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# Association of dietary intake with body mass index and glycemic profile among newly diagnosed patients with type 2 diabetes mellitus

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**Abstract**

**Introduction:** Dietary intake plays an important role in determining body mass index (BMI) and glycemic profile in patients with type 2 diabetes mellitus (T2DM). Our aim was to describe habitual dietary intake and its associations with BMI and glycemic profile in a cohort of patients with newly diagnosed T2DM in Sri Lanka.

**Methods:** A cross-sectional study was carried out among 158 patients with newly diagnosed T2DM in Galle, Sri Lanka. Data on demographic, lifestyle, and family history of diabetes mellitus, and clinical measures were collected. The dietary information was collected using a 24-h dietary recall.

**Results:** Among the total number of study subjects, only 12.0%, 5.7% and 1.3% met the recommended daily consumption value of protein, fat, and fiber, respectively, whereas 99.4% of subjects had taken carbohydrates that exceeded the recommended consumption. There was a positive association between carbohydrate intake and BMI (0.004, [0.002], $p = .048$) and carbohydrate intake and glycated hemoglobin ($HbA_{1C}$) (0.001, [0.000], $p = .049$). Fat intake showed positive associations with BMI (0.029, [0.011], $p = .006$) and $HbA_{1C}$ (0.005, [0.002], $p = .050$). Protein intake showed a positive association with $HbA_{1C}$ (0.006, [0.003], $p = .023$). The aforementioned associations were observed after adjusting for demographic, lifestyle, and history of diabetes among the first-degree family members. The carbohydrate intake was positively associated with BMI (0.010, [0.003], $p = .003$) and $HbA_{1C}$ (0.001, [0.000], $p = .050$) with further adjustment in nutrient intake (except when used as an independent variable). Furthermore, the fat intake was associated with BMI (0.031, [0.011], $p = .004$) and $HbA_{1C}$ (0.005 [0.002], $p = .050$) with additional adjustments.

**Conclusions:** The diet of the majority of newly diagnosed T2DM patients in this cohort consisted of a higher carbohydrate intake than the recommended level. However, they did not meet the recommended daily intake of protein, fat, and fiber. Both carbohydrate and fat intake were significantly and positively associated with BMI and $HbA_{1C}$ in patients with newly diagnosed T2DM.

## 1 | INTRODUCTION

Type 2 diabetes mellitus (T2DM) encompasses individuals who have relative insulin deficiency and/or peripheral insulin resistance. The emerging epidemic of diabetes mellitus has become a prominent global health issue (Standl et al., 2019). According to the recent estimates, nearly half a billion people are living with diabetes mellitus around the world. The International Diabetes Federation (IDF) has estimated that 463 million adults (20–79 years) are suffering from diabetes globally in 2019 and this value is projected to reach 700 million by the year 2045 (IDF, 2019). The Southeast Asian region, where the epicenter of the diabetes mellitus plague, represents 87.6 million people with diabetes mellitus. This prevalence is likely to increase to 153 million by the year 2045. The majority of individuals (99.2%) with diabetes mellitus live in middle-income countries of the South East Asian region (IDF, 2019).

Sri Lanka, a middle-income and developing country located in the Southeast Asian region, had a prevalence of diabetes mellitus of 8.7% in adults (20–79 years) in 2019 (IDF, 2019). Among those affected by diabetes mellitus, the highest proportion included T2DM. The likelihood of developing T2DM depends on several lifestyle factors, including dietary intake, physical activity level, smoking, increased viewing time, sitting, etc. (Kolb and Martin, 2017; ADA, 2020). Studies revealed that lifestyle factors could reduce the relative risk of developing diabetes by 40%–70% in the stage of pre-diabetes and thus delay the occurrence of complications of diabetes (Wawro et al., 2020). Food is a central part of our daily existence. It is useful to have knowledge about an individual's dietary intake by inquiring about his/her regular dietary patterns and exploring possible interactions between the main dietary components such as carbohydrates, fat, and protein and their association with the development of diabetes mellitus. In fact, the dietary intake of carbohydrate, lipid, protein, etc. in food is used for generating energy to strengthen biochemical interactions at the cellular and molecular levels (Alberts et al., 2002). Indeed, macro and micronutrients are needed for the proper function of bio-metabolic pathways in the body. Scientific work to understand biochemical pathways and complex interactions associated with nutrients has been accelerated to a greater extent in the present era. This has continued to explore biochemical processes in humans through greatly complex mechanisms of how these nutrients interact with other food-based biomolecules, enzyme complexes, coenzymes, hormones, and genes to allow growth, development, sustainability, and healthy maintenance throughout human life. Assessment of dietary intake has also grown with scientific advances and demonstrated important effects of food and nutrient intake on all organ systems in the prevention and management of major non communicable diseases such as T2DM (Ley et al., 2014). It is imperative to the pay attention to calorie intake to manage proper body weight of individuals. Accordingly, the association between dietary intake and BMI and glycemic profile provides valuable information for healthcare givers to identify healthy and unhealthy diet patterns and to execute optimal strategies in the dietary management of T2DM. Indeed, the management of dietary intake of diabetic subjects is a consideration for preventing/delaying diabetes-associated complications (ADA, 2020).

