# The Energy Expenditure During Exercise in Type 2 Diabetes Mellitus Patients

**Shaima Abdulhadi Jasim**
**Medical Physiology Department, College of Medicine - Ninevah University, Mosul, Iraq**
**Correspondence: shaimaabdulhadihassims@gmail.com**

**(Ann Coll Med Mosul 2023; 45 (1):120-126).**
**Received: 18th Sept. 2022; Accepted: 25th May 2023.**

## ABSTRACT

***Background:*** Exercise or physical activity is considered of key importance in the clinical management of patients with type 2 diabetes mellitus T2DM and has therefore been included inthe guidelines for diabetes prevention and treatment,

***Aim:*** this study aims to evaluate the relationship between energy expenditure and T2DM parameters during the evaluation of functional exercise capacity.

***Materials and Methods:*** the case series study was included 100 individuals with type 2 diabetes mellitus T2DM. The patients with physical or cognitive disabilities, uncontrollable cardiovascular disease, heart failure, arrhythmia, pulmonary disease, liver failure, kidney failure, cancer, neurological and orthopedic diseases were excluded from this study. Informed consent was obtained from all individuals participating in the study. Data were analyzed with SPSS software (version 25, IBM., NY, U.S.A.)

***Results:*** The patients included in the study were clinically stable. When the visceral adipose index ( VAI) values of individuals according to age are examined, 29.4% had no adipose tissue dysfunction, 5.9% had mild, 35.3% moderate, 29.4% had severe adipose tissue dysfunction. The mean PCI was 0.37 ±0.18 (beats/m). When individuals are classified according to the physiological expenditure index, Physiological cost index (PCI ) values are below 0.23 beats/m in 23.5% of individuals, between 0.23-0.42 beats/m in 29.4%, and 0.42 beats/m in 47.1% of individuals. It was above. The six-minute walk test 6MWT values of 47.1% of individuals were below 82% and above 82% of 52.9%. Considering the relationships between clinical parameters and 6MWT job; Height, PCI, total cholesterol, 6MWT distance, 6MWT percentage, and during 6MWT with PCI

***Conclusions:*** Although the correlation between exercise capacity and (FBG). is modest, it may have accounted for these people's poor functional exercise ability

***Keywords:*** Energy, Expendıture, Exercıse, Dıabetes Mellıtus.

---

# الإنفاق على الطاقة أثناء التمرين فى مرضى السكرى من النوع 2

شيماء عبد الهادي جاسم
فرع الفسلجة الطبية ، كلية الطب ، جامعة نينوى ، الموصل ، العراق

## الخلاصة

**الخلفية:** تعتبر ممارسة الرياضة أو النشاط البدني ذات اهمية في الخطة العلاجية السريرية للمرضى المصابين بداء السكري من النوع الثاني (T2DM) ، وبالتالي فقد تم تضمينها في المبادئ التوجيهية للوقاية من مرض السكري وعلاجه.

**الهدف من الدراسة:** تهدف هذه الدراسة إلى تقييم العلاقة بين إنفاق الطاقة ومعلمات T2DM أثناء تقييم قدرة التمرين الوظيفي.

**المرضى وطريقة البحث:** شملت دراسة سلسلة الحالة 100 فرد يعانون من داء السكري من النوع 2 T2DM. تم استبعاد المرضى الذين يعانون من إعاقات جسدية أو معرفية ، وأمراض القلب والأوعية الدموية التي لا يمكن السيطرة عليها ، وفشل القلب ، وعدم انتظام ضربات القلب ، وأمراض الرئة ، والفشل الكبدي ، والفشل الكلوي ، والسرطان ، والأمراض العصبية والعظام. تم الحصول على الموافقة المسبقة من جميع الأفراد المشاركين في الدراسة. تم تحليل البيانات باستخدام برنامج SPSS (الإصدار 25 ، IBM).

