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Evaluating Knowledge And Awareness Of SGLT-2 Inhibitors' Use, Efficacy, Side Effects, And Cardiovascular And Renal Impacts Among Primary Healthcare Physicians In Makkah, Saudi Arabia

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Abstract

Background: Sodium-glucose cotransporter-2 (SGLT-2) inhibitors are a class of antihyperglycemic medications primarily used for the treatment of T2DM. They have been associated with cardiovascular and renal protective effects, making them beneficial for patients with T2DM and high cardiovascular risk.

Objectives: to assess the knowledge of primary healthcare physicians regarding the use, efficacy, side effects, and cardiovascular and renal impacts of Sodium-glucose cotransporter-2 (SGLT-2) inhibitors among T2DM patients.

Subjects and methods: An analytical cross-sectional study was conducted on a non-probability convenience sample of primary healthcare physicians in Makkah, Saudi Arabia. Data were collected through an electronic self-administered questionnaire composed of two main parts; demographic information of the participants and multiple-choice questions to assess the level of knowledge and awareness about SGLT-2 inhibitors.

Results: A total of 249 physicians participated in the study. Their age ranges between 25 and 47 years with an arithmetic mean of 32.2 and standard deviation of 4.4 years. More than half (56.6%) of them were males. history of ever prescribing SGLT-2 inhibitor medications for a diabetic patient was reported by most of the physicians (89.2%). Overall, good level of knowledge was observed among 38.6% of the physicians whereas poor level was observed among 15.7% of them. Males ($p=0.002$), older physicians ($p=0.050$), Saudis ($p=0.026$), those with experience of 6-10 years (0.046), physicians with lower income ($p=0.001$), consultants ($p<0.001$), and physicians who ever prescribed SGLT-2 inhibitor medications for a diabetic patient ($p=0.026$) were more knowlegeable about SGLT-2 inhibitors compared to their counterparts.

Conclusion: Majority of the primary healthcare physicians expressed average to good level of knowledge about SGLT-2 inhibitors. However, it is recommended to encourage them to attend formal training in diabetology to improve their knowledge.

Keywords: SGLT-2 inhibitors, Knowledge, Efficacy, Primary care, Physicians.

Introduction

Type 2 Diabetes Mellitus (T2DM) accounts for 90%-95% of diabetes cases and is characterized by relative insulin deficiency, peripheral insulin resistance, and high blood glucose levels [1]. The global prevalence of T2DM is increasing rapidly, with projections indicating a rise from 246 million to 380 million people by 2025 [2]. Saudi Arabia has one of the highest prevalence rates of T2DM globally, with recent studies showing rates as high as 30% [3].

Sodium-glucose cotransporter-2 (SGLT-2) inhibitors are a class of antihyperglycemic medications primarily used for the treatment of T2DM. These inhibitors act by blocking the SGLT-2 protein, which is responsible for reabsorbing glucose in the kidneys, this would result in the excretion of glucose through urine, leading to lower blood glucose levels [4]. SGLT-2 inhibitors have also been associated with cardiovascular and renal protective effects, making them beneficial for patients with T2DM and high cardiovascular risk [5].

Studies have highlighted the importance of educating healthcare providers about the benefits and appropriate use of SGLT-2 inhibitors to improve their prescription rates, especially in conditions like diabetic nephropathy [6, 7]. Furthermore, the potential mechanisms of action of SGLT-2 inhibitors in cancer treatment and heart failure have been explored, indicating broader applications beyond diabetes management [6].

This study aims to evaluate the knowledge and awareness of primary healthcare physicians regarding the use, efficacy, side effects, and cardiovascular and renal impacts of Sodium-glucose cotransporter-2 (SGLT-2) inhibitors among T2DM patients.

Subjects and methods

This was an analytical cross-sectional survey conducted on a representative sample of primary healthcare physicians in Makkah, Saudi Arabia; which is the capital of the Makkah Province, and it is the most populous city in Saudi Arabia. It is known for its valuable contribution to the healthcare sector, with numerous hospitals and healthcare centers. The city has a diverse population, which is beneficial to the study as it provided a wide range of responses.

The study population consists of primary healthcare physicians currently practicing in Makkah, Saudi Arabia. This includes general practitioners, and family physicians who are likely to encounter and manage patients with Type 2 Diabetes Mellitus. Primary healthcare physicians from multiple centers were invited to ensure a comprehensive representation of the primary healthcare system in Makkah. Physicians working in other specialties were excluded.

