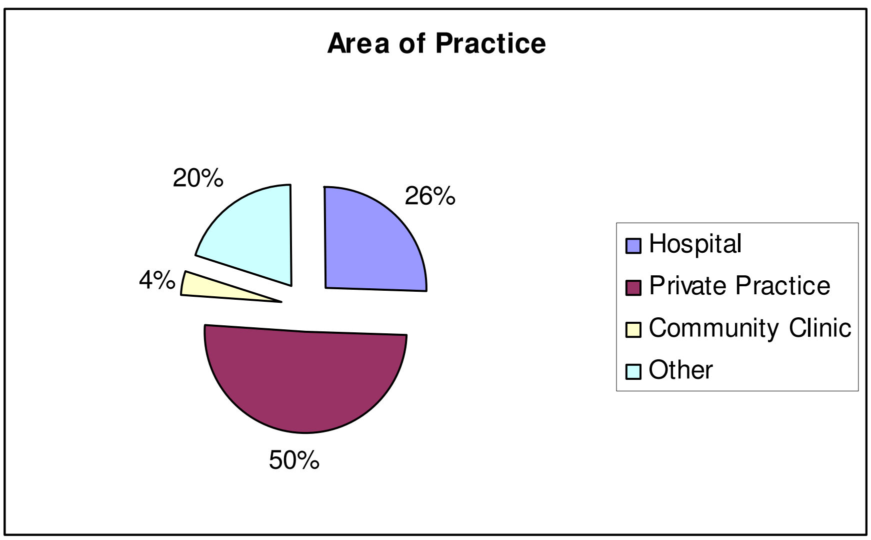

Figure 3.1: Area of practice of participants

A total of 67% of the participants consulted patients with diabetes on a weekly basis (30% daily and 37% weekly), 11% consulted patients with diabetes monthly and 22% consulted patients with diabetes less than once a month (see Table 3.1).

Table 3.1: Frequency at which patients with diabetes were consulted

	Frequency	Percent	Cum.
Daily	34	30.36	30.36
Weekly	41	36.61	66.96
Monthly	12	10.71	77.68
Less than once a month	25	22.32	100
Total	112	100	

Although many of the largest group of participants (41%) graduated from the University of Pretoria, all the universities were well represented (n=111) (see Figure 3.2).

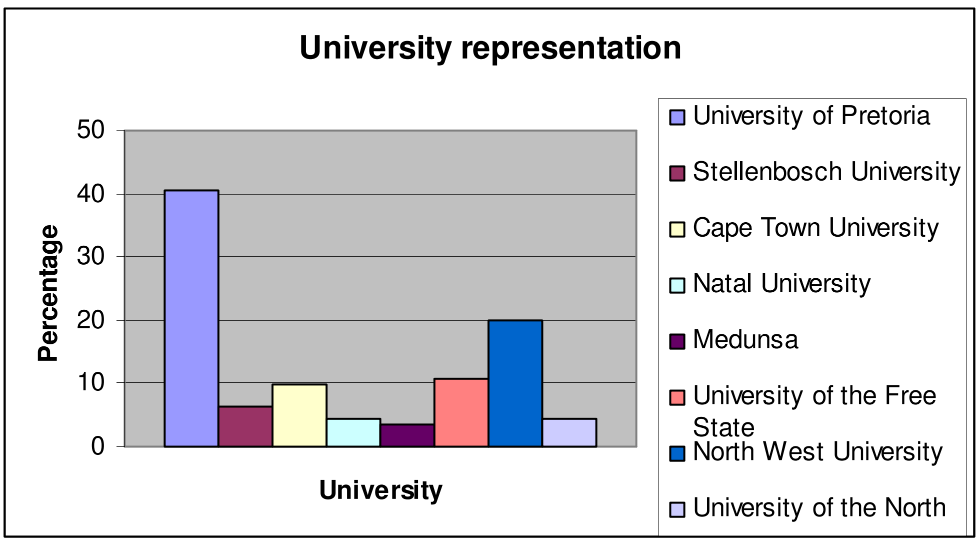

Figure 3.2: University representation

The year of graduation varied from 1962 to 2007 (Table 3.2).

Table 3.2: Year of participants' graduation

Year	Frequency	Percent	Cum
1962	1	1.10	1.10
1963	1	1.10	2.20
1965	1	1.10	3.30
1973	1	1.10	4.40
1974	2	2.20	6.59
1976	1	1.10	7.69
1977	1	1.10	8.79
1980	2	2.20	10.99
1981	3	3.30	14.29
1983	1	1.10	15.38
1984	1	1.10	16.48
1988	1	1.10	17.58
1989	1	1.10	18.68
1990	2	2.20	20.88
1991	1	1.10	21.98
1992	3	3.30	25.27
1993	4	4.40	29.67
1994	3	3.30	32.97
1995	2	2.20	35.16
1996	3	3.30	38.46
1997	5	5.49	43.96
1998	2	2.20	46.15
1999	4	4.40	50.55
2000	3	3.30	53.85
2001	3	3.30	57.14
2002	6	6.59	63.74
2003	7	7.69	71.43
2004	13	14.29	85.71
2005	3	3.30	89.01
2006	5	5.49	94.51
2007	5	5.49	100.00
Total	**91**	**100**	

Participants were allowed to choose more than one option of possible places where they acquired their knowledge on the GI. Seventy two percent of participants included the stated option workshop / lecture / congress as the only or as one of the means by which they were taught GI and GL principals. More than half (54%) of participants reported that they had not been taught GI principles at university and learned these principles through one or more of the other means such as workshops, congresses, or from scientific articles and subject-related books.

Eighty-four percent of participants reported that they used GI principles in their consultations, 5% never used them and 11% rarely used them. (Figure 3.3)

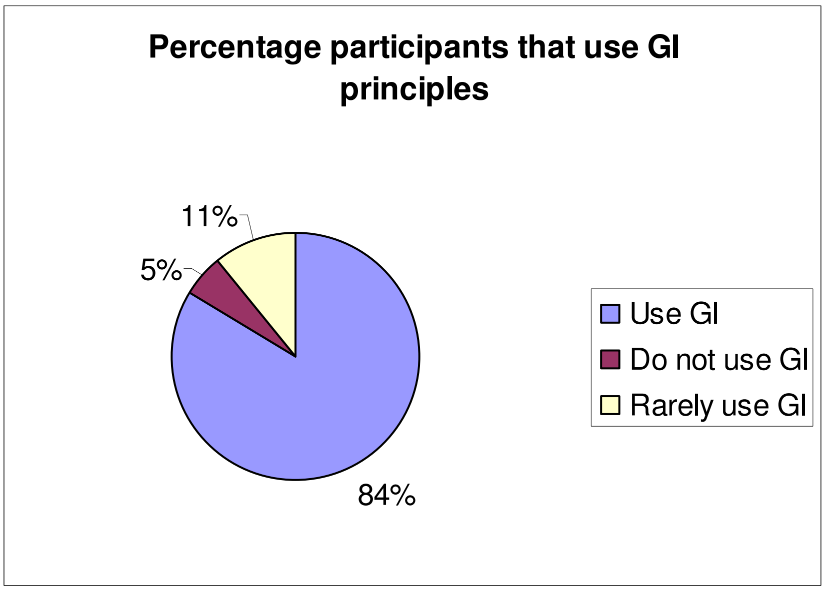

Figure 3.3: Percentage participants who use GI principles

A different picture can be seen for GL where 33% of participants reported that they used GL principles in their practice, 30% never used them and 37% rarely used them. (Figure 3.4)

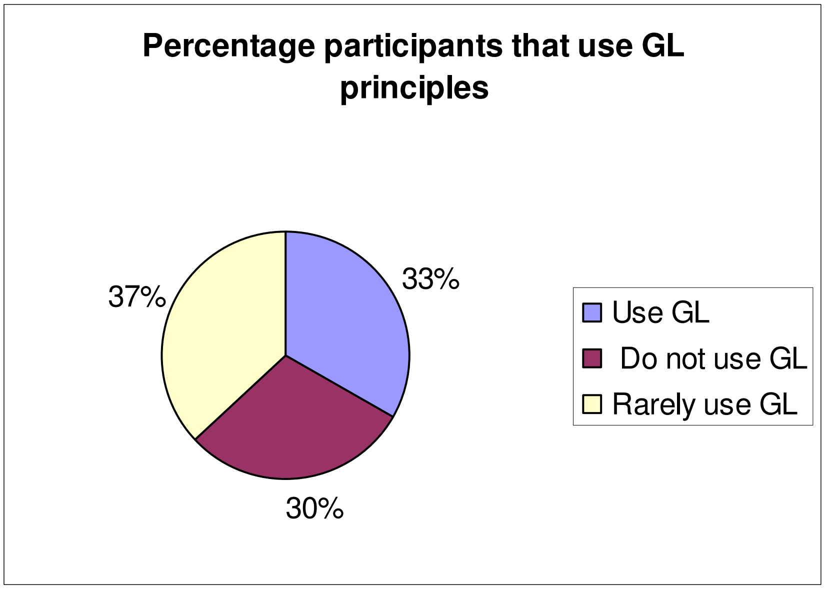

Figure 3.4: Percentage participants who use GL principles

3.2. Test results

Test results showed an average score of 71% for the 114 participants. The lowest score was 43% and the highest score was 97%. Five participants scored between 40 and 49%; 21 scored between 50 and 59%; 22 scored between 60-69%; 31 scored between 70-79%; 29 scored between 80 and 89% and 6 participants scored higher than 90% (see Figure 3.5).

