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# Prevalence of and factors associated with suboptimal glycemic control among patients with type 2 diabetes mellitus attending public hospitals in the Greater Male' Region, Maldives: a hospital-based cross-sectional study

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## Abstract

**Background** Suboptimal glycemic control of type 2 diabetes mellitus (T2DM) which is defined as having HbA1c greater than 7% is a major public health problem in several countries, including the Maldives. The study aimed to estimate the prevalence and determine factors associated with suboptimal glycemic control among T2DM patients.

**Methods** A hospital-based cross-sectional was applied to collect data from T2DM patients who attended public hospitals in the Greater Male' Region, Maldives where were one of the highest reports of T2DM and suboptimal glycemic control cases in the country between January to March 2023 by a validated questionnaire and anthropometric measurements. Five (5) ml blood specimens were collected to measure the glycated hemoglobin (HbA1c) level. Univariable and multivariable logistic regressions were employed to determine factors associated with suboptimal glycemic control of T2DM at a significant level of  $\alpha=0.05$ .

**Results** A total of 341 participants were recruited for the study: 65.7% were female, 42.5% were aged 40–60 years, and 42.2% were married. The overall prevalence of suboptimal glycemic control was 50.7%. Ten variables were found to be associated with suboptimal glycemic control in multivariable logistic regression. Those aged 40–60 years (AOR = 3.35, 95% CI = 1.78–6.30), being single (AOR = 2.53, 95% CI = 1.21–5.30), preparation of food using more than three tablespoons of cooking oil (AOR = 2.78, 95% CI = 1.46–5.28), preparation of food with more than three tablespoons of sugar (AOR = 2.55, 95% CI = 1.31–4.93), no exercise (AOR = 2.04, 95% CI = 1.15–3.61), DM diagnosed with more than twenty years prior (AOR = 2.59, 95% CI = 1.34–4.99), obese body mass index (BMI) (AOR = 3.82, 95% CI = 1.75–8.32), high total cholesterol (AOR = 2.43, 95% CI = 1.36–4.35), high triglycerides (AOR = 3.43, 95% CI = 1.93–

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6.11), and high-level stress (AOR = 2.97, 95% CI = 1.48–5.93) were having a greater odds of having suboptimal glycemic control than those who did not have these characteristics.

**Conclusion** A large proportion of T2DM patients in the Greater Male' Region fail to control their blood glucose. Effective public health interventions should be introduced, especially interventions focused on reducing cooking oil and sugar in daily cooking practices, encouraging regular exercise, and maintaining cholesterol levels, particularly for those diagnosed with diabetes mellitus for more than 20 years prior.

**Keywords** Diabetes mellitus, Suboptimal glycemic control, Factor associated, Maldives

## Introduction

Diabetes mellitus (DM) is a serious public health concern in low and middle-income countries, especially in type 2 diabetes mellitus (T2DM) patients with suboptimal glycemic control [1], which is defined as  $HbA1c \geq 7\%$  [2]. According to the World Health Organization (WHO), T2DM affected 422 million people worldwide, causing 1.5 million deaths annually [3], and an extra 3 million T2DM deaths occurred due to suboptimal glycemic control in 2019 [1]. Aside from T2DM deaths, uncontrolled long-term hyperglycemia can result in the development of macrovascular and microvascular complications, like diabetic nephropathy, neuropathy, cardiovascular disease, and lower limb amputation [1]. It also significantly burdens public health and socioeconomic development in all countries, which requires substantial financial resources for treatment and care, particularly in low-income countries where screening, diagnosis, and treatment are limited [4–7], including the Maldives. Its complications can diminish patients and their family's quality of life [4, 5].

In the same vein, the country is experiencing a rapid increase in non-communicable diseases (NCDs) due to economic development and globalization. The Maldivians have transitioned from an active lifestyle to a sedentary one, consuming processed foods, high-calorie foods, saturated fats, and sugar. Additionally, most of the Maldivian islands are small and many residents depend on motorbikes rather than walking or cycling, particularly in the Greater Male' Region. This has increased NCDs, and the primary cause of morbidity and mortality in the country is accounting for up to 81.0% of all deaths [8]. Poor dietary habits, a higher body mass index (BMI), and elevated blood pressure were found to be the top five risk factors for T2DM with other NCD burdens in the country [9]. The availability and promotion of unhealthy foods increase T2DM prevalence [10], with a 6.7% prevalence among people aged 20–79 years [11]. In 2020, 23 DM deaths were attributed in the country, and the disease ranked as the sixth leading cause of NCD-related deaths [12]. Many T2DM patients are diagnosed and treated, but their ability to control their blood sugar level is often very poor [13].

Year by year, the number of T2DM cases is increasing in the country. According to the National Diabetes Center (NDC) at Indira Gandhi Memorial Hospital (IGMH), a total of 1,733 T2DM patients were registered in the NDC between October 2020 and December 2022, with 293 suboptimal glycemic control cases were attended in January 2023 [14]. This was an alarming figure for being a small, populated country. Since there is little or no information regarding suboptimal glycemic control among T2DM patients. Therefore, the study aimed to estimate the prevalence and to determine factors associated with suboptimal glycemic control among T2DM patients attending public hospitals in the Greater Male' Region, Maldives.

## Methods

### Study design and study setting

A hospital-based cross-sectional study was employed to collect data from T2DM patients attending public hospitals in the Greater Male' Region of the Maldives, including IGMH, Hulhumale' Hospital, Vilimale' Hospital, and Senahiya Hospital.

### Study population and eligible population

Patients with T2DM who attended four selected public hospitals were enrolled in the study population. Those who had been diagnosed with T2DM for at least two years and who attended the IGMH National Diabetic Centre, as well as T2DM patients who attended other public hospitals (Hulhumale Hospital, Villimale Hospital, and Senahiya Hospital) between 24th January and 18th March 2023, met the inclusion criteria. However, those unable to provide the necessary information and pregnant women were excluded from the study.

### Sample size

The sample size of this study was determined using the standard formula for a cross-sectional design [15];  $n = [Z^2_{\alpha/2} P (1-P)] / d^2$ , where the Z = value from the standard normal distribution corresponded to the desired confidence level (Z = 1.96 for 95% CI), P = the expected true proportion (P = 0.72) [16], and d = precision (d = 0.05); after adding 10% for non-response and any other error in

the study, 341 participants were used as the final sample size for analysis.

### Research instruments

The researcher developed a questionnaire that was used to collect data. It entailed four parts. Part I, eight questions were used to collect sociodemographic information, such as age, gender, level of education, marital status, occupation, monthly income, and living status. Part II, twenty-four questions were used to collect information regarding diabetic self-care factors, such as self-monitoring blood glucose, regular follow-up visits, cigarette smoking, alcohol consumption, food consumption behavior, adherence to exercise, and knowledge about DM prevention and care. In this section, under knowledge about DM prevention and care, ten questions were asked to assess the three levels of knowledge. Part III, consisted of seven clinically relevant questions, i.e., duration of diabetes, hypertension, family history of DM, BMI or obesity, waist-to-hip ratio, lipid profile levels, and stress. The anthropometric measurements (such as height, weight, BMI, waist, and hip circumference), blood pressure, as well as a lipid profile were collected in this part. A three mL blood sample was drawn to determine HbA1c level, and a five mL blood sample for lipid profile tests, including total cholesterol, triglycerides, HDL-C, and LDL-C. Under stress, five questions from the stress test (ST-5) [17], were used to determine the stress level. In the last part, questions included the types of antidiabetic medication taken as well as the behavior of taking medication.