According to the literature, proper management of dietary macronutrients is associated with a reduction in glycated hemoglobin ($HbA_{1C}$) by 0.3%–2% in patients with T2DM (Franz et al., 2017). This fact implicates the importance of the assessment of dietary intake as an integral part as well as the keystone of self-management of the progression and development of diabetes and its associated complications. Habitual dietary intake is frequently determined using the food frequency questionnaire (FFQ). FFQ has been widely used to evaluate associations between dietary intake and outcomes of interest due to its simple nature for implementation in studies (Shim et al., 2014). Among the habitual dietary composition, the choice of carbohydrate-rich food plays a major role, as it exerts the ability to influence postprandial hyperglycemia (Wee and Henry, 2020). In fact, there is a consensus that the quantity and quality of carbohydrates are the main predictors of the glycemic load which is calculated by multiplying the glycemic index of a food by its carbohydrate content. The glycemic load has been associated with an elevated risk of insulin resistance, coronary heart disease, stroke, and T2DM in large-scale epidemiological investigations around the world (Barclay et al., 2008; Fan et al., 2012). Low glycemic load diet patterns have been shown to improve glycemic control in patients with T2DM (Brand-Miller et al., 2003; Chiavaroli et al., 2021).

The most challenging step in the management of patients with T2DM is determining what to eat and how to eat. In fact, Sri Lanka lacks country-specific and culturally acceptable recommendations and guidelines for dietary intake for patients with T2DM. Very few scientific investigations have been carried out on energy and nutrient intake in patients with T2DM in Sri Lanka (Jayawardena et al., 2012; Medagama et al., 2015). Interventions to maintain optimal body mass index (BMI), glycemic control, and insulin resistance are the cornerstones of the management of T2DM. Several prospective studies carried out in different settings in other countries have reported various associations of dietary intake with BMI and the glycemic state as assessed via $HbA_{1C}$ and fasting plasma glucose (FPG) concentration in patients with T2DM (Lee et al., 2012; Velázquez-López et al., 2016; Matovu et al., 2017). However, data focused on dietary intake and its' associations with BMI and glycemic profile in diabetic patients is still unexplored in Sri Lanka. Therefore, the present study aimed (1) to describe the usual dietary intake; energy, nutrients, and glycemic load, and (2) to evaluate its associations with BMI and glycemic profile of patients with newly diagnosed T2DM in Southern, Sri Lanka.

# 2 | MATERIAL AND METHODS

## 2.1 | Study design

A cross-sectional study was carried out following the quantitative approaches. Patients who attended the University Medical Clinic, Teaching Hospital, Karapitiya, Galle in the Southern province of Sri Lanka were enrolled for the present study. Teaching Hospital, Karapitiya is the largest tertiary care center in the Southern province, of Sri Lanka, and is the main training facility center for the Faculty of Medicine, University of Ruhuna, Sri Lanka. The clinic is managed by physicians and relevant healthcare personnel. The present investigation was conducted between February 2018 and September 2019. Ethical clerance for the study was granted by the Ethics Review Committe, Faculty of Medicine, University of Ruhuna, Sri Lanka. (14.06.2017:3.9).

## 2.2 | Patients

A total number of 158 patients (30–60 years old) with newly diagnosed T2DM, who presented and were referred to the University Medical Clinic, Galle, Sri Lanka were enrolled in the study. All study participants signed informed consent prior to data collection.

## 2.3 | Eligibility

Newly diagnosed T2DM is defined as FPG concentration of 6.99–8.88 mmol/L and/or a percentage of $HbA_{1C}$ of 6.3–7.5%. All the enrolled patients were able to communicate effectively and understand the study design in the proper way. Patients who had a history of mental health disorders, diabetes mellitus, intake of any type of antilipidemic drug, antihypertensive therapy and long-term steroids for chronic disorders, herbal medicines and food supplements, and pregnant women were excluded from the study.

## 2.4 | Sample size

The equation for cross-sectional studies as $n = z^2pq/d^2$, where the confidence limit of 95% and the absolute error or precision of 5% was used to calculate the sample size. Due to the absence of the estimated prevalence of newly diagnosed T2DM cases in hospital settings, in Sri Lanka, a prevalence of 50% was applied. Considering a non-response rate and screen failures, a total number of 507 individuals with newly diagnosed T2DM were screened. Among them, a total number of 158 individuals were enrolled in the present study based on inclusion and exclusion criteria.

## 2.5 | Study instruments

A research utilization questionnaire was administered to collect demographic characteristics, lifestyle habits, family history of diabetes mellitus, etc. Usual dietary intake was captured using the pretested semi-structured 24-h dietary recall questionnaire. Clinical measurements: blood pressure, body mass, height, and biochemical parameters of the glycemic profile were recorded in the study.

## 2.6 | Demographic, lifestyle, and family history of data

According to demographic characteristics, patients were classified as single, married, divorced/separated, and widowed marital status. Categories such as not-schooled, primary education, secondary education, certificate/diploma, graduate, and any other category were considered under the level of education. The employment status was classified into four categories, unemployed, skills, professional, and any other. Monthly income was divided into four categories as <5000, 5000–15 000, 15 000–30 000, and > 30 000 LKR. Three categories of smoking, namely, current smoker, past smoker, and never smoker were considered. Similarly, in the questionnaire, three categories of alcohol intake were used, current drinker, past drinker, and never drinker. A study participant was defined as current smoker or current drinker in case of smoking or drinking alcoholic beverages once a week on average during the last weeks, excluding those who are smoking or drinking alcoholic beverages only during festivals. Answers regarding gestational diabetes in the past and the birth weight of a newborn >3.5 kg were obtained from female study subjects as the past medical history. Diagnosed T2DM in first-degree relatives (mother, father, both parents, siblings, offspring) of study subjects was also recorded. The age of the study participants at which diabetes mellitus is diagnosed was recorded under one of the important facts in the past medical history.

