The Research of Medical Science Review
ISSN: 3007-1208 & 3007-1216 Volume 3, Issue 5, 2025

EXPLORING THE RELATIONSHIPS AMONG PHYSICAL ACTIVITY, TYPE 2 DIABETES, AND VITAMIN D: INSIGHTS FROM A CROSS-SECTIONAL STUDY

Sidra Naheed[*1], Fazia Ghaffar[2], Ibrar Ahmad[3]

[*1]*Department of Food & Nutrition Sciences, College of Home Economics, University of Peshawar*
[2]*Assistant Professor, Department of Food & Nutrition Sciences, College of Home Economics, University of Peshawar*
[3]*Consultant Endocrinologist, Department of Diabetes and Endocrinology, Lady Reading Hospital, Peshawar*

[*1]malik.sidra.hn@gmail.com

DOI: https://doi.org/10.5281/zenodo.15369438

Keywords
Type 2 Diabetes, Poor glycemic regulation, HbA1c, Physical activity

Article History
Received on 01 April 2025
Accepted on 01 May 2025
Published on 09 May 2025

Corresponding Author: *
Sidra Naheed

Abstract

Introduction: *Globally, diabetes mellitus and obesity are rising due to poor adaptive lifestyle factors like unhealthy diet, higher BMI and physical inactivity, which is the main cause of metabolic syndrome. Daily physical activity can reduce the risk of developing Type 2 diabetes, cardiovascular diseases and severe comorbidities.*

Methodology: *A sample of 200 type 2 diabetic patients was chosen from the Endocrinology Ward at Lady Reading Hospital (LRH) in Peshawar based on written agreement. A self-made questionnaire was designed to collect information on demographics (age, gender, family medical history and education), anthropometrics (weight, height and BMI), biochemical (HbA1c, lipid Profile and CRP) and a standard Global Physical Activity Questionnaire (GPAQ) was used. The descriptive and one-way ANOVA was used to assess the data through SPSS.*

Major Results: *The participants were mostly male (52%), between the ages of 25 and 60, with illiterate (55%) and positive family history of hypertension, heart disease and diabetes. Females showed greater trends of overweight and obesity, with BMI (26.22 ± 5.37), but males typically maintained a normal weight. Glycemic control was inadequate both (9.59 ± 2.41) in males and (9.51 ± 1.76) females. Physical activity data from GPAQ analysis indicated that 30.8% of male respondents had jobs requiring standing or walking throughout the day, while most engaged in little to no physical activity such as walking, cycling, or household chores. Among females, 86.5% were housewives, with most not participating in structured physical activities like exercise, walking, or cycling, though the majority performed household chores for 1–3 hours daily. Overall, physical activity levels were low, with minimal involvement in regular exercise, walking, or recreational activities.*

Conclusion: *The study showed poor glycemic control and limited physical activity, with females exhibiting higher obesity trends. Overall, sedentary lifestyles, poor education and a strong family history of diabetes indicate a high risk for metabolic disorders.*

INTRODUCTION

Globally, diabetes mellitus is among the most prevalent metabolic illnesses. Nearly 150 million people worldwide have been diagnosed with this condition, with estimates that this figure will raise to over 300 million by 2025 [1]. Over the past three decades, obesity has become common worldwide and has been linked to an increase in type 2 diabetes [2]. Type 2 diabetes is predicted by lifestyle factors, but their impact in high- and low-risk groups with and without metabolic syndrome is unknown. A good exercise is a low risk factors, whereas alcohol consumption, smoking, BMI and family history of diabetes were used to identify a high-risk lifestyle. The metabolic syndrome includes fasting glucose, blood pressure, serum HDL cholesterol, serum triglycerides, and overweight that agreed by the International Diabetes Federation [3]. Physical activity improves glycemic control and reduces the risk of cardiovascular disease (CVD) and mortality in patients with type 2 diabetes. The American College of Sports Medicine and the American Diabetes Association have recommended at least 150 min/wk of moderate (50%-70% of an individual's maximum heart rate) to vigorous (> 70% of an individual's maximum heart rate) physical activity for patients with type 2 diabetes [4]. Around 60–80% of people with type 2 diabetes do not meet these guidelines, and in comparison to the general population, they report more relapse from physical activity [5]

Increased insulin sensitivity is an important link between increased PA, body composition, and metabolic health, and it is at this link where increases in PA and energy expenditure exert much of their effect on preventing metabolic disorders and improving symptoms of existing disease. In addition to improving insulin sensitivity, regular PA has several cardioprotective effects, especially for persons with metabolic dysfunction[6].

According to the World Obesity Federation, by 2025, 2.7 billion adults will be overweight and over one billion will suffer from obesity [7].