### Validated questionnaire

The validity and reliability of the questionnaire were assessed using various methods. The item-objective congruence (IOC) technique [18] was used to assess the validity of the questionnaire. Using this method, three experts evaluated the congruence between each question in terms of how well those questions reflect the content and objectives of the study. Each expert provided a score for each item: “1” means that the question is relevant to the content and objectives of the study, which means that the question does not require any improvement. “0” means that the question is relevant to the content and objectives of the study but needs to be improved before use in the study. “-1” means that the question does not reflect the content and objectives of the study and requires improvement before use. Before interpretation, the average scores were calculated by adding and dividing the scores of three experts. If the average score for the question was less than 0.5, it was eliminated from the final questionnaire. If the questions with scores between 0.5 and 0.7 were to be included in the final questionnaire, they needed to be improved before use. Questions with

a score of 0.70 or above were considered for inclusion in the final questionnaire.

Before using the questionnaire in the field, all the questions were tested for reliability with 30 people whose characteristics were similar to those of the study subjects. The pilot testing was conducted on T2DM patients who attended the NDC at IGMH in Male', Maldives. During this process, the feasibility, proper words or sentences, and order of the questions were assessed. The questionnaire's knowledge-related questions were subjected to a reliability test (Cronbach's alpha) with a result of 0.86.

### Measures

Body mass index (BMI) is classified based on the WHO Asian BMI classification standard. BMI is calculated using the formula: a person's weight in kilograms divided by a height in meters squared ( $\text{kg}/\text{m}^2$ ). It is divided into five categories: underweight ( $<18.5 \text{ kg}/\text{m}^2$ ), normal weight ( $18.5\text{--}22.9 \text{ kg}/\text{m}^2$ ), overweight ( $23.3\text{--}24.9 \text{ kg}/\text{m}^2$ ), obese I ( $25\text{--}29.9 \text{ kg}/\text{m}^2$ ), and obese II ( $\geq 30 \text{ kg}/\text{m}^2$ ) [19]. A waist-to-hip ratio (WHR)  $\geq 94.0$  centimeters for males and  $\geq 80.0$  centimeters for females was classified as an unhealthy waist-to-hip ratio [20]. WHR was calculated as waist circumference in centimeters divided by hip circumference in centimeters. Patients with a systolic blood pressure of  $\geq 140$  mmHg and/or diastolic blood pressure of  $\geq 90$  mmHg, or who use antihypertensive medication regardless of their current blood pressure, were classified as hypertensive [21].

To measure the level of stress among participants, the ST-5 was used, and stress was classified into three categories: low ( $\leq 4$  scores), moderate (5–7 scores), and high ( $\geq 8$  scores) [17]. Glycated hemoglobin (HbA1c) levels were classified according to the American Diabetes Association standard, with an HbA1c level of  $>7.0\%$  defining suboptimal glycemic control [2]. Abnormal lipid profiles were defined as total cholesterol (TC) levels  $>200.0 \text{ mg}/\text{dL}$  [22]. High-density lipoprotein cholesterol (HDL-C) was divided into two main groups based on WHO recommendations: low ( $<40.0 \text{ mg}/\text{dL}$ ) and normal ( $\geq 40.0 \text{ mg}/\text{dL}$ ) [20], HDL-C abnormal levels for men ( $<40.0 \text{ mg}/\text{dL}$ ) and women ( $<50.0 \text{ mg}/\text{dL}$ ) [20]. Low-density lipoprotein cholesterol was classified by WHO recommendations. They are classified into two main groups: normal ( $<100.0 \text{ mg}/\text{dL}$ ) and high ( $\geq 130.0 \text{ mg}/\text{dL}$ ) [20]. The triglyceride levels were divided into two groups, which were based on WHO guidelines, which included: optimal ( $<150 \text{ mg}/\text{dL}$ ) and high ( $\geq 150 \text{ mg}/\text{dL}$ ) [22].

### Data gathering procedures

The IGMH and the other three designated public hospital directors and chiefs were contacted, an appointment was made, and a brief meeting was held to explain the research objectives and data collection procedures. All

T2DM patients who attended the clinic on the day of data collection were invited to participate in the study voluntarily. Those who agreed to participate the study were informed about the study objectives, the data collection and blood sample-taking procedures. Before the beginning of the study, participants were informed and asked to sign a written consent form. Then, the participant's height, weight, and waist circumference were measured as part of the physical examination. Blood pressure was assessed using the Omron Automatic Inflation Blood Pressure Monitor. Qualified and experienced nurses assessed anthropometric measurements (such as height, weight, and waist circumference) and blood pressure. Next, participants were asked to fill out the questionnaire or self-administered to complete the questionnaire. Participants who could not sign the written consent form were asked to use their fingerprints. The researcher helped them complete the questionnaire for those who couldn't fill it out by themselves. As part of gathering information from the study subjects, blood specimens were collected from those who hadn't done the recommended blood tests one week before the date of data collection. In these blood specimen tests, patients were asked to fast (nothing to eat or drink) for at least 12 h to determine clinical laboratory tests such as HbA1c, and lipid profiles. Blood samples were obtained after fasting was completed. A medical technician who has a valid license drew blood samples from each participant. All blood specimens were sent to the same hospital medical laboratory on the same day for analysis.

### Statistical analysis

The data were entered into an Excel sheet, coded, cleaned, managed, and then exported into the SPSS IBM SPSS Statistics software, version 20.0 (SPSS, Chicago, IL) for analysis. Descriptive statistics were used to describe the general characteristics of the participants. While percentages were used to describe categorical data, continuous data were described using the mean and standard deviation (SD) for a normal distribution and the median and interquartile range (IQR) for a skewed distribution. The Chi-square was used to determine whether there was any statistically significant association between independent variables and the outcome variable. Logistic regression was applied to find the risk factors for suboptimal glycemic control at a significance level of  $\alpha=0.05$ . The "stepwise method" method was used as a selection variable in the model. In all phases, the Cox-Snell  $R^2$ , Nagelkerke  $R^2$ , and Hosmer-Lemshow were employed to assess the fit of the model. The variables shown to be significant in the univariable logistic model must be included in the multivariable model. The final estimation models were interpreted after fitting all significant variables in the model.

## Results

### General characteristics of the participants

A total of 341 T2DM patients were enrolled from 4 public hospitals: 200 T2DM cases (58.7%) from Indira Gandhi Memorial Hospital, 56 cases (16.4%) from Hulhumale' Hospital, 55 cases (16.1%) from Villimale Hospital, and 30 T2DM cases (8.8%) from Senahiya Hospital. Of these, 173 had suboptimal glycemic control (50.7%), and 168 had controlled blood glucose (49.3%).

More than half of the participants, 65.7% were female, 42.5% were aged 40–60 years, 44.3% had attained informal education, and 42.2% were married. Nearly half (49.6%) were unemployed, 50.2% did not receive a monthly income, and 26.4% received less than 10,000 MVR per month. Slightly more than one-third (44.0%) had more than five members in their family, and 47.8% stayed with a spouse. In the alcohol use concern, 341 (100.00%) participants (Table 1).

Four (4) variables were detected in general characteristics, with statistically significant differences between suboptimal glycemic control group and controlled blood glucose groups: age ( $p$ -value=0.016), education ( $p$ -value=0.002), marital status ( $p$ -value=0.031), and occupation ( $p$ -value=0.031) (Table 1).

### Prevalence of suboptimal glycemic control

The overall prevalence of suboptimal glycemic control was 50.7% (50.5% in females and 51.3% in males). The age group 40–60 had the highest prevalence of suboptimal glycemic control (58.6%) (Table 1).

Three variables were found to be associated with suboptimal glycemic control in the univariable analysis in the dimension of socio-demographic characteristics: age, education, and marital status (Table 2).

However, two variables were found to be associated with suboptimal glycemic control in multivariable logistic regression. Participants aged 40–60 years were 3.35 times (95% CI=1.78–6.30) greater risk of having suboptimal glycemic control, respectively than those aged below 40 and above 60 years. Unmarried participants had 2.53 times (95% CI=1.21–5.30) greater odds of getting suboptimal glycemic control than those who were married and ever married (Table 2).

