Prediction of Glycated Hemoglobin (HbA1c) Using Physical Activity, Eating Behavior and Medication Adherence in Bhutanese Patients with Type 2 Diabetes

นิพนธ์ต้นฉบับ

Original Article

ซิเทอร์ ดอร์จิ[1], อาภรณ์ ดีนาน[2]* และ เขมารดี มาสิงบุญ[2]

[1] นิสิตหลักสูตรพยาบาลศาสตรมหาบัณฑิต (หลักสูตรนานาชาติ)

[2] กลุ่มวิชาการพยาบาลผู้ใหญ่

[1-2] คณะพยาบาลศาสตร์ มหาวิทยาลัยบูรพา 169 ถ.ลงหาดบางแสน ต. แสนสุข อ. เมือง จ. ชลบุรี 20131

* **ติดต่อผู้นิพนธ์:** apornd@buu.ac.th

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Sither Dorji[1]*, Aporn Deenan[2] and Khemaradee Masingboon[2]

[1] Master of Nursing Science student (International Program)

[2] Adult Nursing Division

[1-2] Faculty of Nursing, Burapha University, 169 Long-had, Bangsaen Road, Saensuk, Chonburi, 20131, Thailand

* **Corresponding author:** apornd@buu.ac.th

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บทคัดย่อ

วัตถุประสงค์: เพื่อตรวจสอบการทำนายระดับน้ำตาล (เฮโมโกลบิน) A1c โดยปัจจัยการออกกำลังกาย พฤติกรรมการรับประทานอาหารและความร่วมมือในการใช้ยาของผู้ป่วยเบาหวานชนิดที่ 2 ชาวภูฏาน **วิธีการศึกษา:** ใช้การวิจัยเชิงพรรณนาที่หาความสัมพันธ์ของตัวแปร ดำเนินงานในเดือนมีนาคม 2560 โดยใช้กลุ่มตัวอย่างแบบสุ่มซึ่งใช้สุ่มอย่างง่ายในผู้ป่วยผู้ใหญ่ที่เป็นเบาหวานชนิดที่ 2 จำนวน 88 ราย ที่มารับบริการที่คลินิกผู้ป่วยนอกโรคเบาหวานของโรงพยาบาลทั่วไปพุนโซลิ้งในประเทศภูฏานฝั่งตะวันตก เก็บข้อมูลด้วยแบบสอบถามซึ่งประกอบด้วยข้อมูลส่วนบุคคล แบบสอบถามการออกกำลังโดยรวม แบบสอบถามการจัดการตนเองของผู้ป่วยเบาหวานและแบบสอบถามความร่วมมือในการใช้ยาฉบับสั้น วิเคราะห์ข้อมูลด้วยสถิติเชิงพรรณนาสำหรับข้อมูลของผู้ป่วยและสถิติถดถอยพหุคูณสำหรับการทำนายระดับน้ำตาล A1c **ผลการศึกษา:** กลุ่มตัวอย่างมีค่าเฉลี่ยของระดับน้ำตาล A1C ในเลือดเท่ากับ 7.33% (*SD* = 1.53) ระดับน้ำตาล A1C นี้มีความสัมพันธ์อย่างมีนัยสำคัญในทางเดียวกับความร่วมมือในการใช้ยา (r = 0.24, P-value < 0.05) กล่าวคือคะแนนสูงหมายถึงความร่วมมือในการใช้ยาต่ำ และความสัมพันธ์ที่ตรงกันข้ามกับการออกกำลังกาย (r = -0.37, P-value < 0.01) และพฤติกรรมการรับประทานอาหาร (r = -0.83, P-value < 0.01) โดยปัจจัยทั้งสามสามารถอธิบายความแปรปรวนของ HbA1c ได้ 38.2% (R^2 = 0.382, P-value < 0.001) ปัจจัยที่สามารถทำนายระดับน้ำตาล A1C ได้มากที่สุดคือพฤติกรรมการรับประทานอาหาร (β = -0.426, P-value = 0.001) ตามด้วยการออกกำลังกาย (β = -0.277, P-value = 0.003) และความร่วมมือในการใช้ยา (β = 0.229, P-value = 0.01) **สรุป:** ผลการศึกษานี้สะท้อนถึงบทบาทของปัจจัยการออกกำลังกาย พฤติกรรมการรับประทานอาหารและความร่วมมือในการใช้ยาที่มีต่อระดับน้ำตาล A1C ของผู้ป่วยเบาหวานชนิดที่ 2 ในการส่งเสริมการควบคุมระดับน้ำตาลในเลือดให้ดีขึ้นจึงต้องเน้นการปรับปรุงพฤติกรรมสุขภาพทั้งสามประการดังกล่าว