**النتائج:** كان المرضى المشمولين في الدراسة مستقرين سريريًا. عندما تم فحص قيم مؤشر الدهون الحشوية (VAI) للأفراد حسب العمر ، 29.4٪ ليس لديهم خلل وظيفي في الأنسجة الدهنية ، 5.9٪ لديهم خلل خفيف ، 35.3٪ خلل متوسط ، 29.4٪ لديهم خلل شديد في الأنسجة الدهنية. كان متوسط PCI 0.37 ± 0.18 (نبضة / م).
عندما تم تصنيف الأفراد وفقًا لمؤشر الإنفاق الفسيولوجي ، كانت قيم مؤشر التكلفة الفسيولوجية (PCI) أقل من 0.23 نبضة / م في 23.5٪ من الأفراد ، بين 0.23-0.42 نبضة / م في 29.4٪ ، و 0.42 نبضة / م في 47.1٪ من الافراد.
كانت قيم اختبار المشي لست دقائق MWT6 لـ 47.1٪ من الأفراد أقل من 82٪ وأعلى من 82٪ في 52.9٪ منهم. وفي نظر الاعتبار للعلاقات بين المعلمات السريرية ووظيفة MWT6 ؛ الطول ، PCI ، الكوليسترول الكلي ، مسافة MWT6 ، نسبة MWT6 ، وخلال MWT6 مع PCI.
**الاستنتاجات:** بالرغم من ان العلاقة بين القدرة على التمرين و (FBG) قليلة ، ولكن قد يكون سبب ضعف قدرة هؤلاء الأشخاص على ممارسة التمارين.

**الكلمات المفتاحية:** الطاقة، النفقات، التمارين، السكرى.

## INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a metabolic disease characterized by hyperglycemia due to low insulin secretion, the sensitivity of insulin low, or both [1,2].
The prevalence of T2DM is increasing gradually with the increasing incidence of obesity [3,4].
Complications related to T2DM affect daily physical activity capacity and reduce the quality of life [5, 6]. Functional capacity is the ability of individuals to perform activities of daily living [7, 8].
The six-minute walk test (6MWT) is an easy-to-apply and reliable test used to evaluate functional capacity. The 6MWT work calculated using bodyweight and walking distance is an important parameter that evaluates functional capacity [9-11]. No complicated equipment is required to perform the test [12,13]. 6MWT plays a crucial role in evaluating daily functional exercise capacity, essential in determining the survival of patients in many chronic diseases such as T2D [14, 15]. Studies have reported that functional capacity decreases in T2DM due to impaired glycemic control and related complications [16-18]. Also, studies have shown a decrease in energy expenditure associated with daily physical activity in T2DM due to mechanical and metabolic deficiencies [19]. Energy expenditure during physical activity is measured by determining oxygen uptake and respiratory exchange rate [20, 21]. Physiological cost index (PCI); is used as a valid, reliable, and alternative method that enables the evaluation of energy expenditure of walking, which is an everyday activity in daily life, without requiring clinically complex equipment [22]. This index provides information about energy expenditure and walking performance using an equation defined by MacGregor [23, 24], using walking speed, resting, and heart rate parameters. Studies have reported that PCI is associated with maximum oxygen consumption, one of the essential indicators of energy expenditure [25, 26]. Other studies used PCI to determine energy consumption during 6MWT in healthy individuals, a relationship was found between PCI index and 6MWT distance. There is no study in the literature evaluating the relationship between energy expenditure during 6MWT, physiological responses of 6MWT and T2DM parameters in diabetic patients. The aim of this study to evaluation of the relationship between energy expenditure and T2DM parameters during the evaluation of functional exercise capacity. It is thought that examining the factors associated with energy expenditure will guide the interpretation of exercise performance of patients with T2DM and clinical applications.