Twelve variables were found to be associated with suboptimal glycemic control in the univariable analysis in the dimension of self-care: method of blood glucose checking, frequency of checking blood glucose, missed DM appointments, number of cigarettes smoked per day, number of meals had daily, food prepared with cooking oil, food prepared with sugar, coconut milk-prepared food consumed on every week, eating sugary foods daily, drinking tea with sugar, juice, and exercise (Table 3).

Three variables were found to be associated with suboptimal glycemic control in multivariable logistic

**Table 1** General characteristics of participants

| Characteristics  | Total      |              | Suboptimal glycemic control |             |            |             | $\chi^2$   | p-value    |
|--|------------|--------------|-----------------------------|-------------|------------|-------------|------------|------------|
|  | n          | %            | Yes                         |             | No         |             |            |            |
|  | n          | %            | n                           | %           | n          | %           |            |            |
| <b>Total</b>   | <b>341</b> | <b>100.0</b> | <b>173</b>                  | <b>50.7</b> | <b>168</b> | <b>49.3</b> | <b>N/A</b> | <b>A/A</b> |
| <b>Sex</b>   |            |              |                             |             |            |             |            |            |
| Female   | 224        | 65.7         | 113                         | 50.5        | 111        | 49.6        | 0.02       | 0.884      |
| Male   | 117        | 34.3         | 60                          | 51.3        | 57         | 48.7        |            |            |
| <b>Age (years)</b>   |            |              |                             |             |            |             |            |            |
| ≤40  | 137        | 40.2         | 57                          | 41.6        | 80         | 58.4        | 8.25       | 0.016*     |
| 40–60  | 145        | 42.5         | 85                          | 58.6        | 60         | 41.4        |            |            |
| ≥60  | 59         | 17.30        | 31                          | 52.5        | 28         | 47.5        |            |            |
| <i>Min = 25, Max = 79, Mean = 55, and SD = 11.5</i>                |            |              |                             |             |            |             |            |            |
| <b>Education</b>   |            |              |                             |             |            |             |            |            |
| No schooling   | 151        | 44.3         | 77                          | 51.0        | 74         | 49.0        | 15.34      | 0.002*     |
| Primary school   | 92         | 27.0         | 33                          | 35.9        | 59         | 64.1        |            |            |
| Secondary school   | 50         | 14.7         | 32                          | 64.0        | 18         | 36.0        |            |            |
| Tertiary school  | 48         | 14.1         | 31                          | 64.6        | 17         | 35.4        |            |            |
| <b>Marital status</b>  |            |              |                             |             |            |             |            |            |
| Single   | 89         | 26.1         | 44                          | 49.4        | 45         | 50.6        | 6.94       | 0.031*     |
| Married  | 144        | 42.2         | 84                          | 58.3        | 60         | 41.7        |            |            |
| Ever married   | 108        | 31.7         | 45                          | 41.7        | 63         | 58.3        |            |            |
| <b>Occupation</b>  |            |              |                             |             |            |             |            |            |
| Unemployed   | 169        | 49.6         | 74                          | 43.8        | 95         | 56.2        | 8.90       | 0.031*     |
| Government employee  | 92         | 27.0         | 49                          | 53.3        | 43         | 46.7        |            |            |
| Private sector employee  | 61         | 17.9         | 40                          | 65.6        | 21         | 34.4        |            |            |
| Self-employed  | 19         | 5.6          | 10                          | 52.6        | 9          | 47.4        |            |            |
| <b>Monthly income (MVR)</b>  |            |              |                             |             |            |             |            |            |
| No income  | 171        | 50.2         | 77                          | 45.0        | 94         | 55.0        | 4.65       | 0.199      |
| ≤ 10,000   | 90         | 26.4         | 52                          | 57.8        | 38         | 42.2        |            |            |
| 10,001–20,000  | 61         | 17.9         | 34                          | 55.7        | 27         | 44.3        |            |            |
| ≥ 20,001   | 19         | 5.6          | 10                          | 52.6        | 9          | 47.4        |            |            |
| <i>Min = 1,000, Max = 50,000, Median = 10,000, and IQR = 7,000</i> |            |              |                             |             |            |             |            |            |
| <b>Family members</b>  |            |              |                             |             |            |             |            |            |
| Alone  | 89         | 26.1         | 45                          | 50.6        | 44         | 49.4        | 2.23       | 0.329      |
| ≤ 5  | 102        | 29.9         | 46                          | 45.1        | 56         | 54.9        |            |            |
| > 5  | 150        | 44.0         | 82                          | 54.7        | 68         | 45.3        |            |            |
| <b>Living with</b>   |            |              |                             |             |            |             |            |            |
| Alone  | 77         | 22.6         | 34                          | 44.2        | 43         | 55.8        | 5.17       | 0.160      |
| Child  | 55         | 16.1         | 26                          | 47.3        | 29         | 52.7        |            |            |
| Relatives  | 46         | 13.5         | 20                          | 43.5        | 26         | 56.5        |            |            |
| Spouse   | 163        | 47.8         | 93                          | 57.1        | 70         | 42.9        |            |            |

\*Significance level  $\alpha=0.05$ 

regression. Those who prepared their favorite dish with more than three tablespoons of cooking oil were 2.78 times (95% CI=1.46–5.28) more likely to have suboptimal glycemic control than those who used less than three tablespoons. Participants who added more than three tablespoons of sugar to their favorite dish had 2.55 times (95% CI=1.31–4.93) greater odds of developing suboptimal glycemic control than those who added less than three tablespoons. Those who did not exercise regularly had 2.04 times (95% CI=1.15–3.61) more likely to

have suboptimal glycemic control than those who did (Table 3).

Eleven variables were found to be associated with suboptimal glycemic control in the univariable analysis in the dimension of clinical history with biomarkers and DM treatment-related experiences: duration of diabetes, family history of hypertension for the mother, BMI, waist-hip ratio, total cholesterol levels, LDL cholesterol, triglycerides, and stress, the type of diabetes medication taken, forgetting to take diabetes medication (weekly), and forgetting to take diabetes medication monthly (Table 4).

**Table 2** Identifying socio-demographic factors associated with suboptimal glycemic control among T2DM patients by univariable and multivariable logistic regressions