Physical activity is usually classified by its intensity and duration. The metabolic equivalent (MET) is a useful measurement for representing the intensity of physical activity and is defined as the amount of oxygen uptake while sitting at rest. An oxygen uptake of 3.5 mL/kg per minute is equal to the basal resting metabolic rate and is considered to be 1 MET [8]. Epidemiological studies showed that the prevalence of diabetes mellitus increases every year along with the increase in life expectancy and lifestyle changes (diet and physical activity) [9]. In a large-scale cohort study, individuals who performed low-volume physical activity, which was defined as 15 min/d or 90 min/week, had a 14% reduced risk of all-cause mortality and a life expectancy increase of 3 years. Thus, it is important to note that in addition to moderate-to-vigorous-intensity physical activity, light-to-moderate-intensity daily physical activity should also be considered an alternative and supportive exercise therapy regimen for diabetic individuals[10].

2. Methodology:

2.1 Study Design and Sample:

The endocrinology department of Lady Reading Hospital, a tertiary care facility in District Peshawar, served as the site of this case-control, cross-sectional study. The study met the ethical requirements of the International Review Board (IRB) of Lady Reading Hospital and was approved by the College of Home Economics' Institutional Ethical Approval Committee at the University of Peshawar. All patient needs were secure and private, and the study complied with the Helsinki Protocol. For the current investigation, 200 adult patients with Type 2 Diabetes Mellitus were recruited at random after obtaining written consent (from December 2022 to March 2023). The calculated sample size was 189 at a 95% confidence interval and a 1% probability of comorbidities.

2.1.1 Inclusion Criteria:

The inclusion criteria for the study consisted of patients with Type 2 diabetes, aged between greater than 25 and less than 60 years. Additionally had no serious history of diabetes related comorbidities.

2.1.2 Exclusion Criteria:

The exclusion criteria for the study included Type 2 diabetic patients with amputations, a recent history of infections, those with severe comorbidities, as well as pregnant and lactating mothers.

2.2 Data Collection:
A self-constructed questionnaire and standardized global physical activity questionnaire GPAQ were developed to attain required data.

2.2.1 Sociodemographic Data:
Sociodemographic data include gender, age, educational background and family medical history respectively.

2.2.2 Anthropometric Data:
The anthropometric data comprises height through height board or other measuring device, weight through weighing machine and BMI after calculations in the formula.

2.2.3 Biochemical Data:
Biochemical data was collected to assess the different values including blood glucose level through HbA1c, Lipid profile (LDL, HDL and TC) and CRP respectively.

2.2.4 Global Physical Activity:
GPAQ was used to assess physical activity in patients which is developed by WHO in 2002. It consist of 11 questions and have 3 domains: type and amount of physical activity during work, time spend on physical activity during last week and walking pace.

2.2.6 Statistical Analysis:
Data were analyzed by using latest Statistical Package for Social Sciences (SPSS) version 20 for entering and analysis of collected data. Descriptive statistic was used to determine frequencies, mean and standard deviation for different variables and one way ANOVA was used for comparison.

3. Results and Discussion:
3.1 Sociodemographic results:
. Table 1 clearly explains the gender distribution of patients according to their ages. The total no. of 43 male and female were from 25- 35 age group, 49 from 36 – 45, 60 from 46 – 55 and 48 from 56 – 60 years respectively. If we go through the above table the most affected population group is male i.e 36 in the age range from 46 – 55 years. It is concluded from the present study that type II diabetes mostly affect people in the middle years. These findings are similar to the findings of Zia [11] that adults are greatly affected in middle and late adult ages by type II diabetes.

Table 1: Age Distribution among Male and Female T2DM Patients

Age (years)	No. of patients	Percentage (%)	Male		Female	
			No. of Patients	Percentage (%)	No. of Patients	Percentage (%)
25-35	43	21.5	15	14.5	28	29.1
36-45	49	24.5	25	24.2	24	24.9
46-55	60	30	36	34.5	24	24.9
56-60	48	24.0	28	27	20	20.6
Total	200	100	104	100.2	96	99.5

In Table 2 the educational background showed that 90 of the total patients were educated and the remaining 110 were non-educated, respectively. After the evaluation of education, it can be concluded that education levels and nutritional knowledge have a strong correlation in making good glycemic control, dietary choices, and a healthy lifestyle. While in the second coloumn the family medical history classified by validity (yes or no). Out of 200 Type II diabetic patients, 74 patients (37%) with hypertension, and 126 patients (63%) without, 161 patients (80.5%) with diabetes, and 39 patients (19.5%) without, while 53 patients (26.5%) with heart disease, and 147 patients (73.5%) without. It is concluded from the present data that a higher percentage of patients in this sample had positive family medical history of hypertension, diabetes and heart diseases. The results are similar to the findings of Zafar[12] who also found the strong correlation between frequency and family history of T2DM.