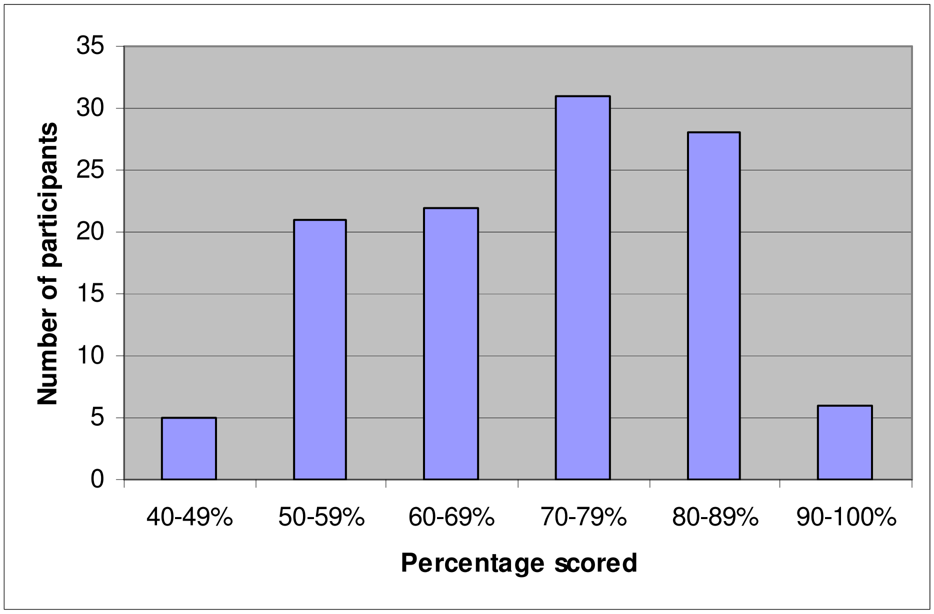

Figure 3.5: Grouping of percentages scored

As a group, dietitians in private practice scored the highest mean score of 76% and dietitians working in community clinics scored the lowest with a mean score of 55%. Dietitians working in hospitals scored a mean score of 67% and dietitians working in other fields, such as food service managements, corporate companies or as company representatives, scored a mean score of 69% (Table 3.3).

Table 3.3: Average test results per practice area (%)

Area of practice	Mean (%)	Standard Deviation (SD)
Hospital	66.86	10.31
Private practice	75.51	11.19
Community clinic	54.50	4.80
Other	69.04	12.89
Overall	**71.23**	**12.15**

As a group, participants who graduated from the University of Cape Town scored the highest (with a mean of 75%) and participants from Medunsa University scored the lowest with an average of 59%. Participants graduating from other universities scored between 66 and 74% (refer to Table 3.4).

Table 3.4: Average percentage scored by participants per university

University	Number of participants who graduated from this university	Mean test score (%)	Standard Deviation (SD)
University of Pretoria	45	72.67	10.79
Stellenbosch University	7	66.43	10.78
Cape Town University	11	75.09	15.14
Natal University	5	72.40	5.14
Medunsa	4	59.00	4.00
University of the Free State	12	73.83	13.39
North West University	22	69.36	13.30
University of the North	5	72.80	15.63

Participants who graduated between 1990 and 1994 scored the highest average (79%) and participants who graduated most recently, between 2005 and 2007, scored the lowest average of 66%. Note that participants who graduated in the first year cluster (1960-1969) scored the second highest average (77%) (See table 3.5)

Table 3.5 Average pecentage scored by participants per year of graduation

Year of graduation	Average test result (%)
1960-1969	76.67
1970-1979	69.4
1980-1989	70.89
1990-1994	79.08
1995-1999	72.5
2000-2004	71.87
2005-2007	66.08

3.2.1 Test results per objective

All questions tested certain aggregates, namely whether the questions were about GI or GL, and whether they tested the participants' knowledge of GI or GL, comprehension regarding GI and GL or ability to implement GI and GL principles.

Table 3.6(a) examines the number of correctly answered questions for each of the five aggregates.

Table 3.6(a): Number of correctly answered questions for 5 aggregates (n=114)

Aggregates	Number of Items	Mean	Standard Deviation (SD)	95% Confidence Interval
GI	25	17.71	3.11	(17.13 ; 18.29)
GL	12	8.66	2.26	(8.24 ; 9.08)
Knowledge regarding GI/GL	14	10.21	1.98	(9.84 ; 10.57)
Level of comprehension regarding GI/GL	17	12	2.44	(11.55 ; 12.45)
Use/implementation of GI/GL ability	6	4.16	1.15	(3.94 ; 4.37)

Table 3.6(b) examines the average percentages scored for questions for each of the five aggregates.

Table 3.6(b): Achievement (%) of the 5 aggregates (n=114)

Aggregates	Mean (%)	Standard Deviation (SD)	95% Confidence Interval
GI	70.84	12.44	(68.53 ; 73.15)
GL	72.15	18.81	(68.66 ; 75.64)
Knowledge regarding GI/GL	72.93	14.17	(70.30 ; 75.56)
Level of comprehension regarding GI/GL	70.59	14.39	(67.92 ; 73.26)
Use/implementation of GI/GL ability	69.30	19.15	(65.75 ; 72.85)

3.2.1.1 Test results concerning knowledge of GI and GL

Eighty-six percent of participants chose the correct definition of the GI (question 2.1) and 97% chose the correct definition of the GL (question 2.19).

The highest average score (98%) for any question was scored for question 2.20 that tested whether participants knew that a low GI diet can lower cardiovascular risk by improving lipid levels.

Seventy-seven percent of participants seem to know that adding 2 teaspoons of sugar will not affect blood glucose levels significantly (question 2.8) and 71% seem to know that sucrose recommendations are similar for those with diabetes and those without diabetes (question 2.9). Sixty-eight percent of participants indicated correctly that maltodextrin can not be used by diabetics as a sweetener (question 2.10) although 94% seem to know that fructose can not be used in unlimited quantities (question 2.11).

With regard to factors influencing the GI, 77% of participants seem to know that an increased acidity will lower the GI of a meal (question 2.13) and 97% seem to know that milling, grinding and adding soluble fibre can affect the GI of a meal (question 3.8) but only 28% indicated that a lesser degree of gelatinization of starch is the reason why cooled mealiemeal porridge has a lower GI than warm mealiemeal porridge (question 3.16).

With regard to questions focusing on the GL, 57% of participants seem to know what the GL for a whole day's meals should be (question 3.5), 75% seem to know what the GL of a meal should be (question 3.6) and 46% correctly indicated what the GL for a snack should be (question 3.7).

Figure 3.6 is a summary of test results for all questions that focused on GI or GL knowledge.