| Factors                     | Suboptimal glycemic control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|-----------------------------|-----------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|                             | Yes (%)                     | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>                | <b>173 (50.7)</b>           | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| <b>Sex</b>                  |                             |                   |                      |            |            |                        |            |            |
| Female                      | 113 (50.5)                  | 111 (49.6)        | 0.97                 | 0.62–1.51  | 0.884      |                        |            |            |
| Male                        | 60 (51.3)                   | 57 (48.7)         | 1.00                 |            |            |                        |            |            |
| <b>Age (years)</b>          |                             |                   |                      |            |            |                        |            |            |
| ≤40                         | 57 (41.6)                   | 80 (58.4)         | 1.00                 |            |            | 1.00                   |            |            |
| 40–60                       | 85 (58.6)                   | 60 (41.4)         | 1.99                 | 1.24–3.19  | 0.004*     | 3.35                   | 1.78–6.30  | <0.001*    |
| ≥60                         | 31 (52.5)                   | 28 (47.5)         | 1.55                 | 0.84–2.87  | 0.159      | 1.65                   | 0.71–3.87  | 0.246      |
| <b>Education</b>            |                             |                   |                      |            |            |                        |            |            |
| No schooling                | 77 (51.0)                   | 74 (49.0)         | 0.57                 | 0.29–1.12  | 0.102      |                        |            |            |
| Primary school              | 33 (35.9)                   | 59 (64.1)         | 0.31                 | 0.15–0.64  | 0.001*     |                        |            |            |
| Secondary school            | 32 (64.0)                   | 18 (36.0)         | 0.98                 | 0.43–2.23  | 0.952      |                        |            |            |
| Tertiary school             | 31 (64.6)                   | 17 (35.4)         | 1.00                 |            |            |                        |            |            |
| <b>Marital status</b>       |                             |                   |                      |            |            |                        |            |            |
| Single                      | 44 (49.4)                   | 45 (50.6)         | 1.37                 | 0.78–2.41  | 0.276      | 2.53                   | 1.21–5.30  | 0.014*     |
| Married                     | 84 (58.3)                   | 60 (41.7)         | 1.96                 | 1.18–3.25  | 0.009*     | 1.82                   | 0.94–3.53  | 0.077      |
| Ever married                | 45 (41.7)                   | 63 (58.3)         | 1.00                 |            |            | 1.00                   |            |            |
| <b>Occupation</b>           |                             |                   |                      |            |            |                        |            |            |
| Unemployed                  | 74 (43.8)                   | 95 (56.2)         | 0.70                 | 0.27–1.81  | 0.464      |                        |            |            |
| Government employee         | 49 (53.3)                   | 43 (46.7)         | 1.03                 | 0.38–2.76  | 0.960      |                        |            |            |
| Private sector employee     | 40 (65.6)                   | 21 (34.4)         | 1.71                 | 0.60–4.87  | 0.312      |                        |            |            |
| Self-employed               | 10 (52.6)                   | 9 (47.4)          | 1.00                 |            |            |                        |            |            |
| <b>Monthly income (MVR)</b> |                             |                   |                      |            |            |                        |            |            |
| No income                   | 77 (45.0)                   | 94 (55.0)         | 0.74                 | 0.29–1.91  | 0.529      |                        |            |            |
| ≤ 10,000                    | 52 (57.8)                   | 38 (42.2)         | 1.23                 | 0.46–3.32  | 0.681      |                        |            |            |
| 10,001–20,000               | 34 (55.7)                   | 27 (44.3)         | 1.13                 | 0.40–3.18  | 0.812      |                        |            |            |
| ≥ 20,001                    | 10 (52.6)                   | 9 (47.4)          | 1.00                 |            |            |                        |            |            |
| <b>Family members</b>       |                             |                   |                      |            |            |                        |            |            |
| Alone                       | 45 (50.6)                   | 44 (49.4)         | 0.85                 | 0.50–1.43  | 0.539      |                        |            |            |
| ≤ 5                         | 46 (45.1)                   | 56 (54.9)         | 0.68                 | 0.41–1.13  | 0.137      |                        |            |            |
| > 5                         | 82 (54.7)                   | 68 (45.3)         | 1.00                 |            |            |                        |            |            |
| <b>Living with</b>          |                             |                   |                      |            |            |                        |            |            |
| Alone                       | 34 (44.2)                   | 43 (55.8)         | 0.60                 | 0.35–1.03  | 0.063      |                        |            |            |
| Child                       | 26 (47.3)                   | 29 (52.7)         | 0.68                 | 0.37–1.25  | 0.209      |                        |            |            |
| Relatives                   | 20 (43.5)                   | 26 (56.5)         | 0.58                 | 0.30–1.12  | 0.105      |                        |            |            |
| Spouse                      | 93 (57.1)                   | 70 (42.9)         | 1.00                 |            |            |                        |            |            |

\*Significance level  $\alpha=0.05$ 

Five variables were found to be associated with suboptimal glycemic control in multivariable logistic regression. Participants diagnosed with DM more than twenty years prior had 2.59 times (95% CI=1.34–4.99) greater odds of having suboptimal glycemic control, respectively, than those diagnosed with DM less than twenty years. Those with an obese BMI were 3.82 times (95% CI=1.75–8.32) more likely to have suboptimal glycemic control than those with a normal BMI. Participants with high total cholesterol had 2.43 times (95% CI=1.36–4.35) more likely to have suboptimal glycemic control than those with normal total cholesterol. Participants with high triglyceride had 3.43 times (95% CI=1.93–6.11) greater

odds of getting suboptimal glycemic control than those with optimal triglycerides, and those who had high-level stress had 2.97 times (95% CI=1.48–5.93) greater chance of having suboptimal glycemic control than those who had low and moderate levels of stress (Table 4).

## Discussion

A large proportion of the T2DM patients in the Greater Male's Region suffer from suboptimal glycemic control, particularly in older age, females, and single. While most people live with low socioeconomic status. Many cooking practices use high volumes of sugar and cooking oil, which leads to high BMI. Lack of regular exercise and

**Table 3** Identifying diabetic self-care and knowledge toward DM prevention and control that associated with suboptimal glycemic control among T2DM patients by univariable and multivariable logistic regressions

| Factors  | Suboptimal glycemic control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|--|-----------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|  | Yes (%)                     | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>                                       | <b>173 (50.7)</b>           | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| <b>Checking blood glucose</b>                      |                             |                   |                      |            |            |                        |            |            |
| Medical staff                                      | 106 (46.1)                  | 124 (53.9)        | 1.00                 |            |            |                        |            |            |
| Themselves at home                                 | 67 (60.4)                   | 44 (39.6)         | 1.78                 | 1.12–2.82  | 0.014*     |                        |            |            |
| <b>Frequency of checking blood glucose</b>         |                             |                   |                      |            |            |                        |            |            |
| Few times  | 23 (63.9)                   | 13 (36.1)         | 1.00                 |            |            |                        |            |            |
| Weekly   | 48 (70.6)                   | 20 (29.4)         | 1.36                 | 0.58–3.19  | 0.486      |                        |            |            |
| Monthly  | 58 (31.5)                   | 126 (68.5)        | 0.26                 | 0.12–0.55  | <0.001*    |                        |            |            |
| Everyday   | 44 (83.0)                   | 9 (17.0)          | 2.76                 | 1.03–7.42  | 0.044*     |                        |            |            |
| <b>Missed DM appointment</b>                       |                             |                   |                      |            |            |                        |            |            |
| No   | 122 (55.7)                  | 97 (44.3)         | 1.75                 | 1.12–2.74  | 0.014*     |                        |            |            |
| Yes  | 51 (41.8)                   | 71 (58.2)         | 1.00                 |            |            |                        |            |            |
| <b>Smoking</b>                                     |                             |                   |                      |            |            |                        |            |            |
| No   | 120 (49.4)                  | 123 (50.6)        | 1.00                 |            |            |                        |            |            |
| Ever   | 11 (44.0)                   | 14 (56.0)         | 0.81                 | 0.35–1.85  | 0.609      |                        |            |            |
| Yes  | 42 (57.5)                   | 31 (42.5)         | 1.39                 | 0.82–2.35  | 0.223      |                        |            |            |
| <b>Smoking(year)</b>                               |                             |                   |                      |            |            |                        |            |            |
| ≤ 20   | 12 (48.0)                   | 13 (52.0)         | 1.00                 |            |            |                        |            |            |
| > 20   | 30 (62.5)                   | 18 (37.5)         | 1.81                 | 0.68–4.80  | 0.237      |                        |            |            |
| <b>No cigarettes smoke(day)</b>                    |                             |                   |                      |            |            |                        |            |            |
| ≤ 10   | 17 (44.7)                   | 21 (55.3)         | 1.00                 |            |            |                        |            |            |
| > 10   | 25 (71.4)                   | 10 (28.6)         | 3.09                 | 1.17–8.17  | 0.023*     |                        |            |            |
| <b>No of the meal (times/day)</b>                  |                             |                   |                      |            |            |                        |            |            |
| ≤ 3 meals  | 55 (64.7)                   | 30 (35.3)         | 2.14                 | 1.29–3.56  | 0.003*     |                        |            |            |
| > 3 meals  | 118 (46.1)                  | 138 (53.9)        | 1.00                 |            |            |                        |            |            |
| <b>Preparing food</b>                              |                             |                   |                      |            |            |                        |            |            |
| Themselves   | 163 (50.2)                  | 162 (49.9)        | 1.00                 |            |            |                        |            |            |
| Buying   | 10 (62.5)                   | 6 (37.5)          | 1.66                 | 0.59–4.66  | 0.339      |                        |            |            |
| <b>Food prepared with cooking oil (tablespoon)</b> |                             |                   |                      |            |            |                        |            |            |
| ≤ 1  | 50 (38.8)                   | 79 (61.2)         | 1.00                 |            |            | 1.00                   |            |            |
| 1–3  | 29 (40.9)                   | 42 (59.2)         | 1.09                 | 0.60–1.97  | 0.773      | 0.86                   | 0.42–1.79  | 0.691      |
| > 3  | 94 (66.7)                   | 47 (33.3)         | 3.16                 | 1.92–5.20  | <0.001*    | 2.78                   | 1.46–5.28  | 0.002*     |
| <b>Food prepared with sugar (tablespoon)</b>       |                             |                   |                      |            |            |                        |            |            |
| ≤ 1  | 40 (40.4)                   | 59 (59.6)         | 1.00                 |            |            | 1.00                   |            |            |
| 1–3  | 34 (48.6)                   | 36 (51.4)         | 1.39                 | 0.75–2.58  | 0.292      | 1.34                   | 0.59–2.99  | 0.480      |
| > 3  | 99 (57.6)                   | 73 (42.4)         | 2.00                 | 1.21–3.31  | 0.007*     | 2.55                   | 1.31–4.93  | 0.006*     |
| <b>Coconut milk-prepared food (day(s)/week)</b>    |                             |                   |                      |            |            |                        |            |            |
| ≤ 3  | 59 (43.7)                   | 76 (56.3)         | 1.00                 |            |            |                        |            |            |
| > 3  | 114 (55.3)                  | 92 (44.7)         | 1.60                 | 1.03–2.47  | 0.036*     |                        |            |            |
| <b>Eating sugary foods</b>                         |                             |                   |                      |            |            |                        |            |            |
| Never  | 43 (38.1)                   | 70 (62.0)         | 1.00                 |            |            |                        |            |            |
| Sometimes  | 100 (58.1)                  | 72 (41.9)         | 2.26                 | 1.39–3.68  | 0.001*     |                        |            |            |
| Regularly  | 30 (53.6)                   | 26 (46.4)         | 1.88                 | 0.98–3.59  | 0.057      |                        |            |            |
| <b>Drinking tea</b>                                |                             |                   |                      |            |            |                        |            |            |
| No   | 10 (47.6)                   | 11 (52.4)         | 1.00                 |            |            |                        |            |            |
| Yes  | 163 (50.9)                  | 157 (49.1)        | 1.14                 | 0.47–2.76  | 0.768      |                        |            |            |
| <b>Drinking tea with sugar</b>                     |                             |                   |                      |            |            |                        |            |            |
| Never  | 35 (27.6)                   | 92 (72.4)         | 1.00                 |            |            |                        |            |            |
| Sometimes  | 86 (66.2)                   | 44 (33.9)         | 5.14                 | 3.02–8.75  | <0.001*    |                        |            |            |
| Regularly  | 42 (66.7)                   | 21 (33.3)         | 5.26                 | 2.74–10.10 | <0.001*    |                        |            |            |
| <b>Drinking coffee</b>                             |                             |                   |                      |            |            |                        |            |            |