คำสำคัญ: ระดับน้ำตาล A1c, การออกกำลังกาย, การรับประทานอาหาร, ความร่วมมือในการใช้ยา, เบาหวานชนิดที่ 2

Abstract

Objective: To examine the prediction of glycated hemoglobin (HbA1c) based on physical activity, eating behavior and medication adherence in Bhutanese patients with type 2 diabetes. **Method:** A descriptive study with the correlational method was conducted in March 2017. A sample with simple random sampling was 88 adult patients with type 2 diabetes visiting the diabetic outpatient clinic of Phuntsholing General Hospital in Western Bhutan. Data were collected using the structured questionnaires that included a demographic questionnaire, global physical activity questionnaire, self-management diabetic behavioral questionnaire, and short medication adherence questionnaire. Descriptive statistics was performed for the demographic data and a multiple regression analysis for the prediction of HbA1c. **Results:** The participants had a mean HbA1c level of 7.33% (SD = 1.53). HbA1c was significantly associated with patients' medication adherence (r = 0.24, P-value < 0.05), i.e. higher scores indicating lower adherence, and inversely associated with patients' physical activity (r = -0.37, P-value < 0.01) and eating behavior (r = -0.83, P-value < 0.01). The three factors could explain 38.2% of HbA1c variance (R^2 = 0.382, P-value < 0.001). Patients' eating behavior was the strongest predictor of HbA1c in this sample (β = -0.426, P-value = 0.001), followed by physical activity (β= -0.277, P-value = 0.003) and medication adherence (β = 0.229, P-value = 0.01). **Conclusion:** The findings of this study shed additional light on the roles of eating behavior, physical activity, and medication adherence in HbA1c of adult patients with type 2 diabetes. To promote a better HbA1c control, the improvement of the three health behaviors should be emphasized.

Keywords: glycated hemoglobin, physical activity, eating behavior, medication adherence, type 2 diabetes

Introduction

Type 2 Diabetes (T2D) is one of the most common chronic non-communicable diseases in nearly all countries, and continues to increase in numbers and significance, due to changing lifestyles.[1] According to the global reports on diabetes, World Health Organization (WHO, 2016), the number of people with diabetes increased nearly four times since 1980, from 108 million in 1980 to 422 million in 2014 and type 2 diabetes was accounted for 90% of people with diabetes in 2014.[2] Four hundred fifteen million adults worldwide were living with diabetes in 2015 (a global prevalence of 8.8%), and the estimation is projected to rise to more than 642 million by 2040.[3] It is projected that there will be a 69% increase in numbers of adults with diabetes in developing countries and a 20% increase in developed

countries.[1] In 2012, WHO estimated 1.5 million deaths were directly caused by diabetes and higher than optimal blood glucose was responsible for an additional 2.2 million deaths as a result of increased risks of cardiovascular and other diseases, for a total of 3.7 million deaths related to blood glucose levels in 2012.[5] Furthermore, the global health expenditure on diabetes was expected to total at least 376 billion US dollars in 2010 and 490 billion US dollars in 2030.[6] It has been estimated that the direct annual cost of diabetes to the world is more than 827 billion US dollars [7] and the total global health-care spending on diabetes more than tripled over the period of 2003 to 2013.[8]

The major problem of T2D people is uncontrolled blood sugar which leads to complications which further increase the risk of premature death. Hyperglycemia is the principal cause of microvasculopathy but also appears to play an important role in causation of macrovasculopathy.[9] Adults with diabetes historically have a two or three times higher rate of cardiovascular disease (CVD) than adults without diabetes.[10] People with T2D not only suffer from physical symptoms and complications but the illness also affects their psychosocial well-being. To reduce progression, T2D patients have to control their blood glucose on a lifelong basis. Controlling glucose to near-normal levels is the key to avoiding emergencies and long-term complications and preventing target organ damage.[11] The critical components of glycemic control among T2D is the lifestyle management including physical activity, nutrition therapy, and pharmacological therapy.[2] The main goal of diabetes management is to restore carbohydrate metabolism to a normal state and prevent complications of the kidney, eye, nerve, heart, and blood vessel.[12-14]