## 2.7 | Anthropometric assessments

The body mass of study subjects was measured in a fasting state with light clothes and without shoes using a portable scale closest to 0.1 kg. The height of the study subjects was measured in a standing position without shoes using a stadiometer nearest 0.1 cm. During the measurement of body height, their shoulders were in an erect position near the wall. The BMI of the study subjects was defined as the body mass divided by height square (kg/$m^2$). Waist circumference (WC) was measured at a level halfway between the lower rib cage and the iliac crest. Blood pressure was monitored as an average of three readings, using a digital blood pressure meter.

## 2.8 | Dietary assessments

All the food items were divided into grains, fast food, meals made with wheat flour, rice and curry, snacks/desserts, beverages, and fruits (common fruits and seasonal fruits). Standard household measures such as plates, spoons of different sizes, cups, and glasses, and food portion sizes on a food atlas were considered in obtaining portion sizes of food from the study participants. When the quantity of food is difficult to measure using habitual portion size, food photographs were used. Additionally, individual food items were used on a medium rice plate as a contextual measure since, in typical Asian countries including Sri Lanka, curries are eaten with rice, not exactly as appetizers or side dishes. The energy and nutrient intake of the food portions was determined collectively using Sri Lankan food composition table (Perera et al., 1979), Indian food composition table (Gopalan et al., 1971), and United States Department of Agriculture (USDA) nutrient database (USDA, 2012). The glycemic load of food was calculated by multiplying the glycemic index of the food item by its intake of carbohydrate content in grams. The glycemic index of the food items was taken from previously published reports (Pirasath et al., 2015; Ekanayake, 2019). The mean/median values of the measures were used in the statistical analysis.

## 2.9 | Blood sampling and biochemical assessments

Study subjects were requested to visit the clinical block, Faculty of Medicine, University of Ruhuna, Sri Lanka, by 8 am after an overnight fasting of 8–10 h. The fasting venous blood samples were collected by a trained phlebotomist. Serum and plasma samples were separated by centrifugation at 2500 rpm for 10 minutes and separated samples were stored at −80°C immediately until they were used in assays. The percentage of $HbA_{1C}$ was determined using the resin exchange method using the Stanbio glycohemoglobin test kit (USA). The concentration of FPG was evaluated following the glucose oxidase method using a spectrophotometric assay kit (Biorex, UK). The serum fasting insulin concentration of the patients was estimated using an enzyme-linked immunosorbent assay kit (DRG, USA). The insulin resistance was calculated using the homeostasis model assessment insulin resistance (HOMA-IR) (Matthews et al., 1985).

## 2.10 | Quality control

Before data collection, all tools were calibrated and pretested. Patients were advised to report their actual dietary intake, as the reported data are the first and foremost facts of the study. The study questionnaires were pretested through several interviews involving participants from a parallel accused group. The interviewer was trained for three days prior to the commencement of the data collection. Pre-testing of questionnaires was carried out to make the required modifications. All the biochemical assessments were quality controlled and performed in duplicates using the same kits.

## 2.11 | Statistical analysis

All data were analyzed using the SPSS 25.0 software version. The normality of the data sets was checked using the Kolmogorov–Smirnov test. Descriptive statistics including mean ± standard deviation (SD), median (range) and percentages (total number) were used to represent the general characteristics of the study subjects in an appropriate way. At the bivariate level, the basic characteristics of females and males were compared using the independent sample t-test or Man–Whitney U test for normal and skewed continuous variables, respectively. Categorical data for both genders were analyzed using the chi-square test or Fisher's exact test. Nutrients intake except for the intake of dietary fiber was reported as the percentage of total energy (% E) whereas dietary fiber intake was represented as g/day in the case of the determination of the percentage of the study participants within the recommended consumption, above the recommended consumption, and below the recommended consumption of nutrients. Records of the ADA were followed to obtain the recommended consumption of nutrients for diabetic patients (ADA, 2020). Associations of dietary intake with BMI and glycemic profile were assessed through multiple linear regression at 95% CI with the adjustment for demographic, lifestyle, and family history data and anthropometric parameters without BMI. Furthermore, multiple regression models were fitted to those components of the dietary intake that were statistically associated with BMI and the glycemic profile parameters with adjustment for more variables. In each case, the primary dependent variable was BMI or one of the glycemic profile parameters; FPG or $HbA_{1C}$, or HOMA-IR. Dietary intake measured by carbohydrates, protein, fat, fiber, and glycemic load was the primary independent variable. The results of the regression models were not expressed in a gender-wise manner as dietary intake did not differ significantly between the two sexes. $p \leq .05$ was considered statistically significant for all cases.

## 3 | RESULTS

A total of 158 newly diagnosed T2DM patients with a mean age of 49 ± 7 years were enrolled for the present investigation. Of the 158 study participants, 96 (60.8%) were females and 62 (39.2%) were males. Table 1 represents the basic characteristics of the entire sample. There were significant associations between gender and residency ($p = .005$), occupation ($p < .001$), smoking ($p < .001$), and alcohol intake ($p < .001$). No significant associations in age, BMI, WC, systolic blood pressure, diastolic blood pressure, marital status, ethnicity, level of education, and monthly income were observed between the genders. Both females and males had a family history of diabetes among the first-degree relatives at 62.50% and 58.06%, respectively, however, the percentages were not statistically significant. There were no significant associations between gender and $HbA_{1C}$ ($p = .743$), FPG ($p = .243$), and insulin resistance quantified by the HOMA-IR index ($p = .710$). The intake of total energy, carbohydrate, protein, fat, fiber and glycemic load did not differ statistically between females and males. As the study population was newly diagnosed with T2DM, the mean age of the study participants at which diabetes mellitus diagnosed was also 49 ± 7 years. The preponderance of the study population showed that the percentage of gestational diabetes in the past was 15.6%, while the percentage of children with a birth weight of >3.5 kg was 37.5%.