## MATERIALS AND METHODS

The case series study was included 100 patients with T2DM. The patients with physical or cognitive disabilities, uncontrollable cardiovascular disease, heart failure, arrhythmia, pulmonary disease, liver failure, kidney failure, cancer, neurological and orthopedic diseases were excluded from this study. All procedures performed in studies involving human participants followed the ethical standards of the institutional and national research committee and the 1964 Helsinki declaration and its later amendments, including informed consent and confidentiality of all personal information. Also, the Ethics committee of Ninevah University has approved the research with ethical N0: IRB:601. Written and verbal consent of patients was obtained before participating in the study. The gathered specific data related to T2DM, such as T2DM duration, prescription diabetes treatment regimen, medical contraindications to participation, diagnostic accuracy, and the number and severity of T2DM sequelae through interviews. Demographic characteristics and medical histories were recorded to all individuals included age, height, body weight, gender, also anthropometric measurement such as Body mass index (BMI) was calculated by dividing the body weight (kg) of the individuals by height in meter squared.To determine central obesity, using a tape measure in the upright standing position, the distance between the iliac crest and the lowest rib is halfway through. Waist circumference (W.C.) and hip circumference (H.C.) were measured the waist circumference by the stand and place a tape measure around the middle just above the hipbones. Sure the tape is horizontal around the waist. Then keep the tape snug around the waist but not compressing the skin, and hip circumference was measured parallel to the ground. The waist-hip ratio was recorded [18]. Waist circumference and hip circumference were recorded for anthropometric measurements. Body fat and lean body weight were calculated using bioelectrical impedance analysis (Tanita, TBF-300, Tokyo, Japan). Laboratory findings of individuals such as fasting blood glucose (FBG), glycosylated hemoglobin (HbA1C), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), C-reactive protein (CRP) was done and recorded. The visceral adipose index (VAI), which is a more sensitive method than classical parameters (waist circumference, BMI.), is associated with cardio metabolic risk, which is used to evaluate adipose tissue dysfunction in individuals, was calculated [19]. When calculating VAI;

For male individuals;

[Waist circumference (cm)/39.68+(1.88*BMI)] * [Triglyceride (mmol/L) *1.03] * [1.31/HDL-C (mmol/L)];

For female individuals;

[Waist circumference (cm)/36.58+(1.89*BMI)] * [Triglyceride (mmol/L) *0.81] * [1.52/HDL-C (mmol/L)]

formulas were used. Individuals were classified by considering the reference values of VAI according to age.

Heart rate and oxygen saturation (SpO2) were recorded with pulse oximetry (Model PM50D, P.R.C.) before and after 6MWT.

Leg fatigue and dyspnea levels of individuals were evaluated with Modified Borg Scale before and after the test. The modified Borg scale scores between 0-10, and high scores indicate more dyspnea and leg fatigue [24]. The physiological cost index (PCI) was calculated to evaluate individuals' energy expenditure and walking effort during the 6MWT. The equation [PCI= (heart rate during walking – resting heart rate) / walking speed (m/min)] was used to calculate PCI [12]. Normal values of PCI in healthy individuals are between 0.23-0.42 beats/m [25]. This test aims to reach the longest possible walking distance after six minutes. The test track is designated as the 10-meter-straight corridor. The test track of 10-meter length was divided into ten equal parts with 1-meter intervals, and the distance reached at the end of the test was easily determined. The purpose and application of the test were explained to the participants before the test, and it was stated to the participants that the test aimed to reach the longest walking distance that could be reached at the end of six minutes at the participants own step but without running. The test was started with the "Start" command and ended with the "Stop" command when the time expired. If participants needed to stop within the six-minute time limit, they were told to rest against a wall if required and keep walking as much as possible. Individuals were told that if they felt tired or breathless during the test, they could rest or terminate the test. Encouraging common words were used during the test. At the end of the test, the 6MWT distance was recorded in meters. Using age and gender, 6MWT expected values. 6MWT distance values expressed as a percentage of expected values and 6MWT work (6MWT distance * Bodyweight (kg) were calculated. If the 6MWT distance is below 82%, it indicates decreased functional capacity [23]. The peak oxygen consumption obtained during the test was determined using the 6MWT distance of the individuals [PO2peak (ml/kg/min) =14.986+(0.025 * 6MWT distance) -(0.161*Bodyweight)] [8]. Quality of Life SF-12: The second version was developed by Ware et al. in 1995 to provide evidence of the quality of life for the last four weeks without focusing on a specific age and disease group. It is an evaluative scale. SF-12 consists of physical functionality, physical role, pain, general health, emotional role, mental health, social functionality and vitality sub-components. Physical functioning is measured by whether and to the degree that the person's health limits moderate activity and climbing several flights of stairs.[27]. On the other hand, the physical role is evaluated by doing less than what he wants to do in his daily work due to his physical health and whether there are limitations in the activities he could do before. General health and pain, respectively, with a single question “How is your health in general?” and “Has the pain prevented you from doing your normal work for the past four weeks? If so, how much?” is determined. The Physical Component Summary Score, which shows the physical domain of quality of life from physical functionality, physical role, general health, and pain sub-components, was calculated as (56.57706). The emotional role is determined by the state of doing less than one would like to do in daily tasks due to emotional problems and whether or not to do daily activities as carefully as usual. Mental health is assessed by how much of the past four weeks he has been depressed and sad and how much of it has been calm and peaceful. Vitality is measured by how much energy he has in four weeks. Social functionality is measured by how much his physical health and emotional problems interfere with his social activities. The Mental Component Summary Score (MCSS), one of the sub-components of emotional role, mental health, vitality, and social functionality, was calculated as (60.75781) .Data were analyzed with SPSS software (version 25, IBM., NY, U.S.A.). The arithmetic means standard deviation (X,SD), minimum and maximum values were used to give descriptive statistics about the variables. The correlation between variables was assessed using the Spearman correlation test. Correlation values ranged from 0.00-0.19 to 0.20-0.39 to 0.40-0.69 to 0.70-0.89 to 0.90-1.00. Statistical significance was defined as a p-value lower than 0.05.