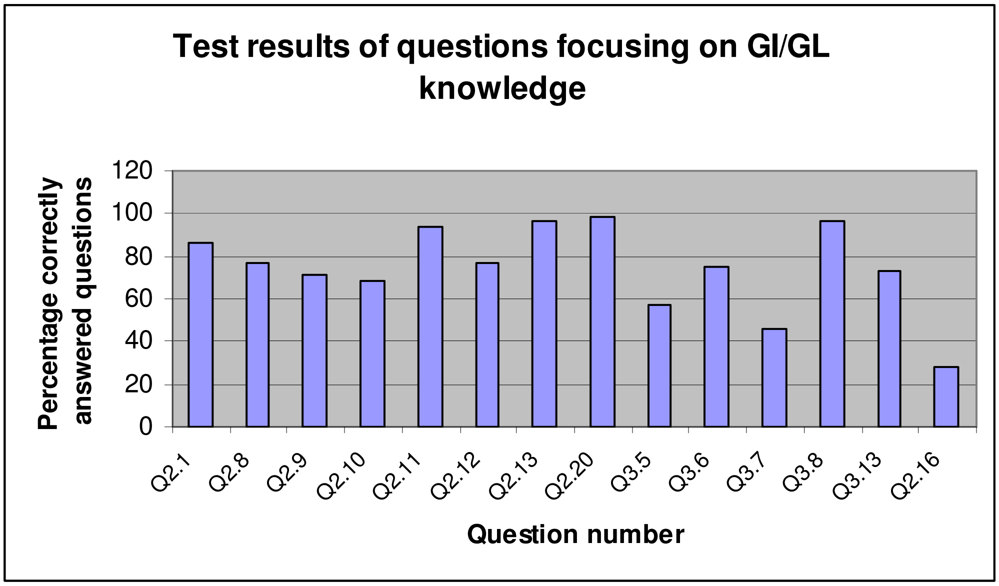

Figure 3.6: Test results of questions focusing on GI/GL knowledge

3.2.1.2 Test results concerning comprehension of GI and GL

Forty-eight (48) percent of participants seem to know that the carbohydrate structure will not affect the GI (question 2.2).

Participants scored an average of 78% for questions related to comprehension on GI testing methods (questions 2.3, 2.4 and 2.18).

Sixty-two percent of participants seem to know that large amounts of protein consumed can cause an insulin response (question 2.6) and 72% seem to know that in order to lower the GI of a meal with protein, 30 grams of protein needs to be added to every 50 grams of carbohydrate in the meal (question 3.2).

Half (50%) of participants incorrectly thought that a small amount of fat (1 teaspoon) can lower the GI of a large meal substantially (question 2.5) and only 25% knew that 1 gram of fat needs to be added to every 1 gram of carbohydrate present in a meal in order to lower the GI of a meal with fat (question 3.1). This was also the lowest average score achieved for any question.

Eighty-nine percent of participants indicated correctly that soluble and insoluble fibre do not affect the GI of a meal to the same extent (question 2.7) and 96% of participants indicated the correct method in which soluble fibre lowers the GI of a meal.

Sixty-eight percent of participants seem to know what the variables needed to calculate the GL (question 2.16) were, but only 56% calculated the GI correctly (question 3.4).

In questions testing comprehension, with regard to the role GI plays in sports nutrition (questions 3.14 and 3.15), 65% and 79% of participants chose the right answer for the respective questions mentioned above.

Figure 3.7 shows the percentage of correctly answered questions for all questions that focused on GI or GL comprehension.

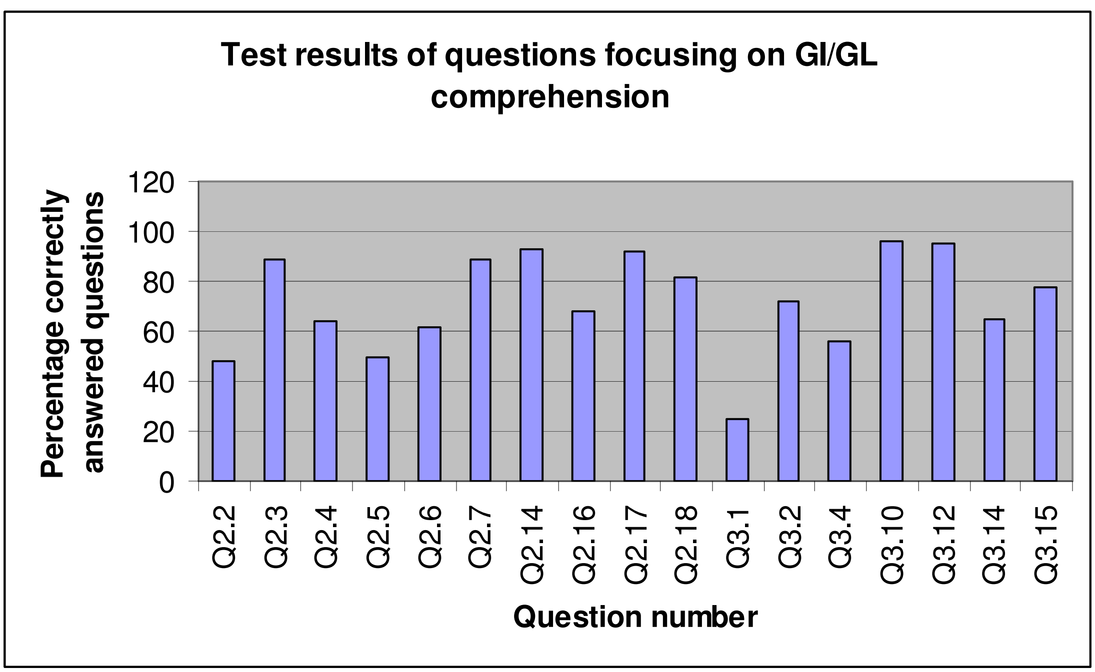

Figure 3.7 Test results of questions focusing on GI/GL comprehension

3.2.1.3 Test results concerning implementation of GI and GL

Seventy-six percent of participants seem to know that when a meal consists of 2 carbohydrates, the overall GI of a meal will be intermediate in relation to the GI values of the carbohydrates (question 2.13).

Question 2.15 tested whether participants understood that high GI vegetables could be used by diabetics due to their low carbohydrate content, 74% indicated the right answer.

Seventy-six percent of participants seem to understand how sugar can be implemented into the diabetic diet (question 3.3).

Most of the participants (96%) seem to understand how a low GI diet could positively affect blood lipid profiles and blood pressure (question 3.9).

Question 3.11 tested participants' ability to implement their knowledge of GI in the treatment of low blood glucose levels. Sixty percent of participants correctly chose the high GI food option in order to correct the low blood glucose level.

In question 3.17 it was asked what can be done to reduce the GI of Maltabella porridge from high to low GI, only 46% participants correctly indicated that it should be cooked in milk instead of in water.

Figure 3.8 shows the percentage of correctly answered questions for all questions that focused on GI or GL implementation.

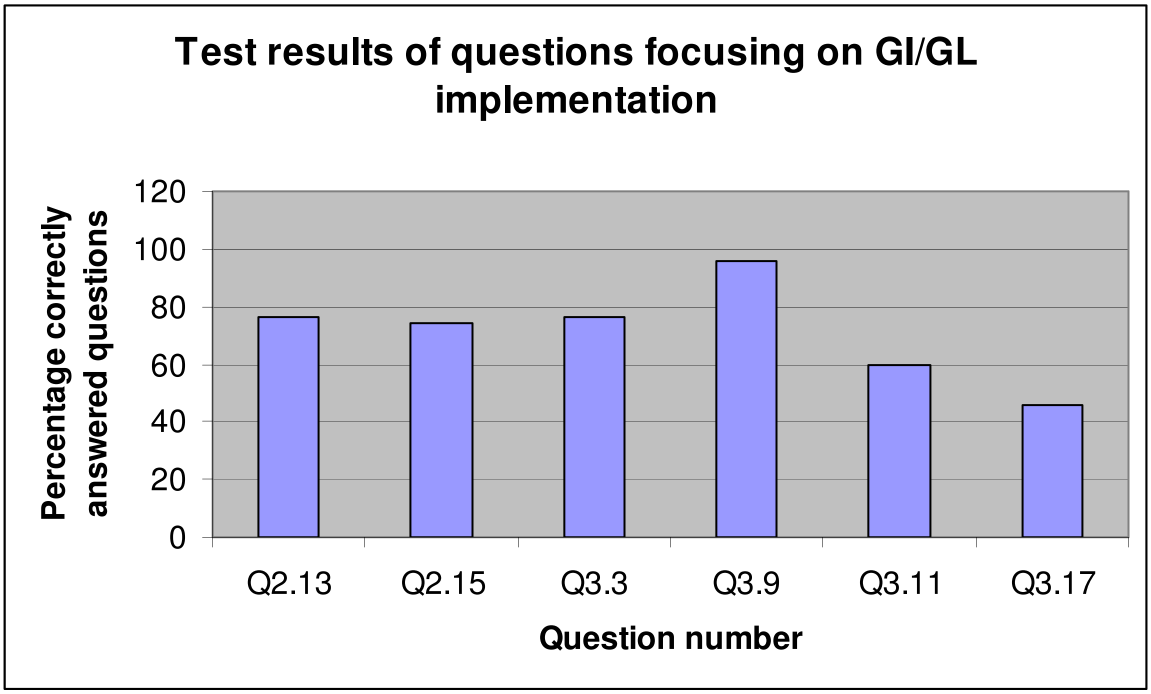

Figure 3.8: Test results of questions focusing on GI/GL implementation

CHAPTER 4

DISCUSSION

4.1 Demographical information

As far as the researcher is aware, a study such as this one has not been done in South Africa or elsewhere.