HbA1c is the best marker of chronic glycaemia.[15,16] Achieving near-normal HbA1c levels has shown to determine whether the treatment is adequate and to guide adjustments.[17,18] HbA1c has a very strong association with the onset of diabetes complications, and moreover, the progression of complications can be slowed if HbA1c is well maintained during the early stage of diabetes.[19] Blood HbA1c levels can indicate how well diabetes is controlled over the past six to eight weeks and is commonly considered to reflect the integrated mean glucose level over the previous 8 – 12 weeks.[15] The cut-off point of HbA1c at $\geq$ 6.5% is recommended by WHO for diagnosis of diabetes.[20] HbA1c of < 7% is targeted for a good control of diabetes persons.[21] Factors influencing blood sugar level in T2D includes dietary intake (carbohydrate), physical activity, medication adherence, insulin level, side effects of medications (steroids, anti-psychotic), illness, stress, pain, alcohol consumption, and dehydrations.[22-24] Several studies and clinical trials have provided strong evidences of the association between lowering value of HbA1c and exercise in type 2 diabetes persons.[25,26] Shadman et al. found that carbohydrate intake was inversely associated with HbA1c (P–value < 0.0001, R^2 = 15%).[27] Similarly, Haimoto et al. found that HbA1c decreased sharply from baseline of 10.9 $\pm$ 1.6% to 7.8 $\pm$ 1.5% at 3 months and to 7.4 $\pm$ 1.4% at 6 months with 30% carbohydrate diet in severe T2D.[28] Additionally, medication adherence was found significantly associated with lower HbA1c (r = -0.346, P–value < 0.001).[29]

The present study was guided by the Translating Research Into Action for Diabetes (TRIAD) conceptual model.[30] The TRIAD assesses and evaluates whether managed care organizations' structures and strategies affect the processes and outcomes of diabetes care among adults. The TRIAD also identifies the barriers to and facilitators of high-quality care and optimal health outcomes associations between system-level structures and strategies and the quality of diabetes care and patient outcomes. Fixed patient factors influence the behaviors such as self-management, adherence, physical activity which directly affect the outcome, which is HbA1c. The outcome is the goals achieved through behaviors, which is influenced by the patient-physician interactions, psychosocial factors and fixed patient factors. From TRIAD conceptual model, three concepts of health behavior including physical activity, eating behavior, and medication adherence were selected in this study. Glycemic control or HbA1c value is viewed as the health outcome of the behavior in T2D patients.

Physical activity plays a key role in the management of type 2 diabetes and glycemic control.[31] Physical activity help people with diabetes improve glycemic control by reducing insulin resistance; decreasing blood sugar; increasing the number of receptors and sensitivity of cells to insulin concentration in tissue and can aid both in the prevention and management of 2 type diabetes.[32,33] Patients with type 2 diabetes exercising either at moderate or high intensities can experience similar results.[34] Bajpeyi and colleagues found exercise increased insulin sensitivity after 15 days of exercise training[35] and they also found a dose-response of

physical activity associated with HbA1c, higher amounts of physical activity associated with lower HbA1c.[36]

Healthy eating behavior is one of the most important behavioral strategies to control blood glucose level in T2D people.[12] However, less than half of individuals with T2D meet the recommended daily servings from food groups, including fruits and vegetables; while many diabetic persons struggle with food intake regulation compounded by a history of dieting and weight cycling.[37] A study by Babio (2010) revealed that low carbohydrate and low fat hypo-caloric diets led to an improvement in HbA1c level[23] and carbohydrate was associated with HbA1c (r = 0.38, P-value < 0.0001,).[27] Similarly, Haimoto[28] reported that restricting carbohydrate diet to 30% led to a greater reduction in HbA1c as compared to diets high in carbohydrates within 6 months. A variety of eating patterns have shown modestly effective in managing diabetes including Mediterranean-style, Dietary Approaches to Stop Hypertension (DASH) style, plant-based (vegan or vegetarian), lower-fat, and lower carbohydrate patterns.[38,39] It is encouraging to consume diets high in fiber on a daily basis because of their beneficial effect on HbA1c.[40] Interestingly, regular consumption of fish improved HbA1c level and had positive effects on glycemic control.[41]