## RESULTS

One hundred patients with T2DM (50 males, 50 females) were included in the study. The demographic and clinical characteristics of the individuals are shown in Table 1. The individuals included in the study were clinically stable. When the VAI values of individuals according to age are examined, 29.4% had no adipose tissue dysfunction, 5.9% had mild, 35.3% moderate, 29.4% had severe adipose tissue dysfunction. The mean PCI was 0.37 ±0.18 (beats/m). When individuals are classified according to the physiological expenditure index; PCI values are below 0.23 beats/m in 23.5% of individuals, between 0.23-0.42 beats/m in 29.4%, and 0.42 beats/m in 47.1% of individuals. It was above. 6MWT values of 47.1% of individuals were below 82% and above 82% of 52.9%. Considering the relationships between clinical parameters and FHI and 6MWT job; Height, PCI, total cholesterol, 6MWT distance, 6MWT percentage and during 6MWT with PCI. A correlation was found between predicted peak oxygen consumption (p<0.05). A statistically significant difference was found between the 6MWT job and age, height, CRP, waist/hip ratio, fat percentage, lean mass, 6MWT distance and the estimated peak oxygen consumption during the 6MWT (p>0.05) (Table 2).

Table1. Descriptive and clinical characteristics of individuals

| Characteristics of individuals | Mean±SD | Min-Max. |
|---|---|---|
| Age (years) | 47.58± 4.11 | 34-59 |
| Height(cm) | 167.17±10.23 | 148-190 |
| BMI (kg/m2) | 33.40±4.12 | 20.19-39.00 |
| Fasting blood glucose (mmol/L) | 113.82±27.91 | 86-189 |
| HbA1c (%) | 7.03±0.73 | 7.10-8.33 |
| Total cholesterol (mmol/L) | 240.55±0.70 | 160-297 |
| HDL-C (mmol/L) | 48.64±0.47 | 34-66 |
| LDL-C (mmol/L) | 158.58±40.09 | 89-266 |
| "VAI" | 3.71±0.67 | 1.04-6.88 |
| 6MWT(m) | 455±0.22 | 412-710 |
| 6MWT% | 81.70±10.30 | 50.30-110.00 |
| 6MWT VO2peak (mL/kg.min) | 13.07±0.53 | 8.04-18.11 |
| 6MWT work (kg.m) | 396.45±0.08 | 40562-71140 |
| 6MWT maximum heart rate (beats/min) | 124.55±0.11 | 88-162 |
| 6MWT maximum heart rate (%) | 61.77±11.04 | 49.22-81.71 |
| Physiological expenditure index (pulse/m) | 0.36±0.16 | 0.07-0.79 |

"* C.R.P.: C-reactive protein HbA1c: Glycose hemoglobin, HDL-C: High-density lipoprotein cholesterol, LDL-C: Low-density lipoprotein cholesterol, T2DM: Type 2 diabetes, VAI: Visceral Adipose Index, B.M.I.: Body mass index, 6MWT: Six-minute walk test."