The percentages of carbohydrate, protein, fat, and fiber that comprised total energy intake of 82.94, 12.47%, 9.17%, and 3.43%, respectively (Table 2). Among the total number of study subjects, only 12.0%, 5.7%, and 1.3% met the recommended daily consumption of protein, fat and fiber, respectively. Almost all patients (99.4%) had taken carbohydrates that exceeded the recommended consumption. Among the patients, 86.7%, 92.4%, and 98.7% had a lower intake of protein, fat, and fiber respectively than the recommended consumption. The glycemic load of the patients ranged from 66.08 to 539.49 with a median of 282.65. Consumption of red rice/white rice caused a high glycemic load in the entire population (Figure 1).

As represented in Table 3, carbohydrate intake showed a significant association with BMI ($p = .048$) and $HbA_{1C}$ ($p = .049$). There was a significant positive association between protein intake and $HbA_{1C}$ ($p = .023$). A high fat intake was significantly associated with high BMI ($p = .006$) and $HbA_{1C}$ ($p = .050$) in patients with newly diagnosed T2DM. Fiber intake and glycemic load in patients with newly diagnosed T2DM did not show significant associations with BMI and glycemic profile parameters. No significant associations were present between dietary intake and FPG concentration and between dietary intake and HOMA-IR in patients with newly diagnosed T2DM (Table 3).

As shown in Table 4, BMI was increased with an increased intake of carbohydrate ($p = .003$) and fat ($p = .004$) with further adjustment in nutrient intake (except when used as an independent variable). Furthermore, carbohydrate and fat intake were associated with $HbA_{1C}$ ($p = .050$) with additional adjustments. However, protein intake was not associated with $HbA_{1C}$ with further adjustments.

## 4 | DISCUSSION

The prevalence of T2DM in Sri Lanka is increasing rapidly and constitutes a significant public health problem and priority. Four out of 10 Sri Lankan adults are dysglycemic either in the form of pre-diabetes or T2DM (Wasana et al., 2021). An unhealthy diet appears to be one of the main risk factors in this regard. As far as we are aware, this investigation was the first to assess the usual dietary intake and its association with BMI and

**TABLE 1** Basic characteristics

| Parameter | Whole population ($n$ = 158) | Female ($n$ = 96) | Male ($n$ = 62) | $p$-value |
|---|---|---|---|---|
| Age (years) | 48.64 ± 7.06 | 47.90 ± 7.35 | 49.79 ± 6.48 | 0.100 |
| BMI (kg/m$^2$) | 24.2 (16.1–36.4) | 24.2 (18.5–35.9) | 24.6 (16.1–36.4) | 0.884 |
| WC (cm) | 88.0 (71.0–115.0) | 86.5 (71.0–115.0) | 89.0 (73.0–107.0) | 0.428 |
| Blood pressure—systolic (mm Hg) | 122.00 (85.00–178.00) | 121.50 (85.00–178.00) | 122.50 (96.00–172.00) | 0.764 |
| Blood pressure—diastolic (mm Hg) | 80.00 (57.00–105.00) | 80.00 (57.00–102.00) | 80.00 (57.00–105.00) | 0.722 |
| $HbA_{1C}$ (%) | 6.34 (5.44–7.80) | 6.33 (5.44–7.80) | 6.37 (5.51–7.60) | 0.743 |
| FPG (mmol/L) | 7.12 (6.31–9.22) | 7.14 (6.60–9.20) | 7.04 (6.31–9.22) | 0.243 |
| HOMA-IR | 5.57 (0.44–15.10) | 5.57 (0.44–15.10) | 5.91 (0.91–13.79) | 0.710 |
| Marital status (%) | | | | 0.124 |
| Single | 10.13 (16) | 11.46 (11) | 8.06 (5) | |
| Married | 86.71 (137) | 86.46 (83) | 87.10 (54) | |
| Divorced | 1.27 (2) | – | 3.23 (2) | |
| Windowed | 1.90 (3) | 2.08 (2) | 1.61 (1) | |
| Residency | | | | 0.005 |
| Urban | 24.68 (39) | 16.67 (16) | 37.10 (23) | |
| Rural | 75.32 (119) | 83.33 (80) | 62.90 (39) | |
| Ethnicity (%) | | | | 0.392 |
| Sinhalese | 99.37 (157) | 100.00 (96) | 98.39 (61) | |
| Tamil | 0.63 (1) | – | 1.61 (1) | |
| Moors | – | – | – | |
| Education level (%) | | | | 0.172 |
| Not schooled | 0.63 (1) | 1.00 (1) | – | |
| Primary | 8.86 (14) | 11.50 (11) | 4.84 (3) | |
| Secondary | 75.32 (119) | 77.10 (74) | 72.58 (45) | |
| Certificate/Diploma | 11.39 (18) | 8.30 (8) | 16.13 (10) | |
| Graduate | 1.27 (2) | 1.00 (1) | 1.61 (1) | |
| Any other | 2.53 (4) | 1.00 (1) | 4.84 (3) | |
| Occupation (%) | | | | <0.001 |
| Unemployed | 25.32 (40) | 39.60 (38) | 3.20 (2) | |
| Skilled | 24.68 (39) | 19.80 (19) | 32.30 (20) | |
| Professional | 5.70 (9) | 3.10 (3) | 9.70 (6) | |
| Any other | 44.30 (70) | 37.5 (36) | 54.8 (34) | |
| Monthly income (%) | | | | 0.069 |
| < 5000 LKR | 3.80 (6) | 6.30 (6) | – | |
| 5000–15 000 LKR | 12.03 (19) | 13.50 (13) | 9.70 (6) | |
| 15 000–30 000 LKR | 46.84 (74) | 49.00 (47) | 43.50 (27) | |
| > 30 000 LKR | 37.34 (59) | 31.30 (30) | 46.80 (29) | |
| Smoking (%) | | | | <0.001 |
| Current smoker | 5.06 (8) | – | 12.90 (8) | |
| Past smoker | 0.63 (1) | – | 1.60 (1) | |
| Never smoker | 33.54 (53) | 100.00 (96) | 85.5 (53) | |
| Alcohol intake (%) | | | | |
| Current drinker | 16.46 (26) | – | 41.90 (26) | <0.001 |