Medication adherence among patients with chronic diseases is crucial. It was revealed in many studies that medication adherence was significantly associated with lower HbA1c.[24,42] Poor medication adherence has been associated with up to a 3.4% rise in HbA1c. Conversely, optimal adherence promotes a greater likelihood of achieving target.[43] Quantitative measures of adherence in the Diabetes Audit and Research have shown a significant inverse association between medication adherence and HbA1c levels, which remain after adjustments for all other covariates (r = 0.62, P-value = 0.001).[42]

The prevalence of T2D in Bhutan has increased threefold over the past five years, from 3,740 cases in 2011 to 12,384 cases in 2015.[4] The Royal Government of Bhutan has already identified diabetes care as the key area to be developed in its 9th 5-Year Plan 2002 - 2007. Furthermore, according to the 11th Five-year plan (2013-2018), the Ministry of Health of the Royal Government of Bhutan would focus on the prevention of non-communicable diseases (NCDs) such as diabetes.

Additionally, the STEPwise approach to risk factors surveillance recommended by WHO in 2014, found that Bhutanese population was at risk for the T2D. The survey found that 66.9% took less than five servings of fruits and vegetables, 6.4% had insufficient physical activity and 33% were overweight. The prevalence of impaired fasting glycaemia among the adult Bhutanese was 10.7% and 6.4% adult Bhutanese had a raised fasting glucose level.[44] A first nationwide study done in Bhutan found that glycemic control was achieved in only 85 (38 %) of 226 patients retained in care.[45]

A review of literature on type 2 diabetes and HbA1c revealed that adults with type 2 diabetes achieving near-normal level of HbA1c helps slow down the progression of complications. From the above background knowledge, it is evident that HbA1c is a very important indicator of glycemic control in people with T2D. There were evidences showing the influence of physical activity, eating behavior, and medication adherence on HbA1c. Despite the significance of HbA1c, there is limited information about the HbA1c among type 2 diabetes in Bhutan. Thus, this study focused on the influence of physical activity, eating behavior and medication adherence on HbA1c. The study findings could be helpful for designing nursing intervention to maintain a near-normal HbA1c level.

Methods

Design and setting

A predictive correlational design was used in this study. The influences of physical activity, eating behavior, and medication adherence on HbA1c were examined among type 2 diabetes persons living in Phuntsholing, Bhutan. This study was conducted at the diabetic outpatient clinic of Phuntsholing General Hospital (PGH), located in Chukha district, the western part of Bhutan. Phuntsholing is one of the hugely populated commercial hub in Bhutan. The study was conducted during the month of March and April, 2017.

Population and sample

The target population of this study was adults diagnosed with type 2 diabetes mellitus who visited the outpatient diabetic clinic at Phuntsholing general hospital. The study sample consisted of 88 adults diagnosed with type 2 diabetes attending the outpatient diabetic clinic during the study period. The inclusion criteria were that these patients

were 1) diagnosed with T2D at least 6 months, 2) currently on treatment with diabetic medications, 3) with age between 20 - 65 years, 4) with HbA1c test in the last 2 months, 5) able to read and write in English, and 6) with no physical disability and no severe conditions such as heart disease, kidney disease or stroke.

The sample size in this study was calculated based on the Thorndike's formula, $N \geq 10(k) + 50$, where N is the sample size and k is the number of independent variables. Since this study had 3 independent variables, a sample size of 80 participants was a result. However, missing data were a pervasive problem in most social science research. Therefore, 10% of participants were added to compensate for the missing data. As a result, a total of 88 participants were recruited.

Research instruments

Data were collected using four questionnaires. The first part of the questionnaires, developed by the researcher, asked the participants about their demographic information. The first six 6 items asked about age, gender, marital status, incomes, education level, and occupation. The rest 6 items recorded the participant's height, weight, and diabetic medications from the participant's health book, and fasting blood sugar, 2- HPP, and HbA1c levels from the hospital laboratory report.