Table 2. Relationships between individuals' clinical parameters and PCI and 6MWT job

| PCI (pulse/m) | | | 6MWT work (m.kg) | |
|---|---|---|---|---|
| | r | P | R | p |
| Age (years) | -0.105 | 0.741 | -0.521 | 0.078 |
| Height(cm) | -0.645 | 0.020 | 0.687 | <0.001 |
| BMI (kg/m2) | 0.627 | 0.019 | -0.410 | 0.180 |
| Fasting blood glucose | -0.501 | 0.055 | 0.180 | 0.413 |
| HbA1c (%) | -0.039 | 0.90 | 0.241 | 0.420 |
| Total cholesterol | 0.399 | 0.050 | -0.399 | 0.164 |
| HDL | -0.180 | 0.473 | -0.241 | 0.357 |
| LDL | 0.471 | 0.080 | -0.090 | 0.680 |
| "VAI" | 0.081 | 0.914 | -0.074 | 0.697 |
| 6MWT | 0.541 | 0.054 | 0.391 | 0.001 |
| 6MWT% | 0.431 | 0.088 | 0.064 | 0.641 |
| 6MWT PO2peak(mL/kg.min) | 0.621 | 0.004 | 0.841 | 0.001 |
| 6MWT work (kg.m) | -0.351 | 0.140 | - | - |
| PCI (beats/m) | - | - | -0.450 | 0.167 |

"* C.R.P.: C-reactive protein HbA1c: Glycose hemoglobin. HDL-C: High-density lipoprotein cholesterol. LDL-C: Low-density lipoprotein cholesterol, VAI: Visceral Adipose Index, B.M.I."

## DISCUSSION

This study is the first to evaluate the relationship between energy expenditure during (6MWT), physiological responses of 6MWT, and T2DM parameters among diabetic patients. The results of the study showed that PCI, which is one of the indicators of energy expenditure during 6MWT, is associated with height, (FBG)., total cholesterol, exercise capacity, and estimated peak oxygen consumption.

Another energy expenditure parameter,(6MWT) work, was associated with age, height, inflammation level, waist/hip ratio, fat percentage, lean mass, exercise capacity, and estimated peak oxygen consumption. This is consistent with earlier research, which showed that individuals with T2DM often had reduced exercise ability. [28, 29]. Patients with T2DM may have reduced exercise ability due to impaired glucose metabolism levels leading to decreased energy. Glucose transporter type 4 (GLUT4) expression at the plasma membrane is linked to fiber volume[30]. Increased stiffness of major conduit arteries has been linked to poor glycemic control among diabetic patients. The aorta's compliance is essential in regulating coronary artery blood flow, which has significant implications for myocardial work capacity and, as a result, decreased exercise capacity[31].

An increasing amount of data supports the theory that muscle blood flow may be reduced in T2DM patients due to suboptimal cell-level blood perfusion, resulting in reduced functional exercise capacity [32]. One of the reasons that have been identified as restricting the capacity to reach peak performance during maximum activity is this. T2DM patients had a poor aerobic performance on submaximal tests even though the 6MWT is a submaximal test[33]. Thus, in patients with T2DM, the help in guiding during a 6-minute walk has become a well-established predictor of cardiovascular risk and all-cause death. However, Carter et al. [26] found that body weight was not considered during the 6MWT, even though bodyweight could influence walking performance. As a result, the 6MWT , which is the product of body weight and distance traveled during a six-minute walk, has been recommended as a method of determining functional exercise capacity[34].

Weight loss is an essential lifestyle modification strategy in diabetes management that may serve as a helpful indication of progress during evaluation. Exercise prescription is typically based on heart rate and other cardiovascular indicators to evaluate exercise safety and progression. The results of this research revealed substantial disparities in cardiovascular parameters between T2DM patients and healthy controls. This is consistent with earlier research that found T2DM patients had decreased cardiovascular function[28,31].