Table 2: Education and Family Medical History of T2DM Patients

Validity	Education		Family Medical History		
	Educated	Uneducated	Hypertension	Diabetes	Heart disease
YES	90	110	74	161	53
NO	-	-	126	39	147
Total	200		200	200	200

3.2 Anthropometric results:

Anthropometric measurements of male and female Type 2 diabetic patients are summarized in Table 1. For males, the average weight was 71.17 ± 10.95kg (range: 50–108 kg) with a P-value of 0.181, showing no statistical significance (P > 0.05). The mean height was 172.75 ± 4.45 cm (range: 164–187 cm, P = 0.231), and average BMI was 24.02 ± 3.66 kg/m² (range: 18.10 – 34.50 kg/m², P = 0.066) both shows non-significant. For females, the average weight was 73.78 ± 11.39 kg (range: 50–100 kg, P = 0.892), and height was 163.42 ± 3.83 cm (range: 151–169 cm, P = 0.497), both non-significant. BMI averaged 26.22 ± 5.37 kg/m² (range: 19–40 kg/m²) with a significant P-value of 0.004. Across all respondents, weight, height, BMI, MUAC, and body fat were analysed by age using ANOVA, showing non-significance (P-values: 0.009, 0.659, 0.106, 0.136, and 0.027). Female respondents had higher weight, BMI, MUAC, and body fat than reference values, suggesting obesity prevalence.

Table 3: BMI categorization among Male and Female T2DM Patients

BMI Category	Female			Male			P Value (with age)
	Frequency	Range (Min – Max)	Mean ± SD	Frequency	Range (Min – Max)	Mean ± SD	
Below 18.5		-	-	10	18.10 – 18.44	18.26 ± 0.15	-
18.5 – 24.9	47	19.00 – 24.10	21.97 ± 1.62	52	18.70 – 24.90	22.21 ± 1.55	0.319
25 – 29.9	27	25.00 – 29.00	26.87 ± 1.13	40	25.00 – 30.00	27.01 ± 1.66	0.076
Above 30	22	30.40 – 40.00	34.50 ± 3.25	02	33.00 – 34.50	34.00 ± 0.86	0.245

Table 3 summarizes the anthropometric results of the type 2 diabetic patients among male and female respectively. The Body Mass Index (BMI) of the patients were calculated after the measurements of weight and height. The BMI is categorized accordingly WHO protocols. The BMI first category for underweight lies only for male patients ranges from (18.10 – 18.44) with mean (18.26 ± 0.15). The normal or healthy weight for both female and male were 21.97 ± 1.62 and 27.01 ± 1.66, while for overweight category for female and male were 26.87 ± 1.13 and 27.01 ± 1.66 respectively. The BMI for obese in female was 34.50 ± 3.25 and in male was 34.00 ± 0.86. The BMI for all the four categories of the collectively respondents was compared with age by applying one-way ANOVA test and the results are presented in the column with P-value. If we go through these data, we can see that BMI wasnot statistical significant according to their respective P-values. The above data analyzed that females have higher frequency of obesity among all the categories. According to Nyamdorj[13], the four indicators of obesity (BMI, waist circumference, waist to hip ratio and waist to statue ratio) were checked for association with diabetes and hypertension. They found a positive correlation among these factors and concluded that they were strongly positively correlated with diabetes among Asian female

population. Multiple lifestyle factors are also of great importance in the development of T2DM, they include sedentary lifestyle, physical inactivity, smoking and alcohol consumption. Thus the results are similar to the findings of Boles[14] who observed that obesity is the utmost important risk factor for developing T2DM, which may affect insulin resistance and disease progression.

3.3: Biochemical Record

3.3.1: Biochemical results:

Table 4: Biochemical Results of the T2DM Patients

Parameters	Male			Female			Reference Value
	Range (Min – Max)	Mean ± SD value (P-value)	P - Value	Range (Min – Max)	Mean ± SD value (P-value)	P- Value	
HbA1C	7.05 - 14.20	9.59 ± 2.41	0.110	7.1 – 14	9.51 ± 1.76	0.616	4.5 – 7.0 %
Total Cholesterol	139 - 220	181.20 ± 17.70	0.143	135 – 236	181.70 ± 20.07	0.845	≤ 199 mg/dL
Triglyceride	100 - 199	149.96 ± 26.58	0.976	100 – 199	143.06 ± 26.47	0.391	≤ 149 mg/dL
LDL	100 - 198	141.98± 26.75	0.938	100 – 199	145.16 ± 28.58	0.637	100 – 159 mg/dL
HDL	40 - 79	51.44 ± 7.77	0.591	41 – 69	52.90 ± 7.86	0.863	40 – 60 mg/dL
CRP	0.20 – 1.00	0.54 ± 0.23	0.96	0.30 – 2.20	0.78±0 .45	0.022	0.00 – 0.50 mg/dL