**Table 3** (continued)

| Factors  | Suboptimal glycemc control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|--|----------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|  | Yes (%)                    | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>   | <b>173 (50.7)</b>          | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| No   | 50 (46.3)                  | 58 (53.7)         | 1.00                 |            |            |                        |            |            |
| Yes  | 123 (52.8)                 | 110 (47.2)        | 1.30                 | 0.82–2.05  | 0.265      |                        |            |            |
| <b>Drinking coffee with sugar</b>                    |                            |                   |                      |            |            |                        |            |            |
| Never  | 100 (52.1)                 | 92 (47.9)         | 1.00                 |            |            |                        |            |            |
| Sometimes  | 8 (57.1)                   | 6 (42.9)          | 1.23                 | 0.41–3.67  | 0.715      |                        |            |            |
| Regularly  | 16 (59.3)                  | 11 (40.7)         | 1.34                 | 0.59–3.03  | 0.485      |                        |            |            |
| <b>Drinking juice</b>                                |                            |                   |                      |            |            |                        |            |            |
| No   | 104 (57.5)                 | 77 (42.5)         | 1.78                 | 1.16–2.74  | 0.008*     |                        |            |            |
| Yes  | 69 (43.1)                  | 91 (56.9)         | 1.00                 |            |            |                        |            |            |
| <b>Drinking juice with sugar</b>                     |                            |                   |                      |            |            |                        |            |            |
| Never  | 28 (38.4)                  | 45 (61.6)         | 1.00                 |            |            |                        |            |            |
| Sometimes  | 22 (43.1)                  | 29 (56.9)         | 1.22                 | 0.59–2.52  | 0.593      |                        |            |            |
| Regularly  | 19 (52.8)                  | 17 (47.2)         | 1.80                 | 0.80–4.02  | 0.155      |                        |            |            |
| <b>Fruit intake (daily)</b>                          |                            |                   |                      |            |            |                        |            |            |
| No   | 33 (44.6)                  | 41 (55.4)         | 0.73                 | 0.44–1.23  | 0.234      |                        |            |            |
| Yes  | 140 (52.4)                 | 127 (47.6)        | 1.00                 |            |            |                        |            |            |
| <b>Vegetable intake (daily)</b>                      |                            |                   |                      |            |            |                        |            |            |
| No   | 38 (44.2)                  | 48 (55.8)         | 0.70                 | 0.43–1.15  | 0.161      |                        |            |            |
| Yes  | 135 (52.9)                 | 120 (47.1)        | 1.00                 |            |            |                        |            |            |
| <b>Exercise</b>                                      |                            |                   |                      |            |            |                        |            |            |
| No   | 115 (58.4)                 | 82 (41.6)         | 2.08                 | 1.34–3.22  | 0.001*     | 2.04                   | 1.15–3.61  | 0.014*     |
| Yes  | 58 (40.3)                  | 86 (59.7)         | 1.00                 |            |            | 1.00                   |            |            |
| <b>No of hours spent doing exercise(minutes/day)</b> |                            |                   |                      |            |            |                        |            |            |
| < 30   | 59 (17.3)                  | 33 (55.9)         | 1.36                 | 0.70–2.65  | 0.364      |                        |            |            |
| > 30   | 85 (24.9)                  | 41 (48.2)         | 1.00                 |            |            |                        |            |            |
| <b>Knowledge regarding DM prevention and control</b> |                            |                   |                      |            |            |                        |            |            |
| Low  | 17 (5.0)                   | 9 (52.9)          | 1.22                 | 0.46–3.29  | 0.690      |                        |            |            |
| Moderate   | 109 (32.0)                 | 61 (56.0)         | 1.38                 | 0.87–2.20  | 0.171      |                        |            |            |
| High   | 215 (63.1)                 | 103 (47.9)        | 1.00                 |            |            |                        |            |            |

\*Significance level  $\alpha=0.05$ 

high stress are also detected among T2DM patients, which are associated with suboptimal glycemc control.

The prevalence of suboptimal glycemc control among T2DM patients attending public hospitals was extremely high (50.7%), which was in line with a study conducted in Brazil (47.3%) [5]. However, this proportion is shown to be higher in studies conducted in northern Thailand (54.8%) [23], Ethiopia 71.9% [24], India (64.1%) [25], Bangladesh (71.8%) [16], and Saudi Arabia (75.9%) [26]. These variations could be attributable to rapid urbanization, cultural attitudes and beliefs, behavioral and clinical characteristics, availability of health services, income, lack of uniform guidelines, and a lack of patient awareness regarding diabetes prevention and care.

In this study, age was identified as an associated factor that contributes to suboptimal glycemc control. Participants aged 40–60 years had a greater chance of having suboptimal glycemc control than those in the age groups below 40 and above 60 years. This coincided with a study

conducted in Western Ethiopia [27], which reported that T2DM patients between the ages of 41 and 60 were more likely to develop suboptimal glycemc control than those in the age groups below 40 and above 60. However, a study conducted in Eastern Sudan [28] did not detect any association between age and suboptimal glycemc control. Contrary to the findings of this study, a study conducted in Ethiopia [21] revealed that T2DM patients over the age of 50 had a greater risk of having suboptimal glycemc control compared to those below the age of 50. The possible reason for suboptimal glycemc control among people in the Greater Male' Region could be that this age group is a working age group. They may have a busy daily life, which results in difficulty seeking health care, exercising, or adhering to medical recommendations and makes it difficult to control their blood glucose levels.