TABLE 1 (Continued)

| Parameter | Whole population ($n = 158$) | Female ($n = 96$) | Male ($n = 62$) | $p$-value |
|---|---|---|---|---|
| Past drinker | 5.06 (8) | – | 12.90 (8) | |
| Never drinker | 15.82 (25) | 100.00 (96) | 45.20 (25) | |
| Family history of diabetes among the first-degree relatives (%) | 60.76 (96) | 62.50 (60) | 58.06 (36) | 0.508 |
| Glycemic load | 282.65 (66.08–539.49) | 282.65 (81.81–539.49) | 282.65 (66.08–369.57) | 0.891 |
| Energy (kcal/day) | 2720.74 (1283.37–3859.18) | 2737.99 (1669.56–3859.18) | 2678.06 (1283.37–3560.62) | 0.609 |
| Carbohydrate (g/day) | 565.54 ± 92.75 | 568.20 ± 90.72 | 561.42 ± 96.42 | 0.655 |
| protein (g/day) | 85.11 ± 18.31 | 85.79 ± 18.46 | 84.06 ± 18.18 | 0.563 |
| Fat (g/day) | 28.58 (9.09–104.80) | 30.78 (10.22–104.80) | 27.04 (9.09–97.75) | 0.158 |
| Fiber (g/day) | 3.43 (1.61–34.05) | 3.43 (1.61–28.03) | 3.45 (1.86–34.05) | 0.654 |

*Note*: Data are presented as mean ± SD or median (range) or percentage (total number).
Abbreviations: BMI, body mass index; FPG, fasting plasma glucose; $HbA_{1C}$, glycated hemoglobin; HOMA-IR, homeostasis model assessment; WC, waist circumference.

TABLE 2 Dietary intake and overview of patients toward the recommended consumption

| Dietary intake | Intake | Recommended consumption | Within the recommended consumption (%) | Above the recommended consumption (%) | Below the recommended consumption (%) |
|---|---|---|---|---|---|
| Energy (kcal/day) | 2720.74 (1283.37–3859.18) | – | – | – | – |
| Glycemic load | 282.65 (66.08–539.49) | – | – | – | – |
| Carbohydrate (% E) | 82.94 (42.11–134.87) | 44–46 | 0.0 | 99.4 | .6 |
| Protein (% E) | 12.47 (6.84–27.88) | 15–20 | 12.0 | 1.3 | 86.7 |
| Fat (% E) | 9.17 (3.38–50.76) | 20–35 | 5.7 | 1.9 | 92.4 |
| Fiber (g/day) | 3.43 (1.61–34.05) | 20 or above | 1.3 | 0.0 | 98.7 |

*Note*: Records of the ADA were followed to obtain the recommended consumption (ADA, 2020).

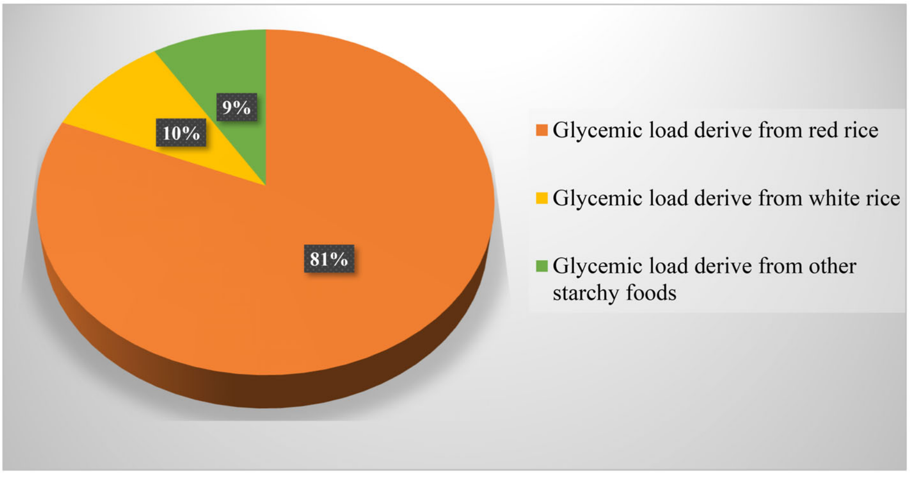


FIGURE 1 Composition of glycemic load in patients having newly diagnosed type 2 diabetes mellitus

**TABLE 3** Variance in average BMI and glycemic profile parameters according to dietary intake

| | β-value (95% CI), p-value | | | | |
|---|---|---|---|---|---|
| | Carbohydrate (g/day) | Protein (g/day) | Fat (g/day) | Fiber (g/day) | Glycemic load |
| BMI (kg/m$^2$) | 0.004 (0.000–0.009), 0.048[a] | 0.014 (−0.008–0.036), 0.207 | 0.029 (0.009–0.050), 0.006[a] | −0.021 (−0.117–0.074), 0.660 | 0.004 (−0.002–0.010), 0.167 |
| FPG (mmol/L) | 7.61 × 10$^{-5}$ (−0.001–0.001), 0.891 | 0.003 (−0.003–0.009), 0.281 | 0.003 (−0.003–0.008), 0.370 | −0.002 (−0.025–0.022), 0.894 | 0.000 (−0.002–0.001), 0.817 |
| HbA$_{1C}$ (%) | 0.001 (0.000–0.002), 0.049[a] | 0.006 (0.001–0.011), 0.023[a] | 0.005 (0.000–0.010), 0.050[a] | 0.008 (−0.014–0.029), 0.482 | 0.000 (−0.001–0.002), 0.683 |
| HOMA-IR | 0.001 (−0.005–0.007), 0.781 | 0.007 (−0.024–0.038), 0.658 | 0.002 (−0.028–0.033), 0.886 | −0.022 (−0.152–0.109), 0.744 | 0.006 (−0.002–0.014), 0.149 |

*Note:* The variance in average BMI for each dietary intake was adjusted for smoking, family history of diabetes, waist circumference, age, marital status, education level, occupation, and income; The variance in average FPG for each dietary intake was adjusted for residency, family history of diabetes; The variance in average HbA$_{1C}$ for each dietary intake was adjusted for residency, waist circumference, marital status, education level, income; The variance in average HOMA-IR for each dietary intake was adjusted for residency, family history of diabetes, marital status, education level, occupation.

Abbreviations: BMI, body mass index; FPG, fasting plasma glucose; HbA$_{1C}$, glycated hemoglobin; HOMA-IR, homeostatic model assessment for insulin resistance.

[a]The statistically significant associations.

glycemic profile of patients with newly diagnosed T2DM in Sri Lanka. Furthermore, this study reported the information on the dietary intake of newly diagnosed T2DM patients toward the recommended amount of the main dietary components, namely carbohydrates, proteins, fats and fiber. The findings of the present study significantly highlighted that the intake of carbohydrate and fat was positively associated with BMI and HbA$_{1C}$ % in patients with newly diagnosed T2DM.

As all members of a family consume similar food items, no significant differences in overall dietary intake were observed between male and female subjects in the present study. This observation was consistent with the previous study which was carried out among patients with T2DM in Sri Lanka (Medagama et al., 2015). Here, it was reported to have the highest daily energy contribution from carbohydrates (82.94%) followed by protein (12.47%), fat (9.17%), and fiber (3.43%) among patients with newly diagnosed T2DM. In general, the proportion of energy intake from carbohydrates is high among Asians while low among those who live in Western countries. According to estimates from the US National Health and Nutrition Examination Survey, the Diabetic Educational Eating Plan Study, and the Strong Heart Study among American Indians, carbohydrates contributed 48–49% to daily energy intake (Ma et al., 2006; Eilat-Adar et al., 2008). Previously conducted studies in Sri Lanka had also revealed that the energy contribution of carbohydrates was 68% among T2DM patients and 71.2% among Sri Lankan adults (Jayawardena et al., 2014; Medagama et al., 2015). A diet survey conducted among Japanese patients with T2DM revealed that the daily energy contribution of carbohydrates was 52.3% (Yamakawa et al., 2019).

Furthermore, in the present study, it was observed that almost all newly diagnosed patients with T2DM (99.4%) had taken more carbohydrates than the recommended consumption. In contrast, the percentages of patients who had protein (86.7%), fat (92.4%), and fiber (98.7%) intake were below the daily recommendations. This could be rationalized by the fact that the Sri Lankan diet includes rice as the staple food for breakfast, lunch, and dinner and is accompanied by small or infrequent portions of food with animal and plant proteins, vegetables, and fruits. In addition, Asians prefer to consume rice-based meals, because of the ease of preparation, low cost, and high satiety. In fact, unfortunate to report that a high percentage of patients in this study had a daily protein intake below the recommended value, although Sri Lanka is an island, with the availability of protein-rich marine fish species. The high cost associated with animal protein food might contribute to the decreased intake of protein-rich foods, which is further

TABLE 4 Variance in average BMI and $HbA_{1C}$ according to dietary intake

| | | Dietary intake | $\beta$-value (95% CI), p value |
|---|---|---|---|
| BMI (kg/m$^2$) | Model 1 | Carbohydrate (g/day) | 0.010 (0.003–0.016), 0.003[a] |
| | Model 2 | Fat (g/day) | 0.031 (0.010–0.052), 0.004[a] |
| $HbA_{1C}$ (%) | Model 3 | Carbohydrate (g/day) | 0.001 (0.000–0.002), 0.050[a] |
| | Model 4 | Protein (g/day) | 0.003 (−0.004–0.009), 0.405 |
| | Model 5 | Fat (g/day) | 0.005 (0.000–0.010), 0.050[a] |

Abbreviations: BMI, body mass index; $HbA_{1C}$, glycated hemoglobin.
*Note*: Model 1: Adjusted for smoking, family history of diabetes, age, marital status, occupation, fat intake. Model 2: Adjusted for smoking, family history of diabetes, waist circumference, age, marital status, education, income, occupation, fiber intake. Model 3: Adjusted for waist circumference, marital status, residency, fiber intake. Model 4: Adjusted for residency, waist circumference, marital status, education, income, energy, fat intake. Model 5: Adjusted for residency, waist circumference, marital status, education level, income, glycemic load.
[a]The statistically significant associations after further adjustments.

corroborated by the middle-income economic status of most of the people in the country. High carbohydrate intake, supported by a high percentage of rice-derived glycemic load (91%). Although 49.59% of patients with T2DM were above the recommended carbohydrate intake in Sri Lanka in 2014 (Medagama et al., 2015), the results of the present study revealed that 99.4% of newly diagnosed patients with T2DM were above the recommended carbohydrate intake. This fact highlights the development of urgent dietary recommendations and paying attention to dietary intake in the prevention and treatment of diabetes.

According to the findings of the present study, both BMI and $HbA_{1C}$ were associated with carbohydrate intake. This fact has been well reported in most of the investigations carried out among the diabetic population (Haimoto et al., 2009; Matovu et al., 2017; Haimoto et al., 2018; Yamakawa et al., 2019). Increasing evidence suggests that carbohydrate is the most important determinant of postprandial blood glucose levels. Carbohydrate comprises starch, sugar, and fiber. Soluble fiber is reported to improve glycemic control by slowing the release and absorption process of macronutrients due to increased intraluminal viscosity in the gastrointestinal tract (Grundy et al., 2016; Goff et al., 2018). However, the results of the present study did not show significant associations of dietary fiber with the glycemic profile, and apparently, 98.7% of newly diagnosed T2DM patients have taken dietary fiber below the recommended consumption. Therefore, this fact suggests that high $HbA_{1C}$ is associated with the intake of non-fiber carbohydrates in the present study group. This finding was in line with previously carried out study, involving T2DM patients in Japan (Yamakawa et al., 2019). It is important to replace carbohydrate-rich foods with food common in Mediterranean-pattern of diets; non-starchy vegetables, fruits, olive oil, grains, etc. to maintain a healthy low carbohydrate diet. It is well documented that low-carbohydrate intake, especially derived from fruits and grains, leads to an improvement in antioxidant status in patients with T2DM and thus slows protein glycation, reduces the production of advanced glycated end products, and thereby reduces the cellular oxidative stress and inflammation. This cascade of events would result in good glycemic control that is reflected in a satisfactory controlled level of fructosamine and percentage of $HbA_{1C}$ (Haimoto et al., 2009). A meta-analysis revealed that carbohydrate restrictions corresponded to a significant reduction in $HbA_{1C}$ in patients with T2DM (Snorgaard et al., 2017). The present study revealed that low BMI is associated with reduced carbohydrate intake. In contrast, a study conducted in Korea has reported that no association was found between carbohydrate intake and BMI (Kim et al., 2012). Additionally, the present study revealed a significant association between fat intake and BMI. The study conducted in Kampala, Uganda, has reported significant associations of BMI with carbohydrate and protein intake in patients with newly diagnosed T2DM (Matovu et al., 2017). According to the results of our study, there was no association between protein intake and BMI. A trend toward recommending low carbohydrate intake is recognized to free oneself from high BMI. High carbohydrate intake leads to developing increased insulin resistance. Recent findings suggest that the increase in insulin level may pay the way to high BMI, rather than the contrary (Wheatley et al., 2021).

High protein intake was associated with increased $HbA_{1C}$ with the potential confounding variables; residency, waist circumference, marital status, education level, and income, entered into the multiple regression model. However, with further adjustment for total energy intake and fat intake, there was no association between protein intake and $HbA_{1C}$. On the other hand, several studies are available on biological insights into the reciprocal association between dietary protein intake and $HbA_{1C}$ in diabetic patients (Dong et al., 2013; Skytte et al., 2019).

Generally, the Asian diabetic population has a low fat intake (Medagama et al., 2015). In our study, the median daily fat intake was 28.58 g and contributed only 9.17% to the total energy intake. Furthermore, fat intake among the newly diagnosed T2DM patients was positively associated with BMI and $HbA_{1C}$ by the adjustment for all the potential confounding variables. Increased fat intake is an important contributor to positive energy balance because more energy is provided by fat than by carbohydrates and protein. Indeed, increased fat intake contributes significantly to elevated energy intake and body adiposity (Thanopoulou et al., 2003; Guasch-Ferré et al., 2017; Wang et al., 2020). In addition, the intake of a high-fat diet caused impaired glucose utilization, which also increases the availability of free fatty acids through the Randle glucose fatty acid cycle (Randle et al., 1988). Accordingly, the underlying effects described above might cause a positive association between dietary fat intake and BMI in the present study group. In contrast to our study findings, a study conducted among newly diagnosed T2DM patients in Kampala found that fat intake is not associated with BMI (Matovu et al., 2017). Furthermore, increased dietary fat might induce hyperinsulinemia accompanied by insulin resistance altering the insulin-protein kinase B signaling pathway and reducing phosphorylation or activation of adenosine monophosphate-activated protein kinase leading to persistent hyperglycemia in patients with T2DM (Shiwa et al., 2015). Our findings support the fact that dietary fat intake is significantly associated with the $HbA_{1C}$ of diabetic study subjects.