3.4 Global Physical Activity of the respondents

Table 4 compares various health parameters (blood glucose, lipid profile, and CRP) between male and female subjects, with P-values indicating statistical significance. For **blood glucose**, fasting and random levels show higher levels between genders after conducting HbA1C levels are elevated for both males (9.59 ± 2.41) and females (9.51 ± 1.76), exceeding the reference range (4.5–7.0). Results of lipid profile for both male and female showed; cholesterol average value (181.20 ± 17.70) (181.70 ± 20.07)mg/dL that falls under reference range (≤ 199) mg/dL, triglycerides average value (149.96 ± 26.58) (143.06 ± 26.47)mg/dL that falls under reference range (≤ 149) mg/dL which indicates lower chances for developing pancreas inflammation and cardiovascular diseases. LDL average value (141.98 ± 26.75) (145.16 ± 28.58) mg/dL that falls under reference value (100 – 159) mg/dL and HDL average value (51.44 ± 7.77) (52.90 ± 7.86) mg/dL that also falls within the reference range (40 – 60) mg/dL which indicates lower chance for developing heart disease and aids in preventing the formation of cholesterol. The lipid profile levels were under controlled ranges due to anti-hyperlipidemic medications prescribed by their endocrinologist. CRP levels were measured to detect the degree of inflammation in the body, average CRP results were (0.54 ± 0.23) (0.78±0 .45) mg/dL which is slightly higher than the normal reference value (0.00 – 0.50) mg/dL which suggests an inflammatory condition in the body. The P value in the second last column indicate the statistical significance of differences between groups, with higher values than 0.005 suggesting less significant differences, lower values than 0.005 generally suggest stronger significance.

It is estimated that the increased frequency of micro- and macrovascular complications in T2DM leads to a delayed illness diagnosis. Managing type T2DM can

be challenging, and unfortunately, a significant portion of individuals struggle to maintain appropriate blood glucose levels despite treatment efforts. This difficulty often leads to increased risks of severe complications associated with diabetes. Lifestyle factors, such as diet and exercise, medication adherence, and the progressive nature of the disease itself, can all contribute in achieving and sustaining target blood glucose levels[15]. Moreover Elimam[16] suggests the significant link observed between inflammation and glycemic control in individuals with T2DM indicates the vital role of inflammation likely plays in the development of diabetes.

Table 5: Type and amount of physical activity during work

Job description	MALE		FEMALE	
	No. of patients	Percentage (%)	No. of patients	Percentage (%)
unemployed, retired	25	24.0	83	86.5
office work	27	26.0	2	2.1
standing or walking at work	32	30.8	10	10.4
definite physical effort at work	17	16.3	1	1.0
vigorous physical effort at work	3	2.9	~~	~~
Total	104	100.0	96	100.0