Although all participants who were contacted by telephone agreed to participate in the study, the response rate was only 29%. The low response rate could be due to the fact that most participants who were approached are busy professionals and participation can be time consuming. Although participants were assured that the results would be treated as confidential, another reason for the low response rate could be because of some participants lacking knowledge on the subject and struggling with the questionnaire, and therefore refraining from sending it back to the researcher for fear of looking incompetent.

Half of the participants (50%) in this study were dietitians.in private practice. The reason for such a large representation from this area of practice could be that private practicing dietitians use ADSA (from which the database for the study population was obtained) as a way to advertise their practices on the internet and to receive information on academic activities which promote continuous learning. Dietitians working in non-clinical settings, such as food service departments or as company representatives, will not share these needs with their private practicing counterparts and thus representation of these groups at ADSA could be poorer. Only dietitians consulting with patients,however, will need the knowledge and skills to understand and implement principles regarding the Glycemic Index and their test results will reflect the level of care that South African Dietitians are able to offer patients.

Although most universities were well represented, almost half of the participants graduated from the University of Pretoria. No reason can be given for the high representation of participants who graduated from the University of Pretoria.

The year of graduation varied from 1962 to 2007. Except for the year 2004 when 13 participants graduated, there were never more than 7 participants who graduated in the same year. As half of participants graduated before the year 2000, when the first South African written book on GI was published by Gabi Steenkamp and Liesbet Delport (that fueled interest about the GI amongst South African dietitians), it was expected that these participants would not achieve good test results. The results also indicate that half of the participants graduated before GI formed any part of the curriculum of their university degree. This was confirmed by the fact that 54% of participants reported that they have not been taught any GI principles at university, but instead learned these principles through a variety of other means such as workshops, congresses, scientific articles or books. Self acquired knowledge, as in the case of most of the participants in this study, has two pitfalls. Firstly, when one is self taught, one's knowledge on the subject has never been formally examined (like the case would be when acquiring knowledge from a university) therefore there is no way that one could tell if one's understanding of the subject matter is indeed correct. Inaccurate or incorrect information might unknowingly be reported to patients or the public. Secondly, due to a lack of practical experience, one's ability to implement knowledge may be inadequate. This study aimed at testing if participants could indeed overcome these pitfalls and acquire sufficient knowledge on the GI regardless by which means the information was gathered.

In the light of the above, it is worth noting that the Continuous Professional Development (CPD) system (aimed at keeping professionals up to date with new and relevant scientific information) does seem to have merit and is having a positive effect in keeping dietitians updated. Seeing that most of the participants were taught GI principles through talks, lectures, congresses and articles (mostly presented as part of CPD activities), and considering the average mean score of participants was above 70%, the results of the study act as proof that the CPD system is indeed valuable to dietitians and accomplishes its aim to achieve continuous learning.

As many studies praise the blood glucose lowering effect of a low GI diet [1,3,5,6,7], and a large number (67%) of participants reported that they consulted patients with diabetes on a weekly basis, good test results would reflect a good standard of diabetes care in our country.

Irrespective of the area of practice, 84% of participants reported that they did use GI principles in their working environment compared to only 33% who reportedly used GL principles. Only 5% participants reportedly never used GI principles, but 30% participants never used GL principles). As the GI cannot be used successfully in blood glucose control without considering the amount of carbohydrate consumed (the GL) [9,10,14,20-25], it is worrying that so few dietitians use the GL in conjunction with the GI. When the GL is not used, dietitians may not be able to judge if a patient's meal or diet provides too high a glucose load [16,18, 21-23] and therefore will not be able to make recommendations accordingly. Dietitians who do not use GL principles will advise against some high GI food without considering whether the GL might in fact be very low (as is the case with vegetables). This means that food lists may be limited unnecessarily and that food with a high nutrient, low kilojoule value might wrongfully be excluded from the diet of those with diabetes or for weight reducers [16,18,21]. As a high GL diet is linked to obesity, an abnormal lipid profile, insulin resistance and an increase in the severity of diabetes [9,10,14,25], it could be described as negligence that so many dietitians ignore the GL, because clearly by doing so they do not provide optimum health care. The main concern about using the GI without considering the GL, is that when used in isolation, the GI principles might fail to successfully control blood glucose levels, causing the GI to lose credibility as a scientific tool and resulting in public scepticism.

4.2 Test results

If could be expected that private practicing and hospital dietitians would score the highest mean score, as they work in the area of practice where GI principles are most often used and where patients are most likely to implement these principles. Although private practicing dietitians did score the highest mean score (76%), hospital dietitians scored a mean score of only 67% that placed them in third place. The reason why hospital dietitians scored less than private practicing dietitians could in part be due to the fact that many of them might be working in a field of specialisation where knowledge about the GI and GL is not applicable like for instance the intensive care unit or oncology unit. One would expect these dietitians to only have a basic knowledge on the subject as it does not form part of the knowledge and skills that they use daily in their area of specialisation. Many of the hospital dietitians may also we working in state hospitals where GI principles might not be used. This could be due to lack of patient understanding, limited variety of food items available to patients and/or poor economic and socio-economic living conditions. The same reasons are valid for community dietitians (they scored the lowest mean score of 55%). What is interesting however, is the fact that dietitians who reported that they practiced in an 'other' field, such as food service management, corporate companies or as company representatives (and therefore not as consulting dietitians) scored a higher mean score (69%) than dietitians working in hospitals or community clinics.

Analysis of test scores linked to the universities where participants graduated showed that average test scores from most universities did not differ significantly from one another, with results varying between 66 to 75%. Participants graduating from Medunsa however, (scoring an average of 59%) scored well below average. Therefore with the exception of Medunsa, the university attended did not seem to affect test results and there was no one university whose participants scored significantly higher than the rest. As already established more than half (54%) of participants reported that they were not taught GI principles at university, and it is therefore advisable that all universities review their curriculum regarding the GI on a continuous basis.

There was no pattern found when average test scores were linked to the year of graduation. What was very interesting however, is that participants who graduated in the first year cluster, more than 40 years ago (1960-1969), scored an average that was 11% higher than participants who graduated in the most recent year cluster (2005-2007). They also scored the second highest average of all the groups. Because the GI concept was only introduced in the 1980's [13, 16] this group could not have been taught anything about GI at university and all their knowledge on the subject must have been self-taught, again enforcing the idea that the CPD system is very valuable in ensuring continuous learning. The fact that participants who graduated most recently scored the lowest average could be because they might lack experience and experience aids the process of translating knowledge into practical implementation and understanding. Participants who graduated between 1990-1994 scored the highest average, interestingly they fall right in the middle of the year clusters. No reason can be given for why this specific group scored the highest average.

4.2.1 Test results per objective

There was no notable difference in average test scores for questions focused on the following aggregates:
Participants' general knowledge regarding the GI/GL (73% average score), level of comprehension regarding GI/GL (71% average score) and ability to use or implement the GI/GL (70% average score). The confidence intervals for these analyses were all very small, confirming the reliability of the results. It therefore seems that participants had the same level of knowledge, comprehension and ability to implement principles for the GI and GL.

On analysis of test results per aggregate, the following results were of interest**:**

4.2.1.1 Test results concerning knowledge of GI and GL

Although a high number (86%) of participants indicated the correct definition of the GI, almost all participants (97%) got the GL definition correct, again enforcing what has been seen throughout this study, namely that scores related to questions focusing on GL were always slightly higher compared to those focusing on GI.

The highest average scored for any question (98%) was for the question which tested whether participants knew that the GI can improve lipid levels. For other questions that focused on the same idea, high average scores were also achieved. It therefore seems that South African dietitians are well informed about the health benefits of a low GI diet and accept its value in lowering risk for cardiovascular disease and other chronic diseases of lifestyle. The first step for a new science to be accepted is when the specialists believe in its value and truth, and as almost all participants indicated through this question that they recognized the value of the GI as a health treatment tool, it will therefore be of great benefit that they are able to use and implement the GI correctly.