Being single was detected as another contributor associated with suboptimal glycemc control in this study. Unmarried participants had greater odds of



**Table 4** Identifying clinical history with biomarkers and DM treatment-related experiences associated with suboptimal glycemic control among T2DM patients by univariable and multivariable logistic regressions

| Factors   | Suboptimal glycemic control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|---|-----------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|   | Yes (%)                     | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>                                      | <b>173 (50.7)</b>           | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| <b>Length of DM diagnosed (years)</b>             |                             |                   |                      |            |            |                        |            |            |
| ≤ 10  | 47 (45.2)                   | 57 (54.8)         | 1.00                 |            |            | 1.00                   |            |            |
| 10–20   | 40 (37.0)                   | 68 (63.0)         | 0.71                 | 0.41–1.24  | 0.228      | 0.89                   | 0.44–1.81  | 0.756      |
| > 20  | 86 (66.7)                   | 43 (33.3)         | 2.43                 | 1.43–4.13  | 0.001*     | 2.59                   | 1.34–4.99  | 0.005*     |
| <b>Having HT</b>                                  |                             |                   |                      |            |            |                        |            |            |
| No  | 53 (54.1)                   | 45 (45.9)         | 1.65                 | 0.67–4.07  | 0.278      |                        |            |            |
| Yes   | 110 (50.2)                  | 109 (49.8)        | 1.41                 | 0.60–3.32  | 0.427      |                        |            |            |
| Do not know                                       | 10 (41.7)                   | 14 (58.3)         | 1.00                 |            |            |                        |            |            |
| <b>Length of HT diagnosed (years)</b>             |                             |                   |                      |            |            |                        |            |            |
| ≤ 5   | 46 (53.5)                   | 40 (46.5)         | 1.00                 |            |            |                        |            |            |
| > 5   | 64 (48.1)                   | 69 (51.9)         | 0.81                 | 0.47–1.39  | 0.438      |                        |            |            |
| <b>Taking medication for HT</b>                   |                             |                   |                      |            |            |                        |            |            |
| No  | 72 (51.4)                   | 68 (48.6)         | 1.00                 |            |            |                        |            |            |
| Yes   | 101 (50.3)                  | 100 (49.8)        | 0.95                 | 0.62–1.47  | 0.830      |                        |            |            |
| <b>Having kidney disease</b>                      |                             |                   |                      |            |            |                        |            |            |
| No  | 118 (49.0)                  | 123 (51.0)        | 0.58                 | 0.32–1.05  | 0.070      |                        |            |            |
| Yes   | 20 (45.5)                   | 24 (54.6)         | 0.50                 | 0.22–1.12  | 0.091      |                        |            |            |
| Do not know                                       | 35 (62.5)                   | 21 (37.5)         | 1.00                 |            |            |                        |            |            |
| <b>Length of kidney disease diagnosed (years)</b> |                             |                   |                      |            |            |                        |            |            |
| ≤ 5   | 12 (46.2)                   | 14 (53.9)         | 1.00                 |            |            |                        |            |            |
| > 5   | 8 (44.4)                    | 10 (55.6)         | 0.93                 | 0.28–3.12  | 0.911      |                        |            |            |
| <b>Taking medication for kidney disease</b>       |                             |                   |                      |            |            |                        |            |            |
| No  | 153 (51.5)                  | 144 (48.5)        | 1.00                 |            |            |                        |            |            |
| Yes   | 20 (45.5)                   | 24 (54.6)         | 0.78                 | 0.42–1.48  | 0.454      |                        |            |            |
| <b>Family history of DM (father)</b>              |                             |                   |                      |            |            |                        |            |            |
| No  | 52 (52.0)                   | 48 (48.0)         | 1.44                 | 0.86–2.43  | 0.169      |                        |            |            |
| Yes   | 80 (53.7)                   | 69 (46.3)         | 1.35                 | 0.76–2.38  | 0.304      |                        |            |            |
| Do not know                                       | 41 (44.6)                   | 51 (55.4)         | 1.00                 |            |            |                        |            |            |
| <b>Family history of DM (mother)</b>              |                             |                   |                      |            |            |                        |            |            |
| No  | 51 (51.5)                   | 48 (48.5)         | 1.59                 | 0.93–2.72  | 0.087      |                        |            |            |
| Yes   | 86 (54.4)                   | 72 (45.6)         | 1.42                 | 0.79–2.54  | 0.243      |                        |            |            |
| Do not know                                       | 36 (42.9)                   | 48 (57.1)         | 1.00                 |            |            |                        |            |            |
| <b>Family history of DM (grandfather)</b>         |                             |                   |                      |            |            |                        |            |            |
| No  | 41 (55.4)                   | 33 (44.6)         | 0.76                 | 0.38–1.51  | 0.430      |                        |            |            |
| Yes   | 17 (43.6)                   | 22 (56.4)         | 1.22                 | 0.72–2.07  | 0.458      |                        |            |            |
| Do not know                                       | 115 (50.4)                  | 113 (49.6)        | 1.00                 |            |            |                        |            |            |
| <b>Family history of DM (grandmother)</b>         |                             |                   |                      |            |            |                        |            |            |
| No  | 29 (49.2)                   | 30 (50.9)         | 1.35                 | 0.72–2.50  | 0.350      |                        |            |            |
| Yes   | 28 (57.1)                   | 21 (42.9)         | 0.98                 | 0.55–1.73  | 0.931      |                        |            |            |
| Do not know                                       | 116 (49.8)                  | 117 (50.2)        | 1.00                 |            |            |                        |            |            |
| <b>Family history of HT (father)</b>              |                             |                   |                      |            |            |                        |            |            |
| No  | 47 (51.1)                   | 45 (48.9)         | 1.52                 | 0.91–2.55  | 0.113      |                        |            |            |
| Yes   | 85 (54.5)                   | 71 (45.5)         | 1.33                 | 0.74–2.36  | 0.341      |                        |            |            |
| Do not know                                       | 41 (44.1)                   | 52 (55.9)         | 1.00                 |            |            |                        |            |            |
| <b>Family history of HT (mother)</b>              |                             |                   |                      |            |            |                        |            |            |
| No  | 73 (49.7)                   | 74 (50.3)         | 1.94                 | 1.09–3.43  | 0.024*     |                        |            |            |
| Yes   | 63 (58.9)                   | 44 (41.1)         | 1.33                 | 0.78–2.27  | 0.291      |                        |            |            |
| Do not know                                       | 37 (42.5)                   | 50 (57.5)         | 1.00                 |            |            |                        |            |            |
| <b>Family history of HT (grandfather)</b>         |                             |                   |                      |            |            |                        |            |            |
| No  | 42 (52.5)                   | 38 (47.5)         | 0.57                 | 0.26–1.26  | 0.570      |                        |            |            |