We estimate a sample size of 197, determined with consideration of the total number of physicians in Makkah Primary Healthcare Centers (400), a 5% margin of error, a 95% confidence level, and a 50% response distribution. To enhance the study's reliability and account for potential missing data, we increased the sample size by 10%, leading to a total of 216 participants.

Given the context and objectives of this study, a non-probability sampling technique, specifically convenience sampling, was employed. Through this technique, the participants are selected based on their availability and willingness to participate in the study. In this study, the researchers approached primary healthcare physicians working in Makkah, Saudi Arabia, and invite them to participate in the study. Those who agree to participate were included in the study sample.

Data for this study were collected through a self-administered questionnaire. The questionnaire was developed based on the best available literature on the subject of SGLT-2 inhibitors and their use, efficacy, side effects, and cardiovascular and renal impacts. The questionnaire was then face validated by experts in the field to ensure its relevance, clarity, and comprehensiveness.

The questionnaire is divided into two sections. The first section collects demographic information of the participants, including age, gender, nationality, marital status, and common morbidities. The second section consists of multiple-choice questions devised to assess the level of knowledge and awareness among primary healthcare physicians about SGLT-2 inhibitors. The questions cover various aspects of SGLT-2 inhibitors, including their mechanism of action, side effects, benefits, and the specific populations who may benefit from their use. For knowledge questions, a score of "1" was assigned to correct answers whereas a score of "0" was assigned to wrong answers. Total scores and their percentages were computed for every participant. Categorized of the total score for knowledge was done based on Bloom's cut-off points for knowledge; ≤59.9% for poor knowledge, 60%–79.9% for average knowledge and 80%–100% for good knowledge [8].

The questionnaire was distributed to the participants electronically for convenience and to encourage a higher response rate. The data were collected with anonymous, and confidentiality of the participants was strictly maintained. Informed consent was obtained from all participants before they complete the questionnaire.

Before beginning data collection, ethical approval was secured from the Research Ethics Committee of the Research and Studies Department at the Directorate of Health Affairs in Makkah city (No. H-02-k-076-0525-1345; dated 31 May, 2025)

Data entry and statistical analysis were performed using the Statistical Package for Social Sciences (SPSS) software, version 29. Categorical variables were described using frequency and percentage whereas numerical continuous variables were described using range, mean and standard deviation (SD). Chi-square test was applied to investigate for association between categorical variables while one-way analysis of variance (ANOVA) test was adopted to compare mean of a numerical continuous variables between three groups. P-values <0.05 were considered statistically significant throughout the analysis.

Results

A total of 249 primary healthcare physicians were participated in the study. Their demographic characteristics are summarized in Table 1. Their age ranges between 25 and 47 years with an arithmetic mean of 32.2 and standard deviation of 4.4 years. More than half (56.6%) of them were males and majority (97.6%) were Saudi nationals. Slightly over half of them (51.9%) had clinical experience range between 1 and 5 years whereas only 3.6% had an experience exceeded 15 years. Monthly income ranges between 20001 and <30000 in almost half of them (53.1%). Slightly less than half of them (47%) were registrars/senior registrars while 12% were consultants.

History of having a formal training in diabetology was mentioned by 33.7% of the physicians as illustrated in Figure 1 while history of ever prescribing SGLT-2 inhibitor medications for a diabetic patient was reported by most of them (89.2%). Figure 2

Knowledge about SGLT-2 Inhibitors

Majority of the primary healthcare physicians could recognize the primary mechanism of action of SGLT-2 inhibitors (98.8%), Dapagliflozin is an SGLT-2 inhibitor (96.4%), SGLT-2 inhibitors have been associated with positive effects on cardiovascular, renal and glycemic control outcomes (95.2%) and SGLT-2 inhibitors have been shown to be beneficial in Non-alcoholic fatty liver disease. aside from T2DM (88%). On the other hand, only 38.6% of them could recognize that based on the literature, decrease in muscle mass is a potential effect of SGLT-2 inhibitors on body composition and 24.1% knew correctly that at estimated glomerular filtration rate (eGFR) between 30 - 45 mL/min/1.73m^2, SGLT-2 agent Empagliflozin initiation is not recommended. Table 2