The second set of questionnaires was the **Global Physical Activity Questionnaire (GPAQ).** Physical activity was measured by the GPAQ developed by WHO for physical activity surveillance.[46] Physical activity participation in three domains as well as the sedentary behavior was evaluated by 16 questions (P1 - P16). These three domains included activity at work (P1 - P6), travel to and from places (P7 - P9), recreational activities (P10 - P15). The sedentary behavior was evaluated by one item (P16). The researcher interviewed the participants using the show card developed by the WHO to let the participants understand the vigorous and moderate activities with examples. To interpret the GPAQ data, metabolic equivalent (MET) was calculated. One MET is defined as 1 kcal/kg/hour and is equivalent to the energy cost of sitting quietly.[46] Based on the person's overall energy expenditure, 4 METs was assigned to the time spent in moderate activities, and 8 METs to the time spent in vigorous ones. Physical activity throughout a week which included all activities during the time of work, transport and leisure were combined. The test-retest reliability of the GPAQ was high with a correlation coefficient of 0.90 in this study.

The third set of questionnaires was the **Self-Management Diabetes Behavioral Questionnaire (SMDBQ)** for evaluating eating behavior. SMDBQ was developed by Primander et al. (2011).[47] SMDBQ comprises of four dimensions with total of 33 statements. These four dimensions recognizing the amount of calorie needs (4 items), selecting healthy diet (16 items), arranging a meal plan (6 items), and managing dietary behavioral challenges (7 items). There are 28 positive and 5 negative statements in SMDBQ. Response for SMDBQ is a 4-point Likert-type rating scale ranging from 1 "never" to 2 "sometimes," 3 "often," and 4 "routinely" for positive statements and from 4 to 1 for the negative ones. The total SMDBQ scores could range from 33 to 132, with a higher score indicating a better dietary behavior. SMDBQ was classified into three levels representing low (33 - 66), moderate (67 - 100), and high (more than 100). Internal consistency reliability in this study was high with a Cronbach's alpha coefficient of 0.85.

The last part of the questionnaire was the **Simplified Medication Adherence Questionnaire (SMAQ)** to measure medication adherence. SMAQ was developed by Knobel et al. (2002).[48] SMAQ consists of six items. Item 1, 2, 3, and 4 have a response choice of "yes" or "no". Item 5 asks about the frequency of missed medication in the last week and has a response of 5 choices (A = never, B = 1 – 2 times, C= 3 – 5 times, D = 6 - 10 times and E = more than 10 times). Item 6 asks how many days of missed medication during past three months. The person is considered non-adherent if responses to item 1 = Yes, 2 = No, 3 = Yes, 4 = Yes, 5 = C, D or E, and 6 = more than two days. The participant's response to item 5 was categorized using semi-quantitative approach where A = 95 - 100% adherent, B = 85 - 94% adherent, C = 65 - 84% adherent, D = 30 - 64% adherent, and E = less than 30% adherent. Higher scores of SMAQ suggest lower adherence. Internal consistency reliability of SMAQ was high with a Cronbach's alpha coefficient of 0.83.

Data collection procedure

The research was approved by the Institutional Review Board for Graduates Studies, Faculty of Nursing, Burapha University, Thailand (approval no. 02-02-2560). Further, it was reviewed and approved by the Research Ethics Board

of Health, Ministry of Health of Bhutan. The permission for data collection was obtained from the medical superintendent of the Phuntsholing General Hospital.

The participants were recruited solely on a voluntary basis. The written consent from the participant was obtained prior to the data collection. The researcher collected the registration numbers of the patients distributed during the period of 8:30 to 9:00 am after screening those who met the inclusion criteria. These numbers were mixed in a container, and then randomly picked to obtain the study participants. In order to maintain the quality of data collection, 6 - 10 participants were recruited each day. It took about 30 – 40 minutes to complete the questionnaire.

Data analyses

Data were coded and entered into a statistical software for analysis. The statistical significance with an alpha level of 0.05 was set. Data were tested for normality and assumptions applicable for standard multiple regression analysis. Descriptive statistics were used to describe the demographic information data. Multiple regression analysis was used to examine the predicting factors of HbA1c.

Results

A total of 88 participants who met the inclusion criteria were recruited for the study. The participants had a mean age of mean age of 51.68 years (*SD* = 8.66) (Table 1). There were more women (54.5%) than men (45.5%). Majority of the participants (50%) had finished primary education. Additionally, 89.8% of the participants were married and majority of them were working in private sectors (37.5%). The average monthly income of the sample was 14,755.68 Bhutan Nu. (approximately 228 US dollars).