**Table 4** (continued)

| Factors   | Suboptimal glycemic control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|---|-----------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|   | Yes (%)                     | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>                                      | <b>173 (50.7)</b>           | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| Yes   | 11 (37.9)                   | 18 (62.1)         | 1.03                 | 0.62–1.72  | 0.905      |                        |            |            |
| Do not know                                       | 120 (51.7)                  | 112 (48.3)        | 1.00                 |            |            |                        |            |            |
| <b>Family history of HT (grandmother)</b>         |                             |                   |                      |            |            |                        |            |            |
| No  | 43 (53.8)                   | 37 (46.3)         | 1.10                 | 0.49–2.43  | 0.823      |                        |            |            |
| Yes   | 14 (51.9)                   | 13 (48.2)         | 1.18                 | 0.71–1.97  | 0.519      |                        |            |            |
| Do not know                                       | 116 (49.6)                  | 118 (50.4)        | 1.00                 |            |            |                        |            |            |
| <b>Systolic blood pressure (mm/Hg)</b>            |                             |                   |                      |            |            |                        |            |            |
| Normal (< 140)                                    | 112 (52.6)                  | 101 (47.4)        | 1.00                 |            |            |                        |            |            |
| High (≥ 140)                                      | 61 (47.7)                   | 67 (52.3)         | 0.82                 | 0.53–1.27  | 0.379      |                        |            |            |
| <b>Diastolic blood pressure (mm/Hg)</b>           |                             |                   |                      |            |            |                        |            |            |
| Normal (< 90)                                     | 153 (49.8)                  | 154 (50.2)        | 1.00                 |            |            |                        |            |            |
| High (≥ 90)                                       | 20 (58.8)                   | 14 (41.2)         | 1.44                 | 0.70–2.95  | 0.322      |                        |            |            |
| <b>BMI (kg/m<sup>2</sup>)</b>                     |                             |                   |                      |            |            |                        |            |            |
| Normal (18.50–22.9)                               | 26 (32.5)                   | 54 (67.5)         | 1.00                 |            |            | 1.00                   |            |            |
| Underweight (< 18.50)                             | 26 (44.8)                   | 32 (55.2)         | 1.69                 | 0.84–3.39  | 0.142      | 1.46                   | 0.59–3.60  | 0.412      |
| Overweight (23–24.9)                              | 27 (47.4)                   | 30 (52.6)         | 1.87                 | 0.93–3.76  | 0.080      | 1.87                   | 0.77–4.57  | 0.167      |
| Obese (> 25)                                      | 94 (64.4)                   | 52 (35.6)         | 3.75                 | 2.11–6.69  | < 0.001*   | 3.82                   | 1.75–8.32  | 0.001*     |
| <b>Waist-hip ratio (W/H in cm)</b>                |                             |                   |                      |            |            |                        |            |            |
| Healthy   | 62 (43.7)                   | 80 (56.3)         | 1.00                 |            |            |                        |            |            |
| Unhealthy   | 111 (55.8)                  | 88 (44.2)         | 1.63                 | 1.06–2.51  | 0.028*     |                        |            |            |
| <b>Total cholesterol (mg/dL)</b>                  |                             |                   |                      |            |            |                        |            |            |
| Normal (< 200)                                    | 52 (41.3)                   | 74 (58.7)         | 1.00                 |            |            | 1.00                   |            |            |
| High (≥ 200)                                      | 121 (56.3)                  | 94 (43.7)         | 1.83                 | 1.17–2.86  | 0.008*     | 2.43                   | 1.36–4.35  | 0.003*     |
| <b>LDL cholesterol (mg/dL)</b>                    |                             |                   |                      |            |            |                        |            |            |
| Normal (< 100)                                    | 69 (42.6)                   | 93 (57.4)         | 1.00                 |            |            |                        |            |            |
| High (≥ 100)                                      | 104 (58.1)                  | 75 (41.9)         | 1.87                 | 1.22–2.87  | 0.004*     |                        |            |            |
| <b>HDL cholesterol (mg/dL)</b>                    |                             |                   |                      |            |            |                        |            |            |
| Low (< 40)  | 67 (51.5)                   | 63 (48.5)         | 1.05                 | 0.68–1.63  | 0.815      |                        |            |            |
| Normal (≥ 40)                                     | 106 (50.2)                  | 105 (49.8)        | 1.00                 |            |            |                        |            |            |
| <b>Triglyceride (mg/dL)</b>                       |                             |                   |                      |            |            |                        |            |            |
| Optimal (< 150)                                   | 69 (41.6)                   | 97 (58.4)         | 1.00                 |            |            | 1.00                   |            |            |
| High (≥ 150)                                      | 104 (59.4)                  | 71 (40.6)         | 2.06                 | 1.34–3.17  | 0.001*     | 3.43                   | 1.93–6.11  | < 0.001*   |
| <b>Stress test (ST-5)</b>                         |                             |                   |                      |            |            |                        |            |            |
| Low   | 33 (33.0)                   | 67 (67.0)         | 1.00                 |            |            | 1.00                   |            |            |
| Moderate  | 47 (48.5)                   | 50 (51.6)         | 1.91                 | 1.07–3.40  | 0.028*     | 1.51                   | 0.72–3.17  | 0.281      |
| High  | 93 (64.6)                   | 51 (35.4)         | 3.70                 | 2.16–6.35  | < 0.001*   | 2.97                   | 1.48–5.93  | 0.002*     |
| <b>Type of medicine taken for DM</b>              |                             |                   |                      |            |            |                        |            |            |
| OHA   | 140 (50.7)                  | 136 (49.3)        | 1.00                 |            |            |                        |            |            |
| OHA + insulin                                     | 16 (38.1)                   | 26 (61.9)         | 0.60                 | 0.31–1.16  | 0.130      |                        |            |            |
| Insulin   | 17 (73.9)                   | 6 (26.1)          | 2.75                 | 1.05–7.19  | 0.039*     |                        |            |            |
| <b>Forgot to take DM medication (day(s)/week)</b> |                             |                   |                      |            |            |                        |            |            |
| No  | 123 (45.22)                 | 149 (54.8)        | 1.00                 |            |            |                        |            |            |
| ≤ 3   | 40 (76.92)                  | 12 (23.1)         | 4.04                 | 2.03–8.03  | < 0.001*   |                        |            |            |
| > 3   | 10 (58.82)                  | 7 (41.2)          | 1.73                 | 0.64–4.68  | 0.280      |                        |            |            |
| <b>Forgot to take DM medication (month)</b>       |                             |                   |                      |            |            |                        |            |            |
| No  | 112 (46.86)                 | 127 (53.1)        | 1.00                 |            |            |                        |            |            |
| Yes   | 61 (59.80)                  | 41 (40.2)         | 1.69                 | 1.05–2.70  | 0.029*     |                        |            |            |
| <b>Having side effects from DM drug</b>           |                             |                   |                      |            |            |                        |            |            |
| No  | 154 (51.9)                  | 143 (48.2)        | 1.40                 | 0.60–3.29  | 0.441      |                        |            |            |
| Yes   | 9 (42.9)                    | 12 (57.1)         | 0.98                 | 0.30–3.22  | 0.967      |                        |            |            |
| Do not know                                       | 10 (43.5)                   | 13 (56.5)         | 1.00                 |            |            |                        |            |            |

**Table 4** (continued)

| Factors                 | Suboptimal glycaemic control |                   | Univariable analysis |            |            | Multivariable analysis |            |            |
|-------------------------|------------------------------|-------------------|----------------------|------------|------------|------------------------|------------|------------|
|                         | Yes (%)                      | No (%)            | OR                   | 95% CI     | p-value    | AOR                    | 95% CI     | p-value    |
| <b>Total</b>            | <b>173 (50.7)</b>            | <b>168 (49.3)</b> | <b>N/A</b>           | <b>N/A</b> | <b>N/A</b> | <b>N/A</b>             | <b>N/A</b> | <b>N/A</b> |
| <b>Medical expenses</b> |                              |                   |                      |            |            |                        |            |            |
| Covered by Aasandha     | 157 (53.4)                   | 137 (46.6)        | 2.29                 | 0.77–6.87  | 0.139      |                        |            |            |
| Private health scheme   | 11 (34.4)                    | 21 (65.6)         | 1.05                 | 0.29–3.84  | 0.944      |                        |            |            |
| Self-paid               | 5 (33.3)                     | 10 (66.7)         | 1.00                 |            |            |                        |            |            |

\*Significance level  $\alpha=0.05$ 

experiencing suboptimal glycaemic control than those who were married and ever married. This is in line with results obtained from studies conducted in Northwestern Nigeria [28], Eastern Sudan [29], and Ethiopia [21], which reported that being unmarried was at greater risk of having suboptimal glycaemic control than being married. However, a study conducted in northeast Ethiopia showed no significant association between marital status and glycaemic control [30]. In contrast, a study conducted in northern Thailand found that married T2DM patients had greater odds of having suboptimal glycaemic control compared to their unmarried counterparts [23]. Perhaps it was assumed that unmarried patients might not receive adequate support from their families in terms of clinic attendance, adherence to a healthy diet, and medication as directed. Maybe this could be the reason they were not achieving glycaemic levels. Even though in our study, marriage status was not found to be associated with suboptimal glycaemic control, a study in Ethiopia [31] reported that it was a protective factor to the suboptimal glycaemic control. Another study [32] conducted in Oman reported that a single marital status was associated with suboptimal glycaemic control. It is important to investigate the associations between social determinants and suboptimal glycaemic control in any social context for further considering effective public health intervention.