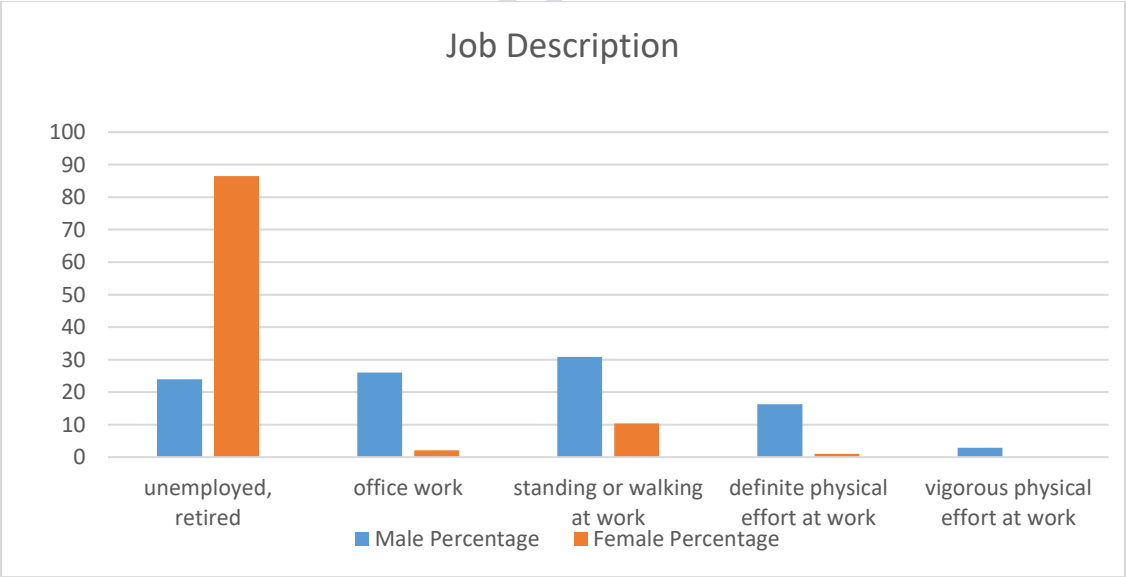

Figure 4: Type and amount of physical activity during work

Table 5 and figure 4 shows the type and amount of physical activity among male and female respondents. This data categorizes individuals according to their employment status or the nature of their work. It provides insight into the distribution of individuals within these job categories among the total surveyed population. Such information can be valuable for understanding occupational influences on health or lifestyle factors, aiding in tailoring health initiatives or interventions accordingly. Among male respondents 24% were unemployed, 26% of the respondents were on daily job doing at office, 30.8% respondents with higher percentage were doing daily routine work by standing or walking at work, 16.3% were involved in

physical effort at work, while only 2.9% respondents were involved in vigorous type of physical effort at regular basis. While among female respondents 86.5% with higher percentage were unemployed, 2.1% of the respondents were on daily job doing at office, 10.4% respondents were doing daily routine work by standing or walking at work, 1.0% were involved in physical effort at work.

Table 6: Last week physical activity of the male respondents

Parameters	Physical Exercise (%)	Cycling to walk (%)	Walking (%)	House work (%)	Gardening/ DIY (%)
None	96.2	99	25.0	63.5	91.3
<1 hour	3.8	1.0	61.5	27.9	8.7
1 hour but <3 hours	-	-	13.5	5.8	-
3 hours or more	-	-		2.9	-
Total	100.0	100.0	100.0	100.0	100.0

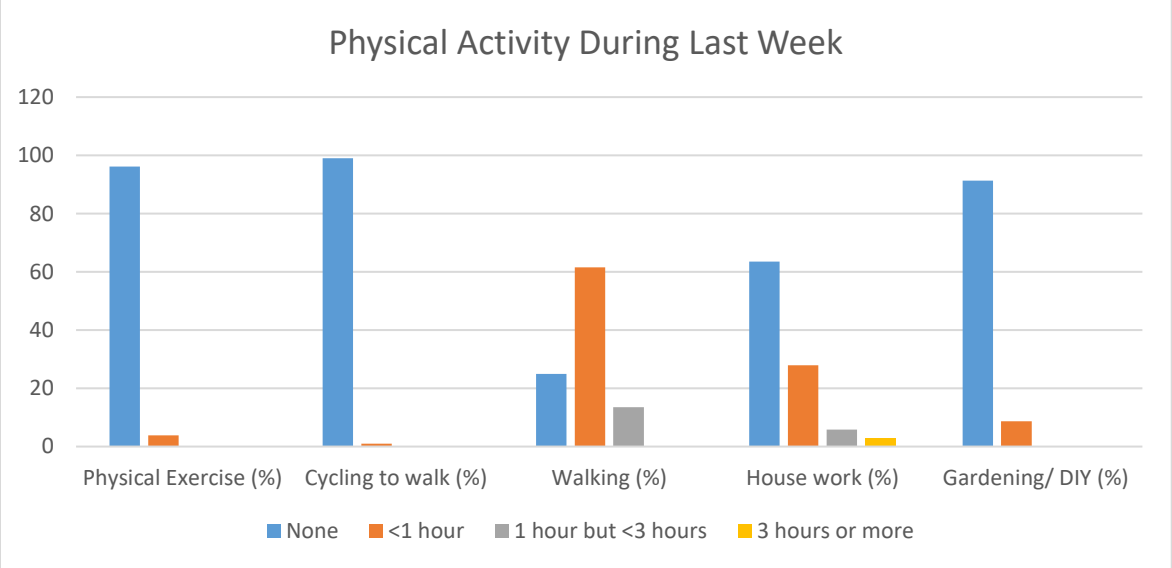

Figure 5:Last week physical activity of the male respondents

Table 6 and Figure 5 presents the percentages for male individuals engaged in various levels of physical activity across different categories. It shows the proportion of individuals within each activity level, offering insights into their participation in different forms of physical exercise. Only 3.8 % of male respondents were involved in physical exercise <1 hour while majority 96.2% were having no physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout etc. 99 % of the respondents were having no cycling, including cycling to walk and during leisure time, while only 1 % were involved in cycling. The last week physical activity including walk (Walking, including walking to work, shopping, for pleasure etc.) was done by 61.5% less than 1 hour, 13.5 % 1 hour but less than 3 hours and 25 % respondents were not involved in walk. 27.9% of the male respondents were involved in house work/ child care less than 1 hour during last week, 5.8% were doing house work 1 hour but less than 3 hours and 2.9% were doing house work 3 hours or more. 63.5% of the total number of respondents were not involved in house work and child care which were mostly older males. Only 8.7% respondents were fond of gardening/ DIY and spent <1 hour in such recreational activities, while 91.3% respondents were not involved in such activities. The majority of individuals report no engagement or very minimal