Overall, good level of knowledge was observed among 38.6% of the physicians whereas poor level was observed among 15.7% of them. Figure 3

Factors associated with participants` knowledge about SGLT-2 inhibitors

Males were more knowlegeable than females as good level of knowledge was observed among 44.7% of them compared to 30.6% of females, p=0.002. Youngest physicians tended to have poor level of knowledge compared to older physicians. However, the difference was borderline insignificant, p=0.050. More than a third (39.6%) of Saudi physicians compared to none of non-Saudis expressed good level of knowledge, p=0.026. The highest rate of good knowledge was observed in physicians with 6-10 years of clinical experience (45.2%) compared to 33.3% of those with higher experience, 0.046. Half of physicians whose monthly income was ≤10000 Saudi Riyals (SR) per month compared to 33.3% of those whose income ranges between 10001- and 20000 SR/month had good level of knowledge, p=0.001. Half of consultants compared to 33.3% of residents expressed good level of knowledge, p<0.001. Physicians who ever prescribed SGLT-2 inhibitor medications for a diabetic patient were more likely than their peers to have good level of knowledge about SGLT-2 inhibitors (39.2% vs. 33.3%), p=0.026. Table 3

Discussion

Given the increasing prevalence of T2DM and the significant potential benefits of SGLT-2 inhibitors in managing this disease, it is crucial to evaluate the knowledge and awareness of these medications among primary healthcare physicians; who regarded as the first line of diabetes management [9].

Vast majority of the primary healthcare physicians in the current study could recognize the primary mechanism of action of SGLT-2 inhibitors. The mechanism of action of SGLT-2 inhibitors involves targeting the SGLT-2 transporter, predominantly expressed in the brush border membrane of the renal proximal tubule, thereby reducing glucose reabsorption and promoting its excretion in the urine [10]. This mechanism results in a decrease in blood glucose levels without stimulating insulin release [11]. This mechanism of action is unique as it is insulin-independent, and makes SGLT-2 inhibitors valuable in managing hyperglycemia[12]. Additionally, SGLT-2 inhibitors have been shown to reduce glucotoxicity, circulating insulin levels, and body weight, contributing to their efficacy in conditions like non-alcoholic fatty liver disease [13].

Similarly, Milder et al (2021) reported that primary care physicians generally have a good understanding of the mechanism of action and clinical benefits of SGLT-2 inhibitors, which include improved glycemic control, blood pressure reduction, and weight loss [6]. However, some gaps in knowledge exist regarding their appropriate use in patients with varying degrees of renal impairment [6,7].

Majority of the primary healthcare physicians in the current study could recognize additional benefit of SGLT-2 inhibitors beside glycymeic control which is improvement of the cardiovascular and renal outcomes as well as weight loss. Moreover, most of them knew correctly that SGLT-2 inhibitors do not increased the risk of heart failure. The same has been reported by March et al (2022) who found that to SGLT-2 inhibitors have pleiotropic effects beyond glycemic control, such as improving cardiovascular outcomes and reducing the risk of heart failure hospitalization [14].

Majority of the primary care physicians in this study reported that use of SGLT-2 inhibitors is not associated with hypoglycemia while one of its significant adverse effects is increasing the risk of diabetic ketoacidosis. However, SGLT-2 inhibitors have shown long-term effectiveness and safety in patients with T2DM, particularly in those with impaired β-cell function, making them suitable for individuals with longstanding diabetes [15]. When used in combination with other glucose-lowering drugs, SGLT-2 inhibitors have been shown to maintain their efficacy in lowering HbA1c levels regardless of the concomitant therapy [16].

Furthermore, also majority of the physicians (nearly 90%) reported history of ever prescribing SGLT-2 inhibitor medications for a diabetic patient. Milder et al., (2021) reported underestimation of the

beneficial cardio-renal effects of SGLT-2 inhibitors by some patients and also they reported low prescription rates of the SGLT-2 inhibitors by general practitioners[6].