Participants scored high averages for questions that focused on their knowledge of how and what type of sugar can be used by those with diabetes. This was surprising as the stigma around the use of sucrose by patients with diabetes was one of the most generally believed misconceptions about the diabetic diet. Although most participants seem to know how sucrose and fructose should be used by diabetic patients, a smaller number seem to know that maltodextrin has a high GI value and is not recommended for those with diabetes.

When participants' knowledge on factors that can influence the GI of a meal was tested, the results were conflicting. A high number of participants (77% and 97% respectively) seem to know that increased acidity and milling, grinding and adding soluble fibre can lower the GI of a meal, but only 28% seem to know that a lesser degree of gelatinization is the reason why cooled porridge has a lower GI than warm porridge. This is disappointing as mealiemeal porridge is the staple food of so many South Africans, and it would be expected that dietitians would be able to explain to their patients why the difference in temperature could affect their blood glucose levels. This shortcoming in their knowledge may have to do with a lack in food science knowledge, and the specific focus on how manipulating a starch structure can affect its digestibility. This point may need attention when curriculums are reviewed.

With regard to questions focusing on GL values of meals, the results were again conflicting. Although a high number (75%) of participants seem to know what the GL of a meal should be, less than half (46%) seem to know what the GL of a snack should be and only 57% knew what the GL of a whole day's meals should be. This points to inadequate knowledge on this particular subject, as a dietitian must surely be able to advise his/her patient on what the GL of a snack should be! The reason for this poor result could be because so few dietitians reportedly use GL in their practice and are therefore not familiar with the subject or it may be that the GL has not received as much attention at CPD activities as the GI did and therefore dietitians have not had as much exposure to the GL principals, however, as discussed before, the GI cannot be used successfully without the GL.This poor result is therefore disappointing.

4.2.1.2 Test results concerning comprehension of GI and GL

Less than half (48%) of participants seem to know that the carbohydrate structure will not influence the GI value of a food item. Again this result could be linked to a lack in understanding of food science as mentioned in 4.2.1.1.

Almost 80% of participants seem to understand how GI testing is done. This is a surprising result, as one would expect that more focus would be placed on issues like the GL values of meals than on testing methods.

An average of 67% participants seem to understand the role that protein can play in lowering the GI of a meal and the amount of protein needed to affect the GI at all. Contrary to this, only an average of 38% participants seem to have the same level of understanding concerning the role of fat and the amount needed to lower the GI of a meal. This result was one of the most confusing of all results that came out of this study. How is it possible for 72% of dietitians to know the exact amount of protein needed to lower the GI of a meal, but only 25% knew the amount of fat needed to lower the GI of a meal? If a dietitian did indeed have such in-depth knowledge on the subject that he/she was able to correctly answer (what was supposed to be a little known fact) on the exact grams of protein needed to lower GI values of a meal, indicating that no guessing was done, how could he/she not have the same in depth knowledge about the effects of fat? No explanation can be given for these results.

An average of 93% of participants seem to understand how and in what ways soluble fibre could effect the GI of a meal or food item more than insoluble fibre could. The good understanding of the different types of fibre and their effects could be accredited to the fact that dietitians receive in-depth training on the gastrointestinal tract and that different types of fibre and the roles of fibre are reviewed throughout the dietetic course.

It was disappointing that only 68% of participants seem to know what the variables needed to calculate the GL are, and even more disappointing that only 56% calculated it correctly. A possible reason for this result is that participants did not have a calculator at hand when completing the questionnaire or refrained from doing the calculation as they wanted to finish the questionnaire quickly.

An average of 72% of participants seems to know the role GI plays in sports nutrition. This result was unexpected as so few dietitians specialize in sports nutrition.

4.2.1.3 Test results concerning implementation of GI and GL

A high percentage of participants seem to know how to estimate the GI of a meal consisting of more than one carbohydrate, and almost the same number seem to understand that high GI, low GL foods are acceptable to diabetics. Both these principles are complicated ones that one would expect only very informed dietitians would be able to understand, however these questions were answered correctly by more dietitians than some of the basic questions (e.g. GL value of meals as discussed before). This finding emphasizes the fact that although in-depth knowledge of some areas may be covered in talks, articles, and such, more attention should be given to ensuring that knowledge on the basic principles of GI and GL is in place.

High average scores, achieved for questions that focused on the ways sugar can be implemented into the diabetic diet and how low GI diets positively affect blood lipid levels, correlated very well with results of other questions focusing on the same subjects.

Only 60% of participants indicated the right choice of food to use in the treatment of hypoglycemia. This is a very disappointing result considering that dietitians are trained to advise patients on correct food choices to treat certain health conditions (including a condition like hypoglycemia), especially as so many with this condition reportedly consult diabetics. This is another basic principle that needs attention in future training.

Only 46% of participants seem to know that by cooking high GI porridge in milk the GI of the porridge can be reduced to low GI. This question was complicated because in this case, adding heat and fluid (as with normal gelatinization), the GI is not increased but decreased. This occurs not only because of milk's lower starch gelatinization ability (compared to water), but also because milk has a low GI and more of it will be present than high GI porridge. It was expected that participants would not score well in this question, however this is an easy way to lower the GI of porridge and as mentioned before, porridge is the staple food of many South Africans and it would be valuable in patient training if dietitians were able to pass this tip on to patients. The poor outcome of this question does point to a lack of in-depth knowledge as far as implementing complicated entities are concerned.

Generally speaking a group average test score of 71% sounds very good, but one needs to consider two aspects in more detail. Firstly, 83% participants reported that they did use the Glycemic Index. This means, that in South Africa the Glycemic Index is a popular scientific tool regularly used by dietitians.. Therefore if misconceptions regarding the GI exist, they would be widely transferred to patients and the general public (through non-scientific magazine articles, talks presented to the public, etc.). Secondly, in order to score 71% (the average) for the questionnaire, one is allowed 11 wrong answers. It is of importance to consider whether it is acceptable that dietitians are not equipped with 100% of the knowledge available on a subject, since they are considered to be nutritional specialists, using their scientific knowledge (on GI for example)) to care for or educate patients, and what errors in teaching and/or implementation of the GI will exist with a 30% gap in knowledge and therefore a 30% chance of interpreting GI principles incorrectly. In this study not one participant scored 100%. This is disappointing considering that so many dietitians reportedly use the GI in their patient training on a daily basis. When a specialist (like a dietitian) uses a scientific concept daily, one would expect that the specialist to know all there is to know on the subject. Of even more concern is the fact that misconceptions about the GI might be published in non-scientific magazines or made public through other forms of media. It wouldl be very hard to change these misconceptions later and convince the public otherwise.

4.3 Study limitations

A limitation of the study was the small response rate (n=114; 29%) of the selected sample (n=388). As participation was voluntary and time consuming, a smaller response rate was expected. Another limitation was the fact that participants did not always fill out demographical information in full, causing the demographical analysis to be incomplete.

Although validity was determined for the questionnaire by the best means possible, the following results could place a question mark behind the validity of the questionnaire:

1. The non-dietitians (who supposedly have no training on the GI) scored an average of 46%, that is 3% higher than the lowest score achieved by a dietitian. This could be due to the fact that South Africans have had huge exposure to the GI, since books on the topic were, and still are best sellers in South Africa and the GI is a popular topic in newspaper and magazine articles, as well as in radio talks. Many corporate health training programmes also focus on the GI.

2. Dietitians working in non-clinical environments, such as food service managements, corporate companies or as company representatives who do not communicate GI principles to patients and do not need to implement these principles in their work environment, who were expected to score the lowest mean results since they are the group whose work has the least connection with the GI, scored a higher mean score than dietitians working in hospitals or community clinics who do consult diabetics. No reason for this outcome can be given.

3. A mere 33% of dietitians reported that they used GL principles compared to 84% dietitians who used GI principles. Despite this huge difference, participants scored an average of 71% for questions related to GI compared to an average of 72% for questions related to the GL. If only 33% used GL compared to 84% using GI, how is it possible that their knowledge level for both GI and GL could be similar? The only possible explanation for this result is that dietitians may in fact understand the principles of the GL and use it to double check portion control for example, but do not actively teach it to their patients. The GL is a complex entity and dietitians may find it difficult to explain the concept of the GL to their patients without confusing them. Therefore dietitians may refrain from using GL principles in their consultations (although their GL knowledge may be excellent) and therefore answered in the questionnaire that they did not use GL principles in their consultations. On the other hand, a small number of participants were able to identify the variables needed to calculate the GL. Surely if they are not able to calculate the GL, their knowledge about the subject must be lacking to a greater degree than the results of this study show.