Health information of the sample

The length of the time being diagnosed with type 2 diabetes ranged from 1 - 17 years with a mean age of 4.64 years (*SD* = 3.96). The average fasting blood sugar was 152 mg/dL, while 56.2% had it uncontrolled. Most of the participants (78.7%) had their 2-hour postprandial blood sugar uncontrolled. The mean HbA1c level was 7.33% (*SD* = 1.53) with 48.9% had their HbA1c controlled (< 7%) and 51.1% uncontrolled (≥ 7%). The most commonly used oral antidiabetic medicines were biguanides with sulfonylureas accounting for 63.6% combined. Among the participants, BMI of normal range and overweight were equal each accounting for 38.6% of participants.

Table 1 Demographic characteristics of the participants (N = 88).

Characteristics	*N*	%
Gender		
Male	40	45.5
Female	48	54.5
Age (years) (mean = 51.63, *SD* = 8.57; Min = 32, Max = 64)		
20 - 39	8	9.1
40 - 59	58	65.9
> 60	22	25.0
Education		
Primary school	44	50.0
High school	32	36.4
College (graduate or above)	12	13.6
Marital status		
Married	79	89.8
Single/divorced/widowed	9	10.2
Occupation		
Government service	4	4.5
Private sectors	33	37.5
Retired	11	12.6
Farmer	19	21.6
Others	21	23.9
Income (Ngultrum) (mean = 14,755.68, *SD* = 9192.69; Min = 5,000, Max = 60,000)		
Nu. 6000 - 11000	43	48.9
Nu. 12000 - 17000	27	30.6
Nu. 18000 - 23000	7	8.0
Nu. ≥ 24000	11	12.5

Table 2 Description of the participants by health status (N = 88).

Information	*N*	%
Duration diabetes (years) (mean = 4.64, *SD* = 3.96; Min = 1, Max = 17)		
1 – 5	63	71.5
6 – 10	18	20.5
> 10	7	8
Body mass index (kg/m^2) (mean = 26.81, *SD* = 4.51; Min = 15.2, Max = 44.9)		
< 18	1	1.1
18.5 – 24.9	34	38.6
25 – 29.9	34	38.7
> 30	19	21.6
HbA1c (%) (mean = 7.33, *SD* = 1.53; Min = 4, Max = 13.3)		
< 7 %	43	48.9
≥ 7 %	45	51.1
Fasting blood sugar (mg/dL) (mean = 152.2, *SD* = 57.49)		
80 – 130	39	43.8
> 130	49	56.2
2-HPP blood sugar (mg/dL) (mean = 250.36, *SD* = 84.32)		
< 180	19	21.3
> 180	69	78.7
Oral medication	88	100.0
Biguanides/sulfonylureas	28	31.9
Both biguanides and sulfonylureas	56	63.6
Both insulin and oral diabetic medication	4	4.5

Predictors of HbA1c among persons with type 2 diabetes in Bhutan

It was found that HbA1c was significantly negatively correlated with physical activity and eating behavior (r = -0.371, P–value < 0.01 and r = -0.525, P–value < 0.01, respectively) (Table 3). In addition, HbA1c was positively correlated with medication adherence (r = 0.235, P–value < 0.05 respectively).

Table 3 Pearson's product moment correlation analysis between predictors and HbA1c (N = 88).

	Physical activity	Eating behavior	Medication adherence
Eating behavior	0.289**		
Medication adherence	0.124	-0.094	
HbA1c	-0.371**	-0.528**	0.235*

* P-value < 0.05, ** P-value < 0.01.

Based on the regression analysis, physical activity, eating behavior, and medication adherence together significantly explained 38.2% of the variance in HbA1c (R^2 = 0.382, P–value < 0.001) (Table 4). Particularly, eating behavior explained the most variance in HbA1c (β = 0.426, P–value = 0.001), followed by physical activity (β = 0.277, P–value = 0.003), and medication adherence (β = 0.229, P–value = 0.01).

Table 4 Summary of regression analysis for predicting HbA1c (N = 88).