It is a key point that dietary intake was not associated with parameters of the glycemic profile parameters; FPG concentration and insulin resistance were quantified by the HOMA-IR index in patients with newly diagnosed T2DM. FPG concentration is less sensitive and nonspecific than the gold standard test of $HbA_{1C}$ to assess overall glycemic control (Ketema & Kibret, 2015). The HOMA-IR model underlines the lack of linearity in the deepening of insulin resistance (Gilmore, 1999). In fact, previous studies have proposed that HOMA-IR is not a good predictor of insulin resistance in the older male population with impaired glucose tolerance and in men and women with diabetes, compared to the gold standard; euglycemic clamp method (Ferrara and Goldberg, 2001; Katsuki et al., 2002). The study population may have varying insulin resistance phenotypes and therefore the calculated HOMA-IR index may not fully reflect the in vivo environment that reflects the full picture of the pathogenesis of T2DM (Diamanti-Kandarakis et al., 2004). Collectively, all the facts might affect non-significant associations of dietary intake with FPG and HOMA-IR.

BMI is a convenient measure of excess tissue mass of bone, fat, and muscle per height rather than a direct measure of fat mass. In addition, the value of BMI is greatly influenced by age, sex, and ethnicity in addition to muscle mass. It is worth mentioning the fact that the association between BMI and the percentage of body fat may not be unique among different ethnic groups and particularly in population groups of Asians (Deurenberg et al., 2002). Indeed BMI has limitations in predicting the percentage of body fat to a greater extent in Asian populations. The percentage of body fat is a strong predictor for assessing cardiovascular risks and interestingly the percentage of fat was elevated at low BMI values (Deurenberg-Yap et al., 2002). BMI does not differentiate the significance between fat and muscle mass and does not trap information on body fat distribution and cardiorespiratory fitness. Therefore, the consideration of high BMI as a dominant and predictive risk factor for the development of T2DM and its cardiovascular mortality is debatable (Han and Boyko, 2018). In fact, a high percentage of body fat is related to increased mortality and morbidity in patients with T2DM. In the present study, the BMI of the patients with newly diagnosed T2DM lay close to the healthy range, and the diagnosis of diabetes was apparent at a low level of BMI. This fact provides a shred of evidence of the necessity for lowering the BMI cut-off value for overweight and obesity among Asians, as suggested in previous reports (Deurenberg-Yap et al., 2002). This is in line with the fact that it represents an increased relative risk for chronic metabolic diseases such as T2DM and cardiovascular diseases at lower BMI levels in the Asian population (Deurenberg-Yap et al., 2000).

There are many strengths of this study. The present study provides the first solid research evidence in Sri Lanka through casual dietary intake and its associations with BMI and glycemic profile in patients with newly diagnosed T2DM. The measured biochemical parameters; serum insulin level, insulin resistance, FPG concentration, and $HbA_{1C}$ had not affected by lifestyle modifications and pharmacological agents since the enrolled study subjects were newly diagnosed T2DM. Therefore, it was able to assess the actual association between dietary intake and glycemic profile in the present study. Furthermore, analyzing dietary intake in newly diagnosed T2DM patients is imperative since dietary modifications prominently affect their glycemic control in the management. Other strengths include a standard protocol for body measurements and stringent quality control in laboratory analysis. There are some limitations that need to be mentioned. Firstly, we cannot formally draw conclusions about causality, and indeed, no association could be established on cause-and-effect relationships since we conducted a cross-sectional study. However, more prospective studies are warranted to understand the causal relationships between dietary intake with glycemic status and BMI. Secondly, 24-h dietary recalls inherit some limitations, such as recall bias, interviewer bias, and selection bias. Thirdly, although we have adjusted for confounders that are related to the risk of T2DM, the influence of uncontrolled confounders on our observed results cannot be ruled out. Finally, the study population consisted of newly diagnosed patients with T2DM in Galle, Southern, Sri Lanka, and the findings of the present study cannot be generalized to the entire Sri Lankan population. A national level, multicenter similar studies representing the whole Sri Lankan population are highly warranted in near future.

## 5 | CONCLUSIONS

The diet of newly diagnosed patients with T2DM consisted of a notable high carbohydrate intake well above the recommended level. Carbohydrate and fat intake were significantly and positively associated with both BMI and $HbA_{1C}$ in patients with newly diagnosed T2DM after adjusting demographic, lifestyle, history of diabetes among the first-degree family members, and nutrient intake (except when used as an independent variable). Understanding the dietary intake that improves BMI and glycemic control would help health-care professionals to identify the main determinants in the management of diabetes alongside pharmacological treatments. There is an urgent necessity of implementing dietary approaches in this regard through comprehensive nutrition education during clinical care, particularly for newly diagnosed patients with T2DM.

## AUTHOR CONTRIBUTIONS

Keddagoda Gamage Piyumi Wasana, Anoja Priyadarshani Attanayake, and Thilak Priyantha Weerarathna designed the study. Keddagoda Gamage Piyumi Wasana performed all laboratory work and statistical analysis, and drafted the manuscript. Devpura Arachchige Bandumalee Nimalshanthi Amarasekera contributed to the statistical data analysis. Anoja PriyadarshaniAttanayake, Thilak Priyantha Weerarathna, Kamani Ayoma Perera Wijewardana Jayatilaka, and Devpura Arachchige Bandumalee Nimalshanthi Amarasekera critically reviewed and edited the manuscript. Anoja Priyadarshani Attanayake and Thilak Priyantha Weerarathna supervised the study with the intellectual aid of Kamani Ayoma Perera Wijewardana Jayatilaka.

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## CONFLICT OF INTEREST STATEMENT

All authors declare that they have no competing interests.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in RESEARCH DATA REPOSITORY at http://www.medi.ruh.ac.lk/biochemistry/.

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