In future similar studies, it would be advisable to consider these points and modify the questionnaire accordingly.

In light of the above, the hypothesis for this study is accepted. Although South African dietitians seem to have a good understanding of the GI, there is still room for improvement and their knowledge therefore cannot be described as adequate.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Research has proven that the Glycemic Index is a valuable scientific tool in the treatment and management of diabetes and other chronic diseases of lifestyle as well as in the improvement of health and weight management [1-15]. If the principles of the GI and GL are correctly understood and implemented by dietitians, they can, and will, make a huge difference to disease management and prevention of diseases of lifestyle [1-15]. However, as the GI is scientifically based and a variety of factors can influence the GI of a meal or an item of food [14,18,37,43,44,47-52], it is of the greatest importance that dietitians who use this valuable tool are well equipped to do so. If dietitians spread conflicting ideas surrounding the GI, it can harm the dietetic profession and cause South African dietitians to lose credibility.

This study demonstrated that South African dietitians have a good understanding of GI and GL principles and are able to implement them. There is, however, room for improvement before South African dietitians can truly be classed as experts on the GI and GL.

5.2 Recommendations

To ensure that results of similar questionnaires in similar studies do reflect the true general knowledge of participants, it's advisable not to post or email the questionnaires (otherwise the participants have the opportunity to check their facts, although advised against doing so, and thus influence the outcome of the study). It is advisable rather to hand out questionnaires at lectures or small group meetings where participants are forced to fill in questionnaires on the spot, ensuring that the answers do indeed reflect their general knowledge.

Facts surrounding the GI and GL should ideally be taught at university level, so that newly registered dietitians can start their careers with the right information and are not left to their own devices to discover and learn these principles. It would be advisible that the curriculum of any university should cover the following:

- The role of GI in disease prevention and promotion of health status with pertinent detail to the physiological mechanisms of insulin and glucose control and the repercussions thereof.
- Food on the GI list should be discussed to ensure dietitians are knowledgeable on choices and test results of new products.
- GI testing methods should be explained with special focus on reference foods and test food portions.
- Ways to calculate the GI of a meal or recipe should be explained.
- Previously believed misconceptions about the diabetic diet should be discussed and reasons for their invalidity should be explained in detail.
- Factors that can influence the GI of a meal or product should be covered as well as ways in which the GI can be manipulated with special attention to how food science affects the above.
- Treatment of hypoglycemia.
- The calculation of the GL should be explained, as well as the way the GL influences the GI and portion sizes.
- Ways to practically explain the GL to patients should be included.
- The role of GI in sports nutrition should be covered.

It is recommended that workshops be offered to dietitians who graduated in the past. These workshops should cover the same spectrum of instruction as recommended above for students. It is advisable that some form of testing is included to enable dietitians to test their own knowledge and skills and to check if their understanding of the subject is correct.

Workshops or congresses with special focus on the GL are also recommended. Since less than a third of participants reportedly used GL principles, it is of the greatest importance that dietitians are made aware of the value and functionality of the GL. These workshops or congresses should not only focus on the calculation of the GL and theory behind it, but special attention should also be paid to the practical implementation of the theory.

Information booklets on GI and GL could be posted to all registered dietitians, accompanied by tests, with answers to the questions provided,.

Finally, South African nutritional journals could publish the latest scientific research and related articles on GI and GL to ensure that dietitians keep up to date with the latest findings.

REFERENCES

1. Björck I, Liljeberg H, Östman, E. Low glycaemic-index foods. Br J Nutr 2000; 83:149-155.
2. Wolever TMS, Jenkins DJA, Jenkins AL, Josse RG. The glycemic index: methodology and clinical implications. Am J Clin Nutr 1991; 54:846-854.
3. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fibre intake and incidence of type 2 diabetes in younger and middle-aged women. Am J Clin Nutr 2004; 80: 348-356.
4. Sahyoun NR, Anderson AL, Kanaya AM, Koh-Banerjee P, Kritchevsky SB, de Rekeneire N, Tylavsky FA, Schwartz AV, Lee JS, Harris TB. Dietary glycemic index and load, measures of glucose metabolism, and body fat distribution in older adults. Am J Clin Nutr 2005; 83:547-552.
5. Hodge AM, English DR, O'Dea K, Giles GG. Glycemic index and dietary fibre and the risk of type 2 diabetes. Diab Care 2004; 27:2701-2706.
6. Brand-Miller JC. Postprandial glycemia, glycemic index and the prevention of type 2 diabetes. Am J Clin Nutr 2004; 80:243-244.
7. Gross LS, Ford ES, Liu S. Increased consumption of refined carbohydrates and the epidemic of type 2 diabetes in the United States: an ecologic assessment. Am J Clin Nutr 2004; 79(5):774-779.
8. Qi L, Rimm E, Liu S, Nader R, Frank B. Dietary glycemic index, glycemic load, cereal fibre, and plasma adiponectin concentration in diabetic men. Diab Care 2005; 28:1022-1028.
9. Rizkalla SW, Taghrid L, Laromiguiere M, Huet D, Boillot J, Rigoir A, Elgrably F, Slama G. Improved plasma glucose control, whole-body glucose utilization, and lipid profile on a low glycemic index diet in type 2 diabetic men: a randomized controlled trial. Diab Care 2004; 27:1866-1872.

10. Burani J, Palma J. Low Glycemic index carbohydrates: an effective behavioral change for glycemic control and weight management in patients with type 1 and 2 diabetes. Diabetes Educator 2006:32:78-88.
11. Björntorp P. Body fat distribution, insulin resistance and metabolic diseases. Nutrition 1997; 13:795-803.
12. Roberts SB, Pittas AG. The role of glycemic index in type 2 diabetes. Nutrition in Clinical Care 2003; 6:73-78.
13. Brand-Miller, J. Glycemic load and chronic disease. Nutrition Reviews 2003; 61:49-55.
14. Vaughan L. Dietary guidelines for the management of diabetes. Nurs Stand. 2005; 19:56-64.
15. Sloth B, Krog-Mikkelsen I, Flint A, Tetens I, Bjorck I, Vinoy S, Elmstahl H, Astrup A, Lang V, Raben A. No difference in body weight decrease between a low-glycemic-index and a high-glycemic-index diet but reduced LDL cholesterol after 10wk ad libitum intake of low-glycemic-index diet. Am J Clin Nutr 2005; 81:940-941.
16. Bell SJ, Sears B. Low-Glycemic-Load Diets: Impact on obesity and chronic diseases. Critical Reviews in Food Science and Nutrition 2003; 43(4):357-377.
17. Delport L, Steenkamp G. Eating for Sustained Energy 1. Tafelberg; 2000.
18. Steenkamp G, Delport L. The South African glycemic index and load guide. 5th Print. GIFSA publication 2005.
19. Republic of South Africa. Draft regulations relating to the labelling and advertising of foodstuffs and the labelling and advertising and composition of nutritional supplements for adults. Department of Health; Directorate Food Control. Government Gazette. In press 2006.
20. Sheard NS, Clark NG, Brand-Miller JC, Franz MJ, Pi-Sunyer FX, Mayer-Davis E, Kulkarni K, Geil P. Dietary carbohydrate (amount and type) in prevention and management of diabetes. Diab Care 2004; 27:2266-2271.