The present study showed that cooking oil beyond the recommended daily was associated with suboptimal glycaemic control. Participants who prepared their favorite dish using more than three tablespoons of cooking oil were more likely to have suboptimal glycaemic control than those who used less than three tablespoons of cooking oil. Thus, this factor tends to play a significant role in developing suboptimal glycaemic control and coronary heart disease. A scoping review reported that people with DM should limit their daily intake of cooking oil to a maximum of three teaspoons to manage their diabetes condition effectively [31]. The possible reason for the suboptimal glycaemic control observed among people in the Greater Male' Region could be that deep-frying oily foods is a more common practice in Maldivian culture, and palm oil is the most common oil used for deep frying.

In the same way, this study also found that using excessive amounts of sugar in daily cooking practices was associated with suboptimal glycaemic control. Those who added more than three tablespoons of sugar to their favorite dish had a greater risk of developing suboptimal glycaemic control than those who added less than three. This finding was consistent with the study conducted in Eastern Sudan, which reported that adding sugar to beverages increased the risk of poor glycaemic control [29]. High added sugar intake lowers the hepatic insulin sensitivity index and increases hepatic lipogenesis and visceral fat, boosting blood insulin levels in DM patients [32]. Furthermore, the Maldivian population has observed an increase in the consumption of sugary foods and drinks with added sugar in recent decades [8]. Traditional Maldivian sweets, drinks, pudding, cakes, pastries, baked foods, and areca nut products contain high-added sugar.

This study detected exercise as a predictor associated with suboptimal glycaemic control. Participants who did not exercise regularly had greater odds of having suboptimal glycaemic control than those who exercised regularly. This finding was supported by studies conducted in Ethiopia [21], Northeast Nigeria [33], Yemen [34], Uganda [35], and Saudi Arabia [26], which reported that those who were not engaged in physical activity had a greater risk of developing suboptimal glycaemic control than those who did exercise. Exercising may lower blood glucose levels because active muscles absorb more glucose than resting muscles, which enhances insulin receptors and sensitivity [36]. One possible reason people in the Greater Male' Region avoid exercise may be due to a lack of time and always being occupied with daily work to support their family.

The duration of diabetes was identified as a significant positive factor in this study. Those diagnosed with DM for more than twenty years prior had greater odds of developing suboptimal glycaemic status compared to those who had been diagnosed with DM for less than twenty years. This result was confirmed by studies in Ethiopia [37], Saudi Arabia [38], northern Thailand [23], Nepal [39], and India [40], which discovered that people who were diagnosed with diabetes more than ten years ago were more likely to have poor glycaemic control than those diagnosed with diabetes less than ten years. A

prolonged period of T2DM is often accompanied by a gradual reduction of insulin production due to pancreatic  $\beta$ -cell failure, which in turn increases insulin resistance, making it more difficult to manage blood glucose [27]. This could be the reason for T2DM patients frequently having suboptimal glycemic control.

Moreover, participants with an obese BMI were more likely to have suboptimal glycemic control than those with normal BMI. This finding was consistent with findings from studies conducted in Ethiopia [6], Saudi Arabia [38], and India [40], which reported that those with an obese BMI had a greater likelihood of developing suboptimal status compared to those with a normal body weight. Obesity causes an increase in the release of Non-Esterified Fatty Acids from adipose tissue, which has been associated with insulin resistance [36]. This might be a possibility for obese diabetics who have poor glycemic control.

TC was discovered to be an important modifiable risk factor associated with suboptimal glycemic control. Participants with high total cholesterol levels were at greater risk of developing suboptimal glycemic control than those with normal total cholesterol. This finding was similar to the study conducted in Southwest Ethiopia [36], and Oman [41] which reported that high total cholesterol had more likelihood of developing suboptimal glycemic control. A possible justification may be the relationship between glycemic control and its influences on total cholesterol in T2DM patients.

Participants with elevated triglyceride levels had a higher risk of developing suboptimal glycemic status than those with optimal triglyceride levels. This was confirmed by a study conducted in India [40], which revealed that DM patients frequently had lipid problems and dyslipidemia was associated with suboptimal glycemic control, especially those with triglycerides > 150 mg/dL. This might occur due to the persistent fatty acid entry into the  $\beta$  cell, resulting in pancreatic  $\beta$  cell dysfunction, which leads to insulin resistance and makes it difficult to manage blood glucose levels [21].

Finally, the results of this study revealed that stress had a significant association with suboptimal glycemic control. Participants who experienced high stress levels had a greater chance of having suboptimal glycemic control than those who experienced moderate or low stress. A study conducted in Iran [42] showed that stress management reduces HbA1c levels among T2DM patients. It is more common among DM patients and has a dual function in its association with DM, like cause and effect. Stress increases HbA1c, whereas diabetes and its complications increase stress in people with T2DM, particularly physical and emotional stress [42].

Throughout the study, some limitations were identified that may have impacted the analysis and interpretation of

the findings. First, the design of this study might not be able to apply to identify the causal relationship between independent variables and suboptimal glycemic control due to assessing both exposures and outcomes at the same time. Second, due to the inability to obtain T2DM statistics from designated hospitals, it was challenging to estimate the sample size for each hospital in this study. Third, some questions asked about participants' experiences might cause recall bias. Lastly, the study settings were hospitals, then generalizing the findings to the population is limited.

## Conclusions

A large proportion of T2DM patients in the Greater Male' Region fail to control their blood glucose. Effective public health interventions should be introduced, especially interventions focused on reducing cooking oil and sugar in daily cooking practices, encouraging regular exercise, and maintaining cholesterol levels, particularly for those diagnosed with T2DM for more than 20 years prior. Policymakers at all levels should be informed of the information to create a proper approach for further national policy development and implementation.

## Abbreviations

|                |                           |
|----------------|---------------------------|
| BMI            | Body mass index           |
| DM             | Diabetes mellitus         |
| Hemoglobin A1c | HbA1c                     |
| IOC            | Item objective congruence |
| NCDs           | Noncommunicable diseases  |
| NDC            | National Diabetes Center  |
| T2DM           | Type 2 diabetes mellitus  |
| WHO            | World Health Organization |
| WHR            | Waist hip ratio           |

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-024-18693-6>.

Supplementary Material 1

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## Author contributions

JS, TA, and PS designed the study, analyzed the data, drafted the manuscript, and approved the final version of the manuscript. JS contacted the hospitals, and collected the data. All authors approved the final version of the manuscript.

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### Availability of data and materials

Supported data for the study findings are available in supplement files.

### Declarations

#### Ethics approval and consent to participate

All research protocols and tools were reviewed and approved by the Mae Fah Laung Human Research Ethics Committee (No. EC 22164 -18) and the Maldives National Health Research Council under certificate number (No. NHRC/2022/27). Before beginning the study, the researcher provided all participants with the necessary study information and obtained written informed consent from each participant voluntarily. The study procedures were performed in accordance with the relevant guidelines, regulations, and within the Declaration of Helsinki of 1975, as revised in 2000 (5).

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare no competing interests.

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