Furthermore, inadequate cardiac output responses to exercise have been linked to impaired cardiac autonomic function in people with Diabetes. Thus, this group should carefully manage exercise prescriptions. Physical activity levels among T2DM patients are below optimum in previous research [35]. As a consequence of inactivity, weaker muscles are smaller and have a higher risk of inadequate glucose absorption and hyperglycemia. Chronic illnesses and their accompanying co-morbidities may have a detrimental influence on cardiovascular system performance. As a compensatory mechanism, the heart may try to alleviate the load of the underlying diseases, reducing the adequate circulation of blood across the body tissues. [32]. A variety of underlying pathologies, such as cardiovascular disease, a history of physical inactivity, and an unhealthy lifestyle, maybe a possible limitation of the current research, leading to inadequate functional exercise capacity. Furthermore, there is limited research on functional exercise ability in the T2DM patients, making comprehensive comparison difficult. Although the correlation between exercise capacity and (FBG). is modest, it may have accounted for these people's poor functional exercise ability.

## REFERENCES

1.Padhi S, Nayak AK, Behera A. Type II diabetes mellitus: A review on recent drug based therapeutics. Biomedicine & Pharmacotherapy. 2020;131:110708.

2.Verboven K, Wens I, Vandenabeele F, Stevens A, Celie B, Lapauw B, et al. Impact of exercise-nutritional state interactions in patients with type 2 diabetes. Medicine and Science in Sports and Exercise. 2020;52(3):720-8.

3.Gu L, Duan L, Xie P, He L, Peng W, Zhou F. The effect of sedentary time on the results of exercise therapy in patients with peripheral arterial disease complicated with type 2 diabetes. Annals of Palliative Medicine. 2021.

4.Magkos F, Hjorth MF, Astrup A. Diet and exercise in the prevention and treatment of type 2 diabetes mellitus. Nature Reviews Endocrinology. 2020;16(10):545-55.

5.Kuziemski K, Słomiński W, Jassem E. Impact of diabetes mellitus on functional exercise capacity and pulmonary functions in patients with diabetes and healthy persons. BMC endocrine disorders. 2019;19(1):1-8.

6.Winding KM, Munch GW, Iepsen UW, Van Hall G, Pedersen BK, Mortensen SP. The effect on glycaemic control of low-volume high-intensity interval training versus endurance training in individuals with type 2 diabetes. Diabetes, Obesity and Metabolism. 2018;20(5):1131-9.

7.Awotidebe TO, Adedoyin RA, Yusuf AO, Mbada CE, Opiyo R, Maseko FC. Comparative functional exercise capacity of patients with type 2-diabetes and healthy controls: a case control study. The Pan African Medical Journal. 2014;19.

8.Yanai H, Adachi H, Masui Y, Katsuyama H, Kawaguchi A, Hakoshima M, et al. Exercise therapy for patients with type 2 diabetes: a narrative review. Journal of clinical medicine research. 2018;10(5):365.

9.Nolen-Doerr E, Crick K, Saha C, de Groot M, Pillay Y, Shubrook JH, et al. Six-minute walk test as a predictive measure of exercise capacity in adults with type 2 diabetes. Cardiopulmonary physical therapy journal. 2018;29(3):124.

10.Kemps H, Kränkel N, Dörr M, Moholdt T, Wilhelm M, Paneni F, et al. Exercise training for patients with type 2 diabetes and cardiovascular disease: What to pursue and how to do it. A Position Paper of the European Association of Preventive Cardiology (EAPC). European journal of preventive cardiology. 2019;26(7):709-27.

11.Zheng Y, Ley SH, Hu FB. Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. Nature reviews endocrinology. 2018;14(2):88-98.

12.Enright PL. The six-minute walk test. Respiratory care. 2003;48(8):783-5.

13.Savikj M, Zierath JR. Train like an athlete: applying exercise interventions to manage type 2 diabetes. Diabetologia. 2020;63(8):1491-9.

14.Laboratories ACoPSfCPF. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002;166:111-7.

15.Society AT. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002;166:111-7.

16.Awotidebe TO, Adedoyin RA, Oke KI, Ativie RN, Opiyo R, Ikujeyisi EO, et al. Relationship between functional capacity and health-related quality of life of patients with type—2 diabetes. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2017;11(1):1-5.

17.Leenders M, Verdijk LB, van der Hoeven L, Adam JJ, Van Kranenburg J, Nilwik R, et al. Patients with type 2 diabetes show a greater decline in muscle mass, muscle strength, and functional capacity with aging. Journal of the American Medical Directors Association. 2013;14(8):585-92.