Variables	β	t	*P*-value
Physical activity	-0.277	-3.050	0.003
Eating behavior	-0.426	-4.707	0.001
Medication adherence	0.229	2.628	0.01

R^2 = 0.382, $F_{(3, 84)}$ = 17.27, P-value < 0.001

Discussions and Conclusion

In this study, the mean HbA1c level of 88 Bhutanese people with type 2 diabetes was 7.33% (SD = 1.53) indicating a poor blood sugar control based on the ADA (2017) recommendation of a level of < 7%.[21] The study revealed that physical activity, eating behavior, and medication adherence significantly explained 38.2 % of the variance in HbA1c (R^2 = 0.382, P-value < 0.001). The factor that explained most of the variance of HbA1c among persons with type 2 diabetes in Phuntsholing was eating behavior (β = 0.426, P–value = 0.001), followed by physical activity (β = 0.277, P–value = 0.003), and medication adherence (β = 0.229, P–value = 0.01). These predictions can be explained by the Translating Research Into Action for Diabetes (TRIAD) model[30] which suggests that behaviors such as physical activity, diet, and adherence which is influenced by the fixed patient factors such as demographics, socioeconomics and environment. These factors directly and indirectly influence the objective outcomes such as HbA1c level.

For **physical activity,** the present study assessed participants' expenditure of energy with moderate or vigorous intensity for at least 10 minutes continuously in three domains of activity including work, travel to and from places, and recreational activities. Overall, participants had a moderate level of physical activity with a mean of 1,918.14 ± 1,943.52 MET-mins. Regarding different subscales, physical activity which was work-related had the highest mean score of 927.77 MET-mins, followed by travel to and from places and recreational activities. For most participants, physical activity was mainly due to the work which was found to be at a high level among the farmers and others whose work needed to take many hours walking uphill as part of their job. Recreational activities related physical activity was observed with the minimum mean score of 473.63 MET-mins. Overall, majority of the participants didn't engage in any kinds of recreational activities.

Physical activity was inversely correlated with HbA1c indicating those who performed higher physical activity had lower HbA1c levels (good control of diabetes). The correlation was moderate (r = -0.37, P-value < 0.01). Multiple regression analysis revealed that physical activity influenced HbA1c (β = 0.277, P–value = 0.003). The possible mechanism is that physical activity causes an increased glucose uptake into active muscles balanced by hepatic glucose production, with a greater reliance on carbohydrate to fuel muscular activity as the intensity increases.[25] Physical activity with moderate and vigorous intensity is also associated with both acute and chronic improvements in insulin action.[26] Several factors influence exercise fuel use. However, the most important factor is the intensity and duration of physical activity.[35] Findings from the study was consistent with many previous studies. Clinical trials have provided a strong evidence for the HbA1c-lowering value of physical activity in older adults with type 2 diabetes.[25] A study about dose-response assicaition of physical activty

by Gay (2016) found that higher amounts of physical acitvity were assocaited with lower HbA1c.[36]

For **eating behavior,** participants' eating behavior was at a moderate level with a mean of 92.18 ± 9.41and inversely correlated with HbA1c (r = -0.53, P-value < 0.01). Eating behavior predicting the HbA1c could be explained by the nature of diabetes caused by islet β cells being unable to secrete adequate insulin in response to varying degrees of nutrition or eating behavior, consequential overweight, and insulin resistance. All of these causes result in an accumulation of glucose to a component of hemoglobin, HbA1c. The moderate eating behavior in this study could be explained based on the fact that Bhutanese's eating behavior included three meals daily consisting of mainly rice.[49] High carbohydrate intake is assocaited with metabloic abnormalities leading to worsening of glycemic control. It was also suggested that food selection was not followed appropriately as recommended and was most likely from rice being the staple diet. It was evident that cultural backgroud served as important influences on dietary behavior.[50] Less than half of individuals with type 2 diabetes meet the recommended daily servings from food groups, including fruits and vegetables while many struggle with food intake regulation compounded by a history of dieting and weight cycling.