Only a third of primary healthcare physicians in the present study had formal training in diabetology. Moreover, those attending such training were more likely than their peers to express good level of knowledge about SGLT-2 inhibitors, although not achieving a statistical significance level. The lack of education and training on the benefits and appropriate use of SGLT-2 inhibitors is a significant reason for gaps in awareness and knowledge among healthcare workers. A study by Alqudah et al, (2022) found that community pharmacists in Jordan who attended diabetes training courses had higher knowledge scores compared to those who did not [7]. Safety concerns and unclear guidelines regarding the introduction of SGLT-2 inhibitors into treatment regimens can also act as barriers to their uptake among clinicians [6, 7].

Most of the primary care physicians in this study could identify the reported side effect of SGLT-2 inhibitors such as genitourinary tract infections, volume depletion and euglycemic diabetic ketoacidosis; however, they not increase risk of heart failure. Their effects on genitourinary tract infections and volume depletion could be attributed to their natriuretic and diuretic effects [17]. While their association with euglycemic diabetic ketoacidosis is particularly seen in patients with type 1 diabetes [18], which is highlighted by the FDA warning in 2015 [19]. Moreover, there have been reports of amputation events associated with SGLT-2 inhibitors [20].

Despite the outcomes of this study could highlights any gaps in knowledge and understanding that may exist among healthcare providers, which, in turn, can inform targeted educational interventions to ensure that T2DM patients receive the most effective and up-to-date care, the study has some important limitations that should be addressed. We could not compare our findings with others as regards the level of knowledge about SGLT-2 inhibitors and its determinants due to lack of studies. The results of the study was conducted in only one Saudi city, thus it is not practical to generalize its findings over other cities.

Conclusion

Majority of the primary healthcare physicians expressed average to good level of knowledge about SGLT-2 inhibitors, particularly males, older physicians, Saudis, those with experience of 6-10 years, physicians with lower income, consultants, and physicians who ever prescribed SGLT-2 inhibitor medications for a diabetic patient. Only a third of primary healthcare physicians in the present study had formal training in diabetology and a quite bit more knowlegeable than their peers. Based on results of this study, it is recommended to encourage primary healthcare physicians to attend formal training in diabetology.

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Table 1: Demographic characteristics of the participants (n=249)

Variables	Frequency	Percentage
Gender		
Male	141	56.6
Female	108	43.4
Age (years)		
Range	25-47	
Mean±SD	32.2±4.4	
Nationality		
Saudi	243	97.6
Non-Saudi	8	2.4
Years of experience		
1-5	129	51.9
6-10	93	37.3
11-15	18	7.2
>15	9	3.6
Monthly income in Saudi Riyals		
≤10000	12	4.8
10001-20000	81	32.5
20001-<30000	132	53.1
≥30000	24	9.6
Job category		
General practitioer	66	26.5
Resident	36	14.5
Registrar/senior registrar	117	47.0
Consultant	30	12.0

SD: Standard deviation

Table 2: Assessment of the participants` knowledge about SGLT-2 Inhibitors' use, efficacy, side effects, and cardiovascular and renal impacts (n=249)

Knowledge questions	Correct answer		
	Response	No.	%
Which of the following medications is an SGLT-2 inhibitor?	Dapagliflozin	240	96.4
What is the primary mechanism of action of SGLT-2 inhibitors?	They block the SGLT-2 protein in the kidneys, promoting glucose excretion through urine	246	98.8
What is the effect of SGLT-2 on weight?	Weight loss	192	77.1
Which of the following is not a reported side effect of SGLT-2 inhibitors?	Increased risk of heart failure	183	73.5
SGLT-2 inhibitors have been associated with positive effects on which of the following outcomes?	Cardiovascular, renal and glycemic control outcomes	237	95.2
Regarding SGLT-2 inhibitors, Which of the following is not true?	Associated with hypoglycemia	198	78.5
Which of the following is not a benefit of SGLT-2 inhibitors in patients with T2DM compared to other antidiabetic agents?	Weight gain	171	68.7
What is a significant adverse effect of SGLT-2 inhibitors?	Increased risk of diabetic ketoacidosis	210	84.3
What is the efficacy of SGLT-2 inhibitors?	Intermediate effect on Hemoglobin A1c% (0.5-0.9 %)	168	67.5
What other disease conditions have SGLT-2 inhibitors been shown to be beneficial in, aside from T2DM?	Non-alcoholic fatty liver disease	219	88.0
Which of the following estimated glomerular filtration rate (eGFR) where SGLT-2 agent Empagliflozin initiation is not recommended?	Estimated glomerular filtration rate (eGFR) between 30 - 45 mL/min/1.73m^2	60	24.1
Based on the literature, what is a potential effect of SGLT-2 inhibitors on body composition?	Decrease in muscle mass	96	38.6
What additional benefit have SGLT-2 inhibitors been associated with, beyond glycemic control?	Improved cardiovascular outcomes	186	74.7