18.Prithiha V, Kumar TS, Venkatesh N, Sridevi S. An Analytical Study on Physical Activity, Functional Capacity and Sleep Health in Patients with Type 1 and Type 2 Diabetes. Indian Journal of Public Health Research & Development. 2019;10(10).

19.Dunstan DW, Daly RM, Owen N, Jolley D, De Courten M, Shaw J, et al. High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. Diabetes care. 2002;25(10):1729-36.
20.Maiolo C, Melchiorri G, Iacopino L, Masala S, De Lorenzo A. Physical activity energy expenditure measured using a portable telemetric device in comparison with a mass spectrometer. British journal of sports medicine. 2003;37(5):445-7.
21.Wingfield HL, Smith-Ryan AE, Melvin MN, Roelofs EJ, Trexler ET, Hackney AC, et al. The acute effect of exercise modality and nutrition manipulations on post-exercise resting energy expenditure and respiratory exchange ratio in women: a randomized trial. Sports medicine-open. 2015;1(1):1-11.
22.Karimi MT. Sensitivity analysis and comparison of two methods of using heart rate to represent energy expenditure during walking. Work. 2015;51(4):799-805.
23.Rana BS, Pun M. Estimation of Physiological Cost Index as an Energy Expenditure Index using MacGregor's Equation. Journal of the Nepal Medical Association. 2015;53(199).
24.Amanat S, Ghahri S, Dianatinasab A, Fararouei M, Dianatinasab M. Exercise and type 2 diabetes. Physical Exercise for Human Health. 2020:91-105.
25.Danielsson A. Studies on energy expenditure in walking after Stroke: Inst of Neuroscience and Physiology. Dept of Clinical Neuroscience; 2008.
26.Yang D, Yang Y, Li Y, Han R. Physical exercise as therapy for type 2 diabetes mellitus: From mechanism to orientation. Annals of nutrition and metabolism. 2019;74(4):313-21.
27.Huo T, Guo Y, Shenkman E, Muller K. Assessing the reliability of the short form 12 (SF-12) health survey in adults with mental health conditions: a report from the wellness incentive and navigation (WIN) study. Health and quality of life outcomes. 2018;16(1):1-8.
28.Verges B, Patois-Verges B, Cohen M, Lucas B, Galland-Jos C, Casillas J. Effects of cardiac rehabilitation on exercise capacity in type 2 diabetic patients with coronary artery disease. Diabetic Medicine. 2004;21(8):889-95.
29.Vancampfort D, De Hert M, Sweers K, De Herdt A, Detraux J, Probst M. Diabetes, physical activity participation and exercise capacity in patients with schizophrenia. Psychiatry and Clinical Neurosciences. 2013;67(6):451-6.
30.De Rekeneire N, Resnick HE, Schwartz AV, Shorr RI, Kuller LH, Simonsick EM, et al. Diabetes is associated with subclinical functional limitation in nondisabled older individuals: the Health, Aging, and Body Composition study. Diabetes care. 2003;26(12):3257-63.
31.Fang ZY, Sharman J, Prins JB, Marwick TH. Determinants of exercise capacity in patients with type 2 diabetes. Diabetes care. 2005;28(7):1643-8.
32.Kingwell BA, Formosa M, Muhlmann M, Bradley SJ, McConell GK. Type 2 diabetic individuals have impaired leg blood flow responses to exercise: role of endothelium-dependent vasodilation. Diabetes care. 2003;26(3):899-904.
33.Fang ZY, Prins JB, Marwick TH. Diabetic cardiomyopathy: evidence, mechanisms, and therapeutic implications. Endocrine reviews. 2004;25(4):543-67.
34.Golpe R, Pérez-de-Llano LA, Méndez-Marote L, Veres-Racamonde A. Prognostic value of walk distance, work, oxygen saturation, and dyspnea during 6-minute walk test in COPD patients. Respiratory care. 2013;58(8):1329-34.
35.Adeniyi A, Uloko A, Sani-Suleiman I. Relationship Between the 6-minute Walk Test and Correlates of Type 2 Diabetes: Indication for caution in exercise prescription. African Journal of Physiotherapy and Rehabilitation Sciences. 2010;2(1):21-4.