A healthful eating pattern is one of the key components of diabetes management.[39] ADA (2016) states that the list of leading risk factors for diabetes includes multiple components of diet, and poor diets constitute the number-one driver of the global burden of diseases.[12] A healthy diet should include the many components thought to be beneficial for cardio-metabolic risk, including all specific types of fat, carbohydrate and protein. All diets associated with prevention of type 2 diabetes share common components, including increased intake of fruit, vegetables, whole grains, nuts, legumes, healthy table oils and proteins, little or moderate alcohol, and reduced intake of processed meats and sugar-sweetened beverages.[51]

Monitoring carbohydrate intake and considering the blood glucose response to dietary carbohydrate are crucial for improving postprandial glucose control. The inverse correlation between eating behavior and HbA1c in this study is consistent with many previous studies. Healthy eating behavior is one of the most important behavioral strategies to control blood glucose level in T2D people.[12] A low carbohydrate and low fat hypo-caloric diets led to an improvement in HbA1c level and carbohydrate was associated with HbA1C (r = 0.38, P-value < 0.0001).[23,27] Study conducted by Haimoto reported that restricting carbohydrate diet to 30% led to a greater reduction in HbA1c as compared to diets high in carbohydrates.[28]

The last variable was **medication adherence**. The analysis of medication adherence for diabetic medication revealed that the mean score was (M = 0.57, SD = 0.88) and positively correlated with HbA1c (r = 0.24, P-value < 0.05), indicating good adherence to medication (low SMAQ score) resulted in good control of diabetes (low HbA1c level). It was also found that 90.9% of the participants never forgot their medication one week prior to the date of data collection (95 - 100% adherent). However, when the timeframe was the past 3 months, only 60.2% reported that they never missed their medication. It was known that medication adherence among patients with chronic diseases were as low as 50%.[52] The finding of the study was consistent with the previous studies that good medication adherence was assocaied with lower HbA1c.[42]

The findings provided important information for designing effective nursing intervention. It also suggested the need to reinforce type 2 diabetes patients to be more confident and motivated to adhere to healthy eating behavior, physically active lifestyle and adherence to diabetic medications. The findings were consistent with many previous studies of individual variables of physical activity, eating behavior, and medication adherence on HbA1c. However, there were no studies done on all these three variables predicting HbA1c in one study. A study by Shadman et al. (2013) about association of the diet with HbA1c in high calorie consuming type 2 diabetics showed that carbohydrate intake was associated with a rise in HbA1C (r = 0.38, p < 0.0001).[27] Similary, the study about dose-response assicaition of physical activty found that higher amounts of physical acitvity were assocaited with lower HbA1c.[36] A study on medication adherence in type 2 diabetes found that optimal adherence promotes a greater likelihood of achieving target.[43]

The findings of the study established that Bhutanese with type 2 diabetes had a mean level of HbA1c higher than the recommended level of < 7%. The results indicated significant relationships between physical activity, eating behavior, and

medication adherence to HbA1c among persons with type 2 diabetes in Phuntsholing, Bhutan. All three variables explained the appreciable amount of variance in HbA1c. Therefore, findings of the present study were consistent with other researches and TRAID model.

In terms of implications, the results of this research added to the literature examining the influences of physical activity, eating behavior, and medication adherence to HbA1c and provided a better understanding on HbA1c among Bhutanese adults with type 2 diabetes. Moreover, findings of this study could provide pragmatic evidence for nurses to enhance type 2 diabetic person's HbA1c control by developing proper interventions accordingly. The confirmation of the role of physical activity, eating behavior, and medication adherence on HbA1c is the basis for clinical nurses to perform specific interventions on promoting the physical activity, eating behavior, and medication adherence. Furthermore, nurses should make patients understand about the benefits of controlling HbA1c levels to help people sustain their commitments to healthy eating behavior, physical activity, and medication adherence. Nurse educators can educate nurses and student nurses about the importance of physical activity, eating behavior, and medication adherence on type 2 diabetic individuals' HbA1c.

This study was not free of limitations. Since the sample was limited only to the people with type 2 diabetes who visited the diabetic outpatient clinic in Phuntsholing general hospital, Bhutan, the findings were limited in generalizability. We recommend future research should replicate the study in different wider settings. The sample might not represent the whole population as those people with type 2 diabetes who were unable to read and write in English were excluded from the study due to the language of the questionnaire.

In conclusion, the study examined the prediction of physical activity, eating behavior, and medication adherence on HbA1c among type 2 diabetes persons in Phuntsholing, western Bhutan. Overall HbA1c was higher than the recommended target level of < 7%. All three studied variables were significant predictors of HbA1c. The study findings confer the importance of enhancing the factors that influence the HbA1c levels among persons with type 2 diabetes. Understanding these predictors will help clinical nurses in particular to provide knowledge, skills and resources necessary to promote good control of diabetes.

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