21. Salmeron J, Ascherio A, Rimm EB, Colditz GA, Spiegelman D, Jenkins DJ, Stampfer MJ, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of NIDDM in men. Diab Care 1997; 20:545-550.
22. Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Spiegelman D, Wing AL, Willett WC. Dietary fiber, glycemic load, and risk of NIDDM in women. J Am Med Ass 1997; 227:472-477.
23. Ludwig DS. Glycemic load comes of age. J. Nutr. 2003; 133:2695-2696.
24. Tapola N, Karvonen, Niskanen L, Mikola M, Sarkkinen E. Glycemic response of oat bran products in type 2 diabetic patients. Nutrition, Metabolism & Cardiovascular Diseases 2005; 15:255-261.
25. Wolever TM, Bolognesi C. Source and amount of carbohydrate affect postprandial glucose and insulin in normal subjects. J Nutr 1996; 126:1619-1626.
26. Wolever TM, Bolognesi C. Prediction of glucose and insulin response of normal subjects after consuming mixed meals varying in energy, protein, fat, carbohydrate and glycemic index. J Nutr 1996; 126:2807-2812.
27. Wolever TM, Mehling C. Long-term effect of varying the source or amount of dietary carbohydrate on postprandial plasma glucose, insulin, triacylglycerol, and free fatty acid concentration in subjects with impaired glucose tolerance. Am J Clin Nutr 2003; 77:612-621.
28. Lenfant C, Ernst N. Daily dietary fat and total food-energy intakes. Third National health and Nutrition Examination Aurvey, Phase 1. M.M.W.R. 1994; 43:116-117.
29. Ludwig DS. Dietary glycemic index and obesity. J Nutr 2000; 130:280S-283S.
30. Willet W, Manson J, Liu S. Glycemic index, glycemic load, and risk of type 2 diabetes. Am J Clin Nutr 2002; 76:274S-280S.
31. Brand JC, Colagiuri S, Crossman S, Allen A, Roberts DC, Truswell AS. Low glycemic index foods improve long-term glycemic control in NIDDM. Diab Care 1991;14(2):95-101.
32 Ludwig DS, Majzoub JA, Al-Zahrani A, Dallal GE, Bianco I, Roberts SB.

High glycemic index foods, overeating and obesity. Pediatrics 1999; 103: 1- 6.

33. Dumesnil JG, Turgeon J, Tremblay A, Poirier P, Gilbert M, Gagnon L, St-Pierre S, Garneau C, Lemieux I, Pascot A, Bergeron J, Despres J-P. Effect of a low-glycemic index low-fat-high-protein diet on the atherogenic metabolic risk profile of abdominally obese men. Br. J. Clin. Nutr 2000; 73:560-566.
34. Brand-Miller JC, Holt SHA, Pawlak DB, McMillan J. Glycemic index and obesity. Am J Clin Nutr 2002; 76:281S-285S.
35. Ludwig DS. The glycemic index: physiological mechanism relating to obesity, diabetes and cardiovascular disease. JAMA 2000; 287:2414-2423.
36. Jenkins DJA, Wolever TMS, Jenkins AL, Giordano C, Giudici S, Thompson LU, Kalmusky J, Josse RG, Wong GS. Low glycemic response to traditionally processed wheat and rye products: bulgar and pumpernickel bread. Am J Clin Nutr 1986; 43:516-20.
37. Pi-Sunyer XF. Glycemic index and disease. Am J Clin Nutr 2002; 76:290S-298S.
38. Ross SW, Brand JC, Thorburn AW, Truswell AS. Glycemic index of processed wheat products. Am J Clin Nutr 1987; 46:631-635.
39. Liljeberg H, Björck I. Delayed gastric emptying rate may explain improved glycaemia in healthy subjects to a starchy meal with added vinegar. Eur J Clin Nutr 1998; 52(5):369-371.
40. Östman E, Granfeldt Y, Persson L, Björck I. Vinegar supplementation lowers glucose and insulin responses and increases satiety after a bread meal in healthy subjects. Eur J Clin Nutr 2005; 59:983-988.
41. Jenkins DJA, Wolever TMS, Taylor RH, Barker H, Fielden H, Baldwin JM, et al. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 1981; 34:362-366.
42. Gulliford MC, Bicknell EJ, Scarpello JH. Differential effect of protein and fat ingestion on blood glucose response to high- and low-glycemic-index

carbohydrates in noninsulin-dependant diabetic subjects. Am Soc Clin Nutr 1989; 50:773-777.

43. Nuttall FQ, Mooradian AD, Gannon MC, Billington C, Krezowski P. Effect of protein ingestion on the glucose and insulin response to a standardized oral glucose load. Diab Care 1984; 7:465-470.
44. Wolever TMS, Bologensi C. Prediction of glucose and insulin responses of normal subjects after consuming mixed meals varying in energy, protein, fat, carbohydrate and glycemic index. J Nutr 1996; 126:2807-2812.
45. Estrich D, Ravnik A, Schlierf G, Fukayama G, Kinsell L. Effects of co-ingestion of fat and protein upon carbohydrate-induced hyperglycemia. Diab 1967; 16:232-237.
46. Karamanlis A, Chaikomin R, Doran S, Bellon M, Bartholomeusz FD, Wishart JM, Jones KL, Horowitz M, Rayner CK. Effects of protein on glycemic and incretin responses and gastric emptying after oral glucose in healthy subjects. Am J Clin Nutr 2007; 86:1364-1368.
47. Collier G, O'Dea K. The effect of congestion of fat on the glucose, insulin and gastric inhibitory polypeptide responses to carbohydrate and protein. Am J Clin Nutr 1983; 37:941-944.
48. Gannon MC, Nuttall FQ. Effect of a high-protein, low-carbohydrate diet on blood glucose control in people with type 2 diabetes. Diab 2001; 53:2375-2382.
49. Wolever TMS, Jenkins DJA. The use of the glycemic index in predicting the blood glucose response to mixed meals. Am J Clin Nutr 1986; 43:167-172.
50. Burke LM. Pre-event meals: high or low glycemic index foods? [Online} Available: http://www.sportsci.org. 1998. Accessed: 1 April 2009.
51. Thomas DE, Brotherhood JR, Brand JC. Carbohydrate feeding before exercise: effect of glycemic index. Int J Sports Med 1991; 12(2):180-186.
52. DeMarco HM, Sucher KP, Cisar CJ, Butterfield GE. Pre-exercise carbohydrate meals: Application of glycemic index. Med Sci Sports Exerc 1999; 31:164-170.

53. Wee S-L, Williams C, Gray S, Horabin J. Influence of high and low glycemic index meals on endurance running capacity.Med Sci Sports Excer 1999; 31:393-399.
54. Thomas DE, Brotherhood JR, Brand JC. Plasma glucose levels after prolonged strenuous exercise correlate inversely with glycemic response of food consumed before exercise. Int J Sport Nutr 1999; 4:361-373.
55. Franz MJ, Horton ES, Bantle JP, Beebe CA, Brunzell JD, Coulston AM, Henry RR, Hoogwerf BJ, Stacpoole PW. Nutrition principles for the management of diabetes and related complications. Diab Care 1994; 17(5):490-518.
56. Delport L, Volschenk P. Eat Smart For Sport. South Africa: Tafelberg Publishers; 2007.
57. Delport E. A comparison of the glycemic index (GI) results obtained from two techniques on a group of mixed subjects. Magister at University of Pretoria. 2006.
58. Jenkins DJA, Mayer A, Jenkins AL, Wolever TMS, Collier GR, Wesson V, et al. Simple and complex carbohydrates; lack of glycemic difference between glucose and glucose polymers. J Clin Nutr Gastroenterol 1987; 2: 113-116.
59. Brand Miller J, Pang E, Broomhead L. The glycaemic index of foods containing sugars: comparison of foods with naturally-occurring v. added sugars. Br J Nutr 1995; 73:613-623.
60. Berger M. Review: the bridge science and patient care in diabetes. Diab 1996; 39:749-57.
61. Brand Miller J, Foster-Powell K. Diets with a low glycaemic index: from theory to practice. Nutr Today 1999; 34(2):64-72.
62. Wursch E, Pi-Sunyer X. The role of viscous soluble fiber in the metabolic control of diabtetes. Diab Care 1997; 20(11):1774-1780.
63. Ha TKK, Lean MEJ. Technical review: recommendations for the nutritional management of patients with diabetes mellitus. Eur J Clin Nutr 1998; 52(7):467-481.

64. Jenkins DJA, Wolever TMS, Taylor RH, Barker HM, Fielden H. Exceptionally low blood glucose response to dried beans: comparison with other carbohydrate foods. Br Med J 1980; 578-580.

65. Jenkins DJA, Wolever TMS, Taylor RH. Rate of digestion of foods and postprandial glycaemia in normal and diabetic subjects. Br Med J 1980; 280:14-17.

ADDENDA 1

QUESTIONNAIRE

Respondent nr:	

GI QUESTIONNAIRE

*Please note: The aim of the questionnaire is to test your **current**, general knowledge on the Glycemic Index and load. Please do not use any text books or other means to assist you with the questionnaire. The questionnaire should take 20 minutes at the very most to complete. Your answers will remain anonymous.*

PART 1

Please mark the appropriate box with an 'X'.

1.1 Specify your area of practice

Hospital	
Private practice	
Community clinic	
Other	

If other, please specify:

1.2 How often do you consult patients with diabetes?

Daily	
Weekly	
Monthly	
Less than once a month	

1.3 At which University did you graduate?

University of Pretoria	
Stellenbosch University	
Cape Town University	

Natal University	
Medunsa	
University of the Free State	
North West University	
University of the North	

What year did you graduate? ___________________________________

1.5 Do you use the Glycemic Index principals in your consultations?

Yes	
No	
Rarely	

1.6 Do you use Glycemic load principals in your consultations?

Yes	
No	
Rarely	

1.7 Where were you taught principals about the glycemic index? (Can tick more than one option)

At University as part of the dietetic degree	
At a workshop / lecture / congress	
From scientific articles	
From books	
Other – specify	

Respondent nr:	

PART 2

Answer only True or False. Tick the appropriate box:

2.1 The GI can be defined as a blood sugar reading. *(1)(2)*

True	
False	X

2.2 A complex carbohydrate (polysaccharide or starch) will have a smaller effect on blood glucose levels than a simple carbohydrate (mono-, di, or oligosaccharides): *(10)*

True	
False	X

2.3 GI testing rests on the principal that if carbohydrates are consumed in amounts that all yield 50 grams of glucose to the body, all these carbohydrates will not have the same effect on blood glucose levels: *(3)*

True	X
False	

2.4 When testing the GI values of food, either or both white bread or glucose can be used as standard food in the same test as they both yield the same GI values: *(12)*

True	

False	X

Respondent nr:	

2.5 Even a very small amount of fat (1 teaspoon) added to a large meal can lower the GI of the meal substantially. *(4)(5)*

True	
False	X

2.6 Protein can cause an insulin response when large amounts are consumed. *(5)(6)*

True	X
False	

2.7 The same amounts of soluble and insoluble fibre can lower the GI of a meal to the same extent. *(7)(8)*

True	
False	X

2.8 Adding 10g (2 teaspoons) of sugar (sucrose) to a low GI meal, will not affect blood glucose levels significantly. *(9)*

True	X
False	

2.9 Recommendations on sugar (sucrose) intake for patients with diabetes should be similar to recommendations on sucrose intake for healthy persons.*(9)(11)(26)*

True	X
False	

Respondent nr:	

2.10 Patients with diabetes can use maltodextrin as a sweetener instead of regular sugar (sucrose). *(13)*

True	
False	X

2.11 Patients with diabetes can use fructose in unlimited amounts as a sweetener instead of regular sugar (sucrose). *(13)(14)*

True	
False	X

2.12 Increasing the acidity of a meal by adding appreciable amounts of vinegar will have no effect on the GI of the meal. *(19)*

True	
False	X

2.13 If two carbohydrate sources with different GI values are incorporated into a meal, the overall glycemic response of the meal will be intermediate in relation to the GI values of the two carbohydrate sources. *(5)*

True	X
False	

2.14 Food processing such as mixing, milling, mashing and grinding do not effect the GI of food. *(24)*

True	
False	X

Respondent nr:	

2.15 A person with diabetes should never have more than 2 tablespoons (30ml) of high GI vegetables (pumpkin, parsnips and turnips). *(13)*

True	
False	X

2.16 To calculate the Glycemic Load (GL) of a food, meal or food product, the GI and energy (kilojoules) of the portion eaten is needed. *(13)(25)*

True	
False	X

2.17 If the first 3 ingredients of a product with 5 ingredients are: Flour, modified starch and maltodextrin, the product will probably have a high GI. *(13)*

True	X
False	

2.18 Tested GI values of commercially produced foods are internationally applicable, and will not differ between countries. *(13)(16)(18)*

True	
False	X

2.19 The GL can be defined as an expression of the glucose load a specific portion will yield. *(13)(25)*

True	X
False	

Respondent nr:	

2.20 A low GI diet can lower cardiovascular risk by improving blood lipid levels. *(20)(21)(22)(23)*

True	X
False	

PART 3

Mark your answer with a 'x' There is only one correct answer per question

3.1 To lower the GI of a meal with **fat**, one must: *(5)(6)*

A. Add 1 gram of fat for every 1 gram of carbohydrate in the meal	X
B. Add 1 teaspoon of fat to the meal	
C. Add 1 teaspoon of mono-unsaturated fat to the meal	
D. Does not have to add fat, as fat cannot lower the GI of a meal	

3.2 To lower the GI of a meal with **protein**, one must: *(6)*

A. Add 1 gram of protein for every 1 gram of carbohydrate in the meal	
B. Add 30 grams of protein for every 50 grams of carbohydrate in the meal	X
C. Add 80 grams of protein for every 20 grams of carbohydrate in the meal	
D. Adding protein cannot lower the GI of a meal	

Respondent nr:	

3.3 Sugar: *(9)(11)(13)*

A. Has an intermediate GI	
B. Can be used by diabetics in controlled portions	
C. Can be used in cakes suitable for those with diabetes as long as the bulk of the ingredients are lower GI	
D. All of the above	X

3.4 The GI of a regular South African white bread is 72 and it contains 20,3 grams of carbohydrates per 44g slice (machine cut). Therefore the GL will be: *(13)*

A. 8	
B. 15	X
C. 20	
D. 26	

3.5 For a weight loss program, the recommended GL for a whole day's meals should be: *(13)*

A. 120-130	
B. 100-120	
C. 80-100	X
D. 50-80	

3.6 For good blood glucose control, in a normal weight, lightly exercising person with diabetes, the GL of a main meal should be no more than: *(13)*

A. 10	
B. 15	
C. 25	X

D. 35	
Respondent nr:	

3.7 For good blood glucose control, in a normal weight, lightly exercising person with diabetes, the GL of a snack should be no more than : *(13)*

A. 5	
B. 10	
C. 15	X
D. 25	

3.8 The following will not affect the GI value of a meal at all: *(5)(6)(15)*

A. Adding appreciable amount of proteins and fat	
B. Milling or grinding the carbohydrate source of the meal	
C. Increasing the amount of soluble fibre of the meal	
D. Consuming large amounts of water with the meal	X

3.9 Long-term low GI diets have shown to: *(20)(21)(22)(23)*

A. Reduce triglicerides	
B. Reduce LDL-cholesterol and total cholesterol	
C. Reduce blood pressure	
D. All of the above	X

3.10 Soluble fibre influences the GI of a meal by: *(15)*

A. Speeding up the transit time of food through the GIT	
B. Improving bowel movements	
C. Increasing absorption of glucose from the gut	
D. Decreasing the rate of absorption of glucose from the gut	X

Respondent nr:	

3.11 The best choice of food to use (within controlled portions according to individual responses) when treating a low blood glucose level (below 4mmol/L) will be: *(13)*

A. Marie Biscuits	X
B. Yoghurt	
C. Fruit	
D. Seed loaf	

3.12 A large Chelsea bun will have a higher GL than a smaller Chelsea bun because: *(13)(25)*

A. The large bun has a higher GI than the small bun	
B. The large bun contains more fat than the small bun	
C. The large bun contains more carbohydrates than the small bun	X
D. The large bun contains more protein than the small bun	

3.13 1 Serving (1/2 cup) of Pumpkin has: *(13)*

A. A high GI and a high GL and should be avoided by diabetics	
B. A high GI and a low GL and can be eaten by diabetics	X
C. A low GI and a high GL and can be eaten by diabetics	
D. None of the above	

3.14 When having a high GI food 15-60 minutes before exercise: *(17)*

A. Blood glucose levels will rise	
B. Insulin levels will rise	
C. Endurance will decrease	

D. All of the above	X
Respondent nr:	

3.15 When having a high GI food during exercise: *(17)*

A. Blood glucose levels will rise	
B. Blood glucose levels will drop	
C. Blood glucose levels will be maintained	X
D. None of the above	

3.16 The GI value of mealiemeal porridge (high GI) can be reduced by cooling down the porridge because: *(12)(13)*

A. The amylose chains of the starch are broken when the porridge is cooled down	
B. The starch becomes less gelatinized when the porridge is cooled down	X
C. People tend to eat smaller portions if the porridge is cooled down	
D. None of the above	

3.17 The GI value of Maltabella porridge can be reduced from a high GI product to a low GI product by: *(5)(13)*

A. Cooking it in milk instead of in water (1 cup porridge : 3 cups milk)	X
B. Adding a table spoon of digestive bran to 1 serving (1 cup) of cooked porridge	
C. Adding 1 teaspoon of bicarbonate of soda to the porridge mixture before cooking it	
D. All of the above	

Thank you for your time.