engagement in physical exercises like cycling, walking, and gardening/DIY. It has been estimated that there would be 13.8 million cases of diabetes in Pakistan by 2030, which is concerning and indicates that diabetes control and treatment should be investigated. Diets high in carbohydrates and a lack of physical activity are contributing factors to the rising prevalence of T2DM in South Asian nations like Pakistan. The Global Action Plan for the Prevention and Control of NCDs 2013–2020 of the World Health Organization had as its objective to encourage individuals to adopt an active lifestyle in order to both lower their chance of developing diabetes as well as manage the disease. Along with a variety of other workouts, the National Association of Diabetes Educators of Pakistan advises walking for 30 minutes 5 days a week [17].

Table 7: Last week physical activity of the female respondents

Parameters	Physical Exercise (%)	Cycling to walk (%)	Walking (%)	House work (%)	Gardening/ DIY (%)
None	99.0	99.0	37.5	35.4	85.4
<1 hour	1.0	1.0	51.0	44.8	14.6
1 hour but <3 hours	-	-	11.5	14.6	-
3 hours or more	-	-		5.2	-
Total	96	100.0	100.0	100.0	100.0

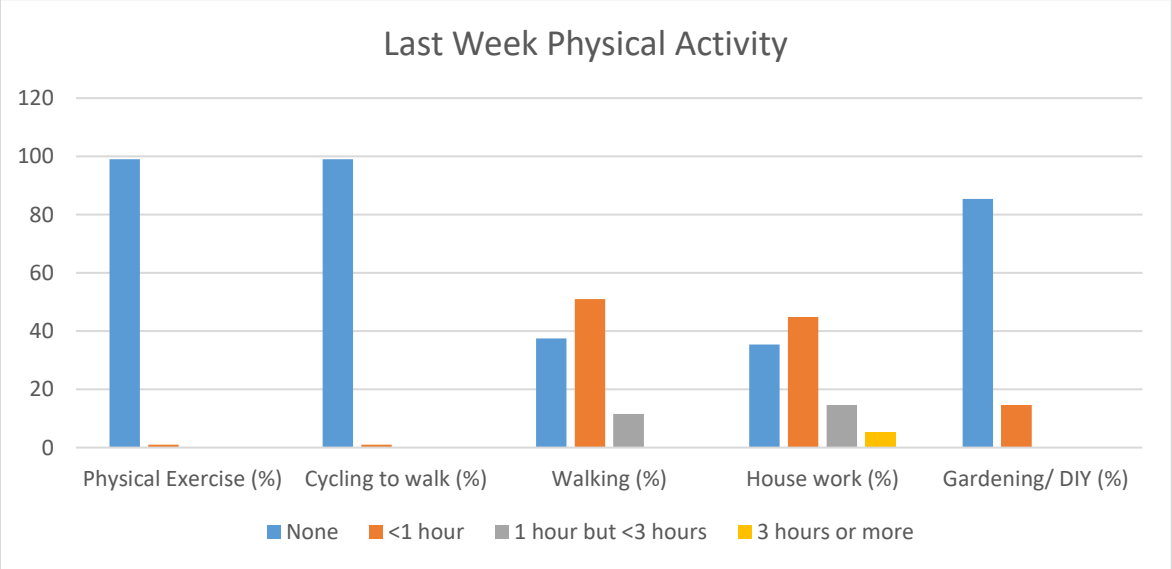

Figure 6:Last week physical activity of the female respondents

Table 7 and Figure 6 indicate the percentage distribution for female individuals engaged in various levels of physical activity across different categories. It shows the proportion of individuals within each activity level, offering insights into their participation in different forms of physical exercise. Only 1 % of female respondents were involved in physical exercise <1 hour while majority 99% were having no physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout etc. 99 % of the respondents were having no cycling, including cycling to walk and during leisure time, while only 1 % were involved in cycling. The last week physical activity including walk (Walking, including walking to work, shopping, for pleasure etc.) was done by 51% less than 1 hour, 11.5 % 1 hour but less than 3 hours and 37.5% respondents were not involved in walk. 44.8% of the female respondents were involved in house work/

child care less than 1 hour during last week, 14.6% were doing house work 1 hour but less than 3 hours and 5.2% were doing house work 3 hours or more. 35.4% of the total number of respondents were not involved in house work and child care which were mostly older females. Only 14.6% respondents were fond of gardening/ DIY and spent <1 hour in such recreational activities, while 85.4% respondents were not involved in such activities. The majority of individuals report no engagement or very minimal engagement in physical exercises like cycling, walking, and gardening/DIY. It has been found that time, affordable resources, support from family members, informational and skill gaps, access to locations for workouts, and lack of enthusiasm were significant barriers to physical activity [18].

Table 8: Walking Pace of the respondents

Walk pace	MALE		FEMALE	
	No. of patients	Percentage (%)	No. of patients	Percentage (%)
slow pace(i.e >3mph)	27	26.0	34	35.4
steady average pace	32	30.8	19	19.8
brisk pace	19	18.3	14	14.6
fast pace (i.e <4mph)	26	25.0	29	30.2
Total	104	100.0	96	100.0

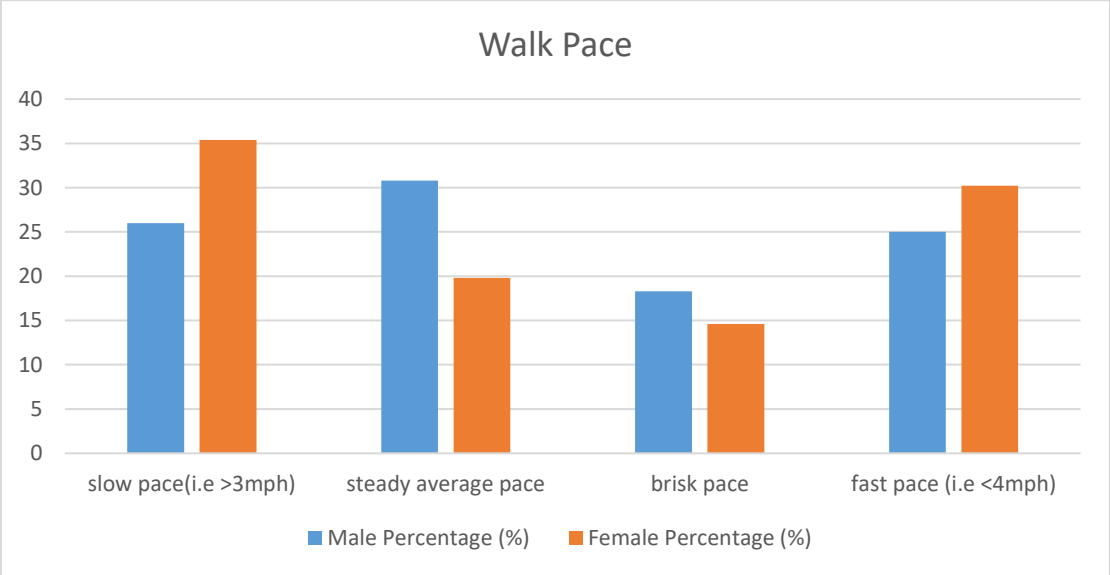

Figure 7: Walking Pace of the respondents

Table 8 and Figure 7 categorizes male and female respondents based on their walking speeds and demonstrates the percentage of respondents within each walking pace category. 26% male respondents and 35.4% female respondents do walk on slow pace (i.e. >3mph), 30.8% male and 19.8% female respondents with steady average pace, 18.3% male and 14.6% female with brisk pace and 25% male and 30.2% female with fast pace (i.e. <4mph) were recorded. Lunde findings clearly imply that, if done on a regular basis, low-intensity post-meal walking may constitute a "low barrier" lifestyle recommendation with significant preventative potential. It appears that walking is a good method of exercise for those with diabetes. To support this theory and determine the ideal amount of time and effort needed to combat the post-meal glucose rise, more research is necessary [19].

Conclusion: Current research indicates that low physical activity and a sedentary lifestyle significantly increase the risk of developing type 2 diabetes. Our society has evolved into a technological hub, allowing most daily responsibilities to be handled with just a

few clicks. As a result, it has become increasingly common for people to lead inactive and sedentary lives, a trend that often begins at a young age. Certain factors, such as being female, older age, living in urban areas, low self-efficacy, poor attitudes, and lack of social support, increase the risk of physical inactivity. Diabetes education should focus on encouraging individuals to engage in physical activity and overcoming barriers to doing so. Governments and health professionals must emphasize the importance of evidence-based physical activity to change attitudes and foster social support from families.

REFERENCES:

Nasri H, Behradmanesh S, Maghsoudi AR, Ahmadi A, Nasri P, Rafieian-Kopaei M. Efficacy of supplementary vitamin D on improvement of glycemic parameters in patients with type 2 diabetes mellitus; a randomized double blind clinical trial. Journal of renal injury prevention. 2013 Nov 30;3(1):31.

Kabadi SM, Liu L, Auchincloss AH, Zakeri IF. Multivariate Path Analysis of Serum 25-Hydroxyvitamin D Concentration, Inflammation, and Risk of Type 2 Diabetes Mellitus. Disease markers. 2013;35(3):187-93.

Laaksonen MA, Knekt P, Rissanen H, Härkänen T, Virtala E, Marniemi J, Aromaa A, Heliövaara M, Reunanen A. The relative importance of modifiable potential risk factors of type 2 diabetes: a meta-analysis of two cohorts. European journal of epidemiology. 2010 Feb;25:115-24.

Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, Chasan-Taber L, Albright AL, Braun B. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes care. 2010 Dec 1;33(12):e147-67.

KRUG LM, HAIRE-JOSHU DE, HEADY SA. Exercise habits and exercise relapse in persons with non-insulin-dependent diabetes mellitus. The Diabetes Educator. 1991 Jun;17(3):185-8.

Burr JF, Rowan CP, Jamnik VK, Riddell MC. The role of physical activity in type 2 diabetes prevention: physiological and practical perspectives. The Physician and sportsmedicine. 2010 Apr 1;38(1):72-82.

Hebebrand J, Hinney A. Environmental and genetic risk factors in obesity. Child and adolescent psychiatric clinics of North America. 2009 Jan 1;18(1):83-94.

Balducci S, Sacchetti M, Haxhi J, Orlando G, D'Errico V, Fallucca S, Menini S, Pugliese G. Physical exercise as therapy for type 2 diabetes mellitus. Diabetes/metabolism research and reviews. 2014 Mar;30(S1):13-23.

Hidayat R, Setiati S, Soewondo P. The association between vitamin D deficiency and type 2 diabetes mellitus in elderly patients. Age. 2010;42:123-9.

Wen CP, Wai JP, Tsai MK, Yang YC, Cheng TY, Lee MC, Chan HT, Tsao CK, Tsai SP, Wu X. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. The lancet. 2011 Oct 1;378(9798):1244-53.

Zia A, Bhatti A, Jalil F, Wang X, John P, Kiani AK, Zafar J, Kamboh MI. Prevalence of type 2 diabetes–associated complications in Pakistan. International Journal of Diabetes in Developing Countries. 2016 Jun;36:179-88.

Zafar U, Qureshi HJ, Sandhu QS. Frequency and Association of Family History of Type 2 Diabetes in Type 2 Diabetic Patients. PAKISTAN JOURNAL OF MEDICAL & HEALTH SCIENCES. 2013 Apr 1;7(2):411-3.

Nyamdorj R, Qiao Q, Söderberg S, Pitkäniemi J, Zimmet P, Shaw J, Alberti G, Nan H, Uusitalo U, Pauvaday V, Chitson P. Comparison of body mass index with waist circumference, waist-to-hip ratio, and waist-to-stature ratio as a predictor of hypertension incidence in Mauritius. Journal of hypertension. 2008 May 1;26(5):866-70.

Boles A, Kandimalla R, Reddy PH. Dynamics of diabetes and obesity: Epidemiological perspective. Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease. 2017 May 1;1863(5):1026-36.

Blonde L, Aschner P, Bailey C, Ji L, Leiter LA, Matthaei S, Global Partnership for Effective Diabetes Management. Gaps and barriers in the control of blood glucose in people with type 2 diabetes. Diabetes and Vascular Disease Research. 2017 May;14(3):172-83.

Elimam H, Abdulla AM, Taha IM. Inflammatory markers and control of type 2 diabetes mellitus. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2019 Jan 1;13(1):800-4.

Tariq O, Rosten C, Huber J. Experiences of living with type 2 diabetes in Pakistan: the role of culture and family in physical activity. International journal for equity in health. 2022 Jul 29;21(1):103.

Samir N, Mahmud S, Khuwaja AK. Prevalence of physical inactivity and barriers to physical activity among obese attendants at a community health-care center in Karachi, Pakistan. BMC research notes. 2011 Dec;4:1-7.

Lunde MS, Hjellset VT, Høstmark AT. Slow post meal walking reduces the blood glucose response: an exploratory study in female Pakistani immigrants. Journal of immigrant and minority health. 2012 Oct;14:816-22.