Table 3: Factors associated with participants` knowledge about SGLT-2 inhibitors

Variables	Level of SGLT-2 inhibitors` knowledge			p-value
	Poor N=39 N (%)	**Average N=114 N (%)**	**Good N=96 N (%)**	
Gender				
Male (n=141)	27 (19.1)	51 (36.2)	63 (44.7)	
Female (n=108)	11 (11.1)	63 (58.3)	33 (30.6)	0.002*
Age (years)				
Mean±SD	30.6±4.2	32.6±4.6	32.3±4.1	0.050**
Nationality				
Saudi (n=243)	39 (16.0)	108 (44.5)	96 (39.6)	
Non-Saudi (n=6)	0 (0.0)	6 (100)	0 (0.0)	0.026*
Years of experience				
1-5 (n=129)	27 (20.9)	57 (44.2)	45 (34.9)	
6-10 (n=93)	9 (9.6)	42 (45.2)	42 (45.2)	
11-15 (n=18)	0 (0.0)	12 (66.7)	6 (33.3)	
>15 (n=9)	3 (33.3)	3 (33.3)	3 (33.3)	0.046*
Monthly income in Saudi Riyals				
≤10000 (n=12)	0 (0.0)	6 (50.0)	6 (50.0)	
10001-20000 (n=81)	24 (29.6)	30 (37.1)	27 (33.3)	
20001-<30000 (n=132)	9 (6.8)	69 (52.3)	54 (40.9)	
≥30000 (n=24)	6 (25.0)	9 (37.5)	9 (37.5)	0.001*
Job category				
General practitioer (n=66)	24 (36.4)	15 (22.7)	27 (40.9)	
Resident (n=36)	9 (25.0)	15 (41.7)	12 (33.3)	
Registrar/senior registrar (n=117)	3 (2.6)	72 (61.5)	42 (35.9)	
Consultant (n=30)	3 (10.0)	12 (40.0)	15 (50.0)	<0.001*
Having a formal training in diabetology				
No (n=165)	30 (18.2)	78 (47.3)	57 (34.5)	
Yes (n=84)	9 (10.7)	36 (42.9)	39 (46.4)	0.119
History of ever prescribing SGLT-2 inhibitor medications for a diabetic patient				
No (n=27)	9 (33.3)	9 (33.3)	9 (33.3)	
Yes (n=222)	30 (13.5)	105 (48.3)	87 (39.2)	0.026

*Chi-square test

**One-way analysis of variance test

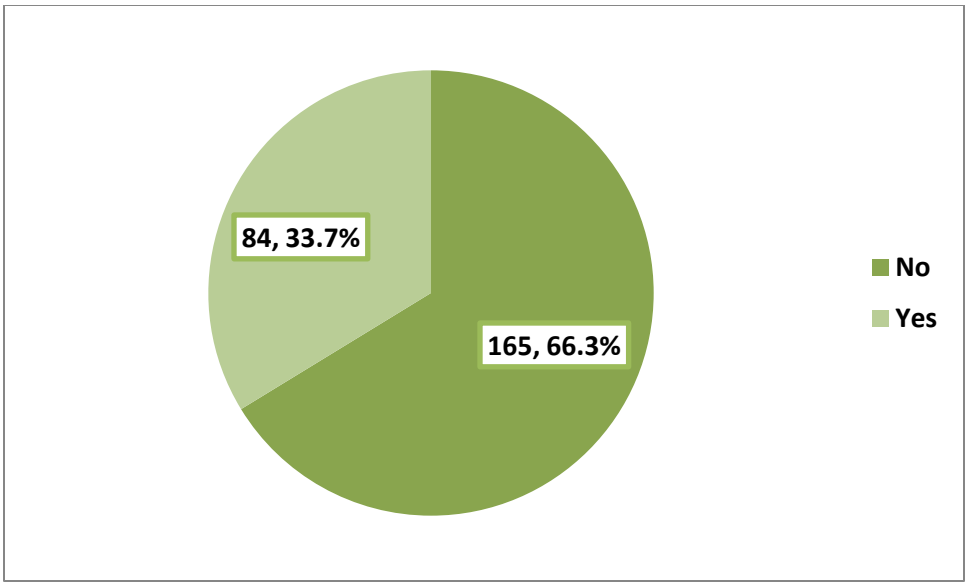

Figure 1: History of having a formal training in diabetology among the participants

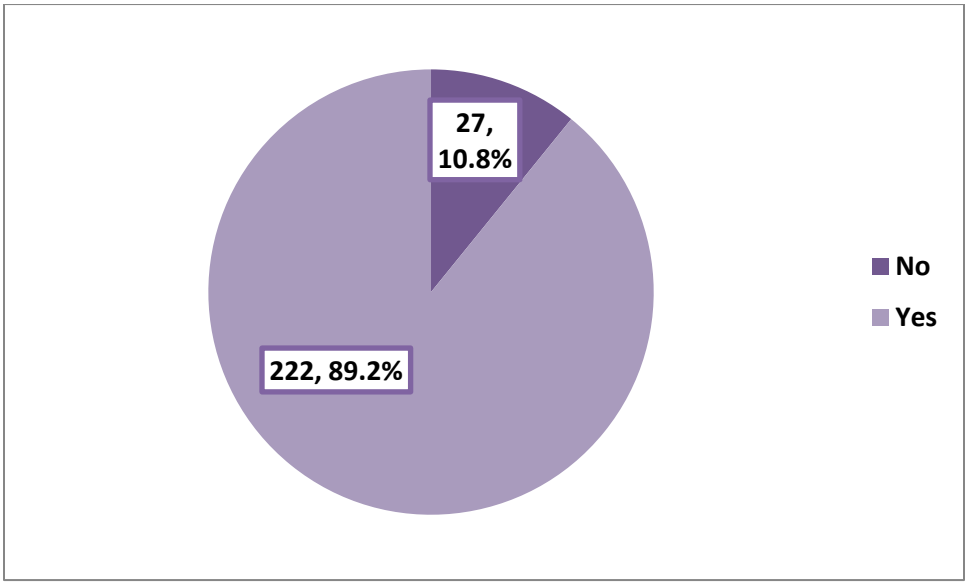

Figure 2: History of ever prescribing SGLT-2 inhibitor medicationd for a diabetic patient among the participants

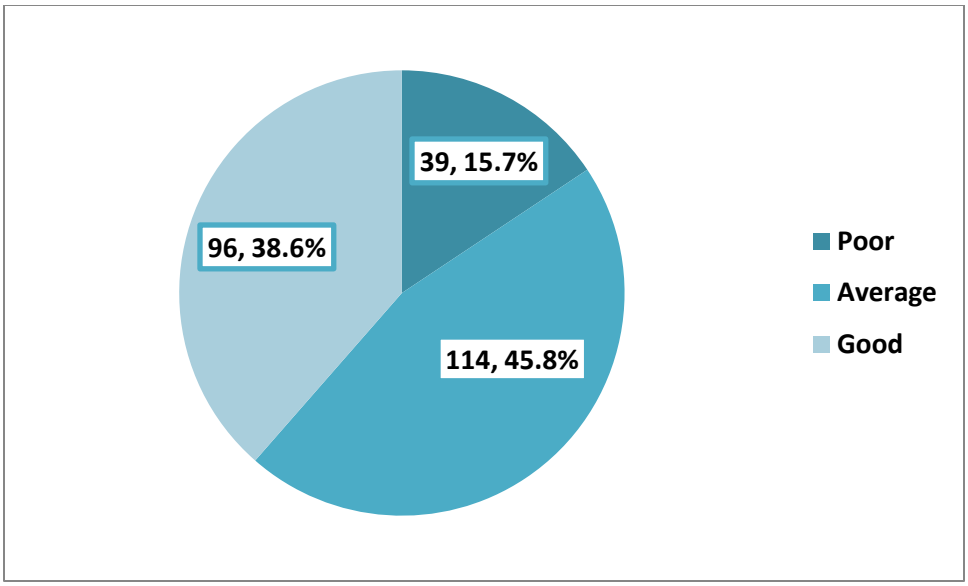

Figure 3: Overall level of knowledge about SGLT-2 inhibitors among the participants