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Original Research

Effect of acute bout of exercise on postprandial blood glucose and cardiovascular reactivity in offspring of type II diabetes mellitus

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ABSTRACT:
Background: The incidence of type 2 diabetes in adolescents is rising and only recently recognized as affecting children. While rare among youth, its increasing rate is concerning due to potential serious progression, significant complications in young adulthood, and higher mortality. Managing post-prandial glucose is critical, greatly influencing glycemic exposure, and essential for controlling glucose levels in type 2 diabetes treatment. Timely screening of at-risk populations is crucial for primordial disease prevention. Previous studies focused on diabetic patients to assess how exercise affects blood glucose levels and cardiovascular responses. This study investigates how acute moderate exercise impacts post-prandial glucose levels and cardiovascular reactivity with normal weight and those overweight in the offspring of type 2 diabetics. **Material and methods**: Sixty subjects were recruited, out of them thirty young adults were aged 18-22 with a parent diagnosed with type 2 diabetes, and thirty healthy age- and sex-matched individuals served as a control group. Following a fixed-calorie breakfast, we assessed postprandial blood glucose levels and evaluated the effect of 20 minutes of moderate-intensity exercise on post-prandial glucose and cardiovascular reactivity. **Results:** The offspring of diabetes showed notably elevated post-prandial glucose levels and cardiovascular reactivity (p-value $\leq$ 0.002). Notably, 20 minutes of moderate-intensity exercise substantially reduced the post-prandial glucose levels (p-value $\leq$ 0.001). **Conclusion**: Genetically predisposed children show higher post-prandial glucose levels. Findings suggest children of T2DM parents benefit more from an acute bout of moderate-intensity continuous exercise (MICE), improving glucose levels and cardiovascular reactivity compared to those with non-diabetic parents.
Keywords: Post prandial; blood glucose, type 2 diabetes mellitus, physiological stress reactivity, adult children, cardiovascular

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INTRODUCTION

Diabetes is rapidly evolving into a potential epidemic in India, with a staggering increase from 33 million people in 2000 to 72 million in 2021. This trajectory will peak at 125 million affected individuals by 2045 [1], underscoring the urgent need for proactive measures.

Various factors influence disease prevalence across a nation, making it vital to identify them to initiate change in health challenges. What are the current factors impacting diabetes in India that contribute to this severe issue?

The type 2 diabetes rate among adolescents is double that of type 1 in many non-White communities and has only recently been recognized as a pediatric illness. While type 2 diabetes in youth is rare, its rise in children and teenagers is concerning due to severe progression, serious complications risk in young adulthood, and increased all-cause mortality. [2].

Type 2 Diabetes mellitus (T2DM) often runs in families, and having a family history of T2DM heightens the likelihood of its occurrence in their children. Environmental contributors, like obesity—often linked to improved living standards, ongoing urban migration, and changes in lifestyle—

significantly influence diabetes development. However, these factors affect individuals differently. Even among those with similar environmental conditions, susceptibility to diabetes varies, indicating an inherited risk [3]. First-degree relatives of people with T2DM are approximately three times more likely to develop the condition compared to those without a family history of the disease [4].

The primary aim of treatment for type 2 diabetes is to reach and sustain optimal levels of blood glucose, lipids, and blood pressure (BP) to prevent or postpone the chronic complications associated with diabetes [5]. Exercise has been a key focus in managing blood glucose levels in individuals with T2DM. Nonetheless, it remains uncertain what specific amount and type of exercise should be recommended for those with T2DM. Regulating post-prandial glucose is crucial for managing glucose levels, especially in type 2 diabetes treatment. It plays a significant role in overall glycemic exposure. Numerous studies highlight the importance of controlling the sharp increases in plasma glucose levels that occur after meals [6]. Both mechanistic and epidemiological research show that post-prandial glucose substantially impacts total glycemic exposure [6]. Specifically, post-prandial hyperglycemia is the leading factor influencing A1C levels, particularly when A1C is below 7.5% [7]. Thus, addressing post-prandial hyperglycemia is essential for meeting A1C targets.

A systematic review conducted by Wu et al. found that the estimated incidence of T2DM among Indian children and adolescents in 2021 was 397 per 100,000, making it the second highest worldwide [8]. This increased risk of early complications highlights the pressing need for vigorous diabetes management, especially in younger individuals, to lessen the effects on their productive years of life [9].

Earlier research in this area mainly focused on diabetic individuals to evaluate how exercise impacts blood glucose levels and cardiovascular reactivity. To our knowledge, limited studies have investigated the children of individuals with type 2 diabetes mellitus, particularly given the rise of this condition among younger populations. Key risk factors include obesity and a family history of diabetes, which can increase the likelihood of type 2 diabetes in youth. Therefore, this study examines how acute moderate exercise sessions affect post-prandial glucose levels and cardiovascular reactivity in normal-weight and overweight children of type 2 diabetes mellitus patients.

MATERIAL AND METHODS

Study design

This case-control study was conducted in the Department of Physiology, Maulana Azad Medical College, New Delhi, after institutional ethical committee approval and informed consent was obtained from all the participating subjects explaining the study's objectives.

Participant screening and analysis

Sixty subjects were recruited from the general population based on inclusion and exclusion criteria. Out of 60 subjects, 30 subjects included in the study are young adults aged 18 -22 years whose at least one of the parents should be a diagnosed case of type 2 diabetes mellitus. Exclusion criteria for the subjects are subjects with BMI ≤ 19kg/m^2 and BMI >30 kg/m^2., doing regular exercise, with any comorbid conditions like hypertension, diabetes mellitus, bronchial asthma, hypothyroidism, hyperthyroidism, renal disease, endocrine disorder, etc., subjects under any medication, subjects with a habit of smoking or tobacco chewing and with any recent history of illness to be excluded.

Thirty controls are taken who are normal healthy young adults, age and sex-matched, offsprings of parents with no family history of diabetes.These controls are selected to provide a baseline for comparison with the study subjects.

The subjects included in the study are divided into the following groups:

Group A (Control group): 30 subjects aged 18-22 years, offspring of non-diabetic parents are considered controls.

Group A1: With a normal BMI of 19-24.9 kg/m^2

Group A2: With a BMI of 25-29.9kg/m^2

Group B (Subject group): 30 subjects aged 18-22 years, offspringof diagnosed type 2 diabetes mellitus parents are considered study subjects.

Group B1: With normal BMI 19-24.9 kg/m^2

Group B2: With BMI 25- 29.9 kg/m^2

Study protocol

The subject reported at the Department of Physiology, MAMC, New Delhi, at 8:00 am. Informed consent is taken. Before doing moderate exercise, the subject should abstain from tea, coffee, and ice cream at least 12 hours before testing; the subject should do overnight fasting. Clinical data recording including detailed history Name, age, sex, any history of relevant present or past illnesses (as per our inclusion and exclusion criteria), any relevant personal history (like smoking, exercise training, etc.), family, and treatment history. The anthropometric measurements of weight in kg and height in meters (m) were recorded using a balance beam scale and stadiometer. Body Mass Index (BMI) was calculated by dividing weight in kg by Height in meter square (m)^2. BMI 18.5 kg/m^2 to 24.9 kg/m^2 is normal,25 kg/m^2 to 29.9 kg/m^2 is overweight,30 kg/m^2 to 34.9 kg/m^2 is obese, 35 kg/m^2 and above is morbidly obese.

The subject is asked to do breakfast at 9:00 a.m. For breakfast, the subject is given a mixed nutrient diet of fixed 410kcal, i.e., one glass of milk 250ml (242kcal), two bread slices (64kcal), and one banana(100kcal).

Subjects should be relaxed and comfortable. Resting baseline blood pressure (SBP and DBP) and heart rate (baseline) are measured. After 1.5 hours of breakfast, blood glucose levels were assessed with the help of a glucometer.
The subjects are then asked to do moderate aerobic exercise on a Bicycle ergometer for 20 minutes. Blood pressure, heart rate, and blood glucose levels are measured immediately after the exercise. Cardiovascular Reactivity scores are calculated by subtracting the Heart rate and blood pressure test values from the baseline values.Blood glucose level is measured just before beginning the exercise and immediately after the exercise.

Blood Glucose Level Assessment
Blood glucose level is measured by the Accu-Chek Glucometer machine.
The meter displays the level in units ofmg/dl or mmol/l.

Exercise Test
This involves 20 minutes of moderate aerobic isotonic exercise on a bicycle ergometer, aligning with the target heart rate of 60-70% of maximum heart rate (MHR) as per the modified Bruce protocol. The maximum heart rate is calculated using the formula MHR = 220 - Age. In all subjects, resting heart rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured in the sitting position on the left arm using a mercury sphygmomanometer. Following a rest period of 5 to 10 minutes, participants are instructed to engage in 50 rotations per minute (rpm) on the bicycle ergometer with a minimum load of 30 watts (W) for warm-up. The speed of the bicycle ergometer was slowly increased until the participant reached the target heart rate. This target heart rate (THR) was determined using the Karvonen formula, also referred to as the heart rate reserve (HRR) formula: THR = ((MHR - HRrest) x % intensity) + HRrest. Once the target heart rate was achieved, the exercise continued for 20 minutes before stopping. Immediately after exercising, heart rate, SBP, and DBP measurements were taken again.
Cardiovascular reactivity (▲HR, ▲SBP, ▲DBP) is calculated by subtracting the resting value from after exercise value.

Statistical evaluation
Statistical analysis was performed using SPSS. Continuous variables were expressed as mean +/- Standard Deviation (S.D). One way ANOVA with Post Hoc Tukey test was used for comparison of means between multiple groups. Paired t-test was used to compare the means of the pre and post of the same group.P value less than 0.05 is considered as significant.

OBSERVATION AND RESULTS
In this study, 60 subjects are recruited from the general population based on inclusion and exclusion criteria. Out of 60 subjects, 30 subjects included in the study were young adults aged 18 -22 years whose at least one of the parents had a diagnosed type 2 diabetes mellitus, and 30 subjects were taken as controls who are normal healthy subjects whose none of the parents are having type 2 diabetes mellitus meeting the inclusion and exclusion criteria and provided valid written consent. The baseline characteristics of all the groups shows no significant difference in age, gender, heart rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP) between the groups (Table 1).

Table 1: Baseline characteristics of all the groups.

	A1	**A2**	**B1**	**B2**
Age (years)	18 -21	18 -21	18 -21	18 -21
BMI (Kg/m^2)	21.35	26.82	21.25	27.49
Gender distribution(M/F)	7/8	6/9	8/7	7/8
Heart Rate (bpm)	81.2 ± 8.2	82.6 ± 6.7	81.6 ± 3.8	83.7 ± 4.1
SBP (mmHg)	116 ± 6.4	118 ± 8.8	117 ± 10.5	121 ± 3.1
DBP (mmHg)	72.8 ± 4.7	77.3 ± 4.3	75.2 ± 4.8	80.8 ± 3.2

Note: **Group A (Control group):** 30 subjects aged 18-22 years offsprings of non- diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2
Group B (Subject group): 30 subjects aged18-22 years offsprings of diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^2 and Group B2: With BMI 25- 29.9 kg/m^2
After a fixed-calorie breakfast meal, the post-prandial glucose shows a significant difference when normal weight and overweight subjects of diabetic parents are compared with normal weight and overweight subjects of diabetic parents (Table 2).

Table 2: **Comparison of means of post prandial blood glucose level between the groups**

Group	**Group**	**p - Value**
A1 (109.3mg/dl)	A2 (111.1mg/dl)	0.745

	B1 (116.8mg/dl)	0.002*
	B2 (125.3mg/dl)	0.000*
A2 (111.1mg/dl)	A1 (109.3mg/dl)	0.745
	B1 (116.8mg/dl)	0.038*
	B2 (125.3mg/dl)	0.000*

Table 2: Values of post prandial blood glucose level in mg/dl for 30 subjects and 30 controls. Statistical analysis between groups was calculated using the one-way ANOVA followed by post hoc Tukey test. *p value <0.05 is significant. Note: **Group A (Control group):** 30 subjects aged 18-22 years offsprings of non- diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2

Group B (Subject group): 30 subjects aged18-22 years offsprings of diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^2 and Group B2: With BMI 25- 29.9 kg/m^2

Group	Group	p - Value
B1 (116.8mg/dl)	A1 (109.3mg/dl)	0.002*
	A2 (111.1mg/dl)	0.038*
	B2 (125.3mg/dl)	0.002*
B2 (125.3mg/dl)	A1 (109.3mg/dl)	0.000*
	A2 (111.1mg/dl)	0.000*
	B1 (116.8mg/dl)	0.002*

*p value ≤ 0.05 is significant.Note: **Group A (Control group):** 30 subjects aged 18-22 years,offsprings of non-diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2

Group B (Subject group): 30 subjects aged18-22 years offspringof diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/$m^{2,}$ and Group B2: With BMI 25- 29.9 kg/m^2

After an acute bout of moderate exercise for 20 min, there was a significant decrease in postprandial glucose levels in all the groups except in the normal-weight children of the non-diabetic group (Figure 1).

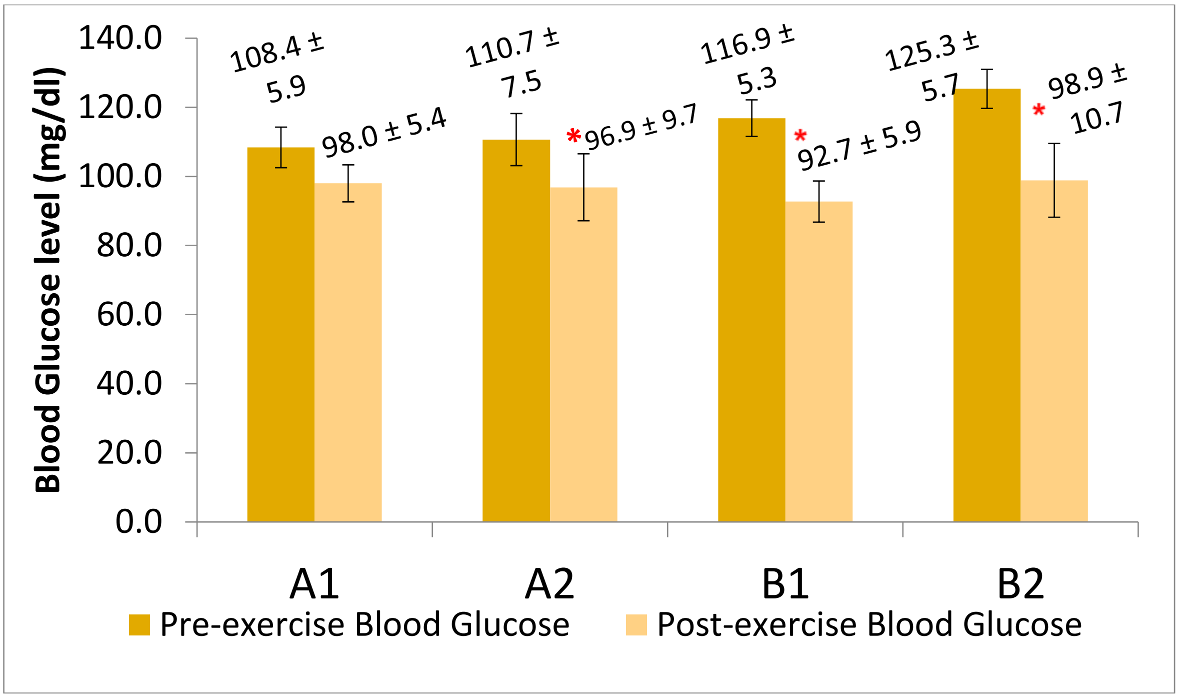

Figure 1: Effect of an acute bout of moderate exercise on post-prandial blood glucose levels in different groups. The graph comparespost-prandial glucose levels pre and post of moderate exercise in all the groups. Statistical significance was calculated using paired t-test. *p value ≤ 0.05 is significant.

Note: **Group A (Control group):** 30 subjects aged 18-22 years,offsprings of non-diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2

Group B (Subject group): 30 subjects aged18-22 years offspringof diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^{2,} and Group B2: With BMI 25- 29.9 kg/m^2

It was observed that heart rate reactivity is significantly increased in Group B2 (overweight offspring of a diabetic parent) compared to normal and overweight offspring of a non-diabetic parent (Figure 2).

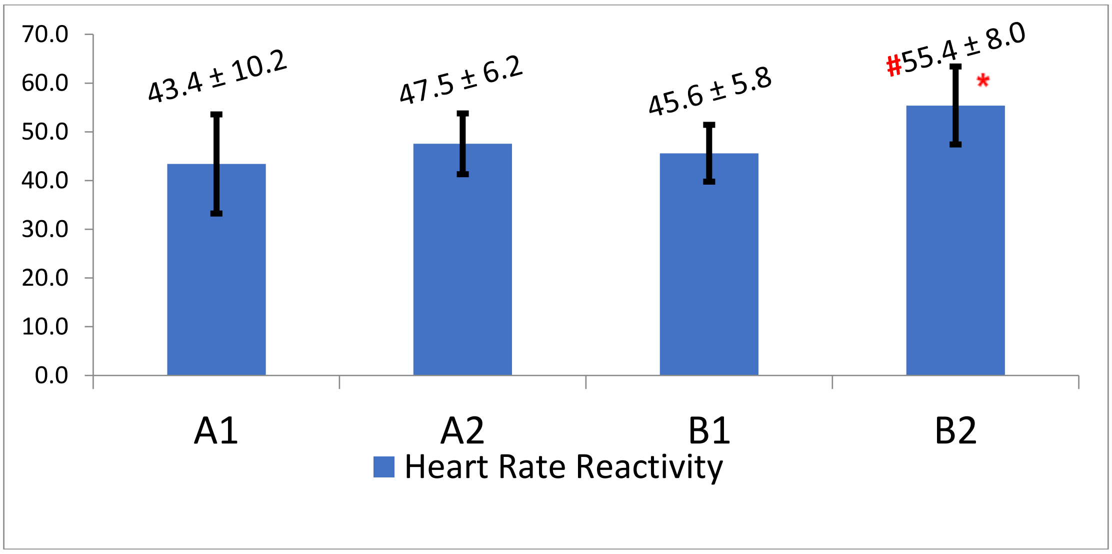

Figure 2: Effect of acute bout of moderate exercise on heart rate reactivity (▲HR) in different groups. One way ANOVA post hoc tukey test is used for the statistical analysis. *p value ≤ 0.05 is significant when compared with A1 group. # p value ≤ 0.05 is significant when compared with A2 group.

Note: **Group A (Control group):** 30 subjects aged 18-22 years,offspringof non-diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2

Group B (Subject group): 30 subjects aged18-22 years offspringof diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^{2,} and Group B2:

With BMI 25- 29.9 kg/m^2
It is seen that SBP reactivity is significantly increased in both normal-weight and overweight offspring of diabetic parents (Figure 3).

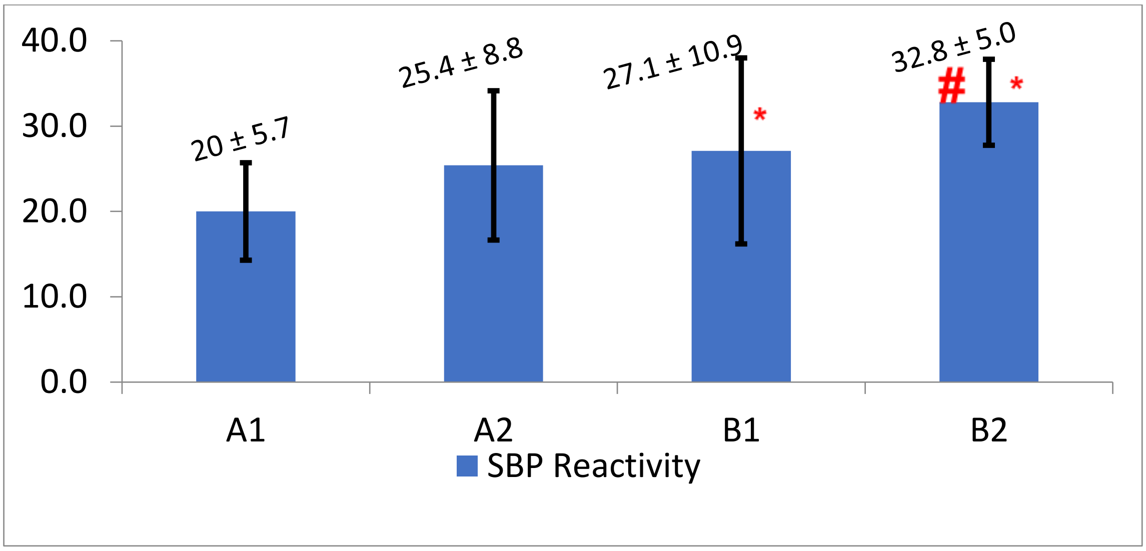

Figure 3: Effect of an acute bout of moderate exercise on systolic blood pressure reactivity (▲SBP)in different groups. One-way ANOVA post hoc Tukey test is used for the statistical analysis.*p value ≤ 0.05 is significant when compared with A1 group. # p value ≤ 0.05 is significant when compared with A2 group.
Note: **Group A (Control group):** 30 subjects aged 18-22 years,offsprings of non-diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2
Group B (Subject group): 30 subjects aged18-22 years offspringof diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^{2,} and Group B2: With BMI 25- 29.9 kg/m^2
It is also observed that DBP reactivity is significantly increased in overweight offspring of both non-diabetic and diabetic parents. In contrast, DBP reactivity is significantly decreased in normal-weight offspring of diabetic parents compared to overweight offspring of non-diabetic parents(Figure 4).

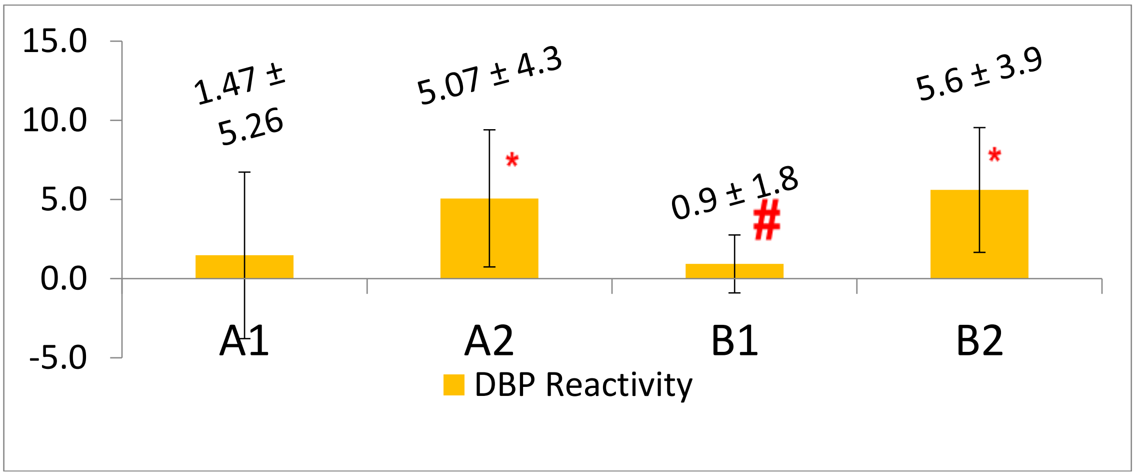

Figure 4: Effect of an acute bout of moderate exercise on diastolic blood pressure reactivity (▲DBP)in different groups. One-way ANOVA post hoc Tukey test is used for the statistical analysis.*p value ≤ 0.05 is significant when compared with A1 group. # p value ≤ 0.05 is significant when compared with A2 group.
Note: **Group A (Control group):** 30 subjects aged 18-22 years,offspringof non-diabetic parents are considered as controls, subdivided into Group A1: With normal BMI 19-24.9 kg/m^2 and Group A2: With BMI 25-29.9kg/m^2
Group B (Subject group): 30 subjects aged18-22 years,offspringof diagnosed type 2 diabetes mellitus parents are considered as study subjects, subdivided into Group B1: With normal BMI 19-24.9 kg/m^{2,} and Group B2: With BMI 25- 29.9 kg/m^2

DISCUSSION

To our knowledge, no comparative study has been reported yet on the effect of an acute bout of exercise on post-prandial glucose and cardiovascular reactivity in the offspring of T2DM parents. This study is unique as it found higher post-prandial blood glucose levels in both normal-weight and overweight offspring of T2DM parents compared to those of non-diabetic parents (Table 2). Consistent with other research, this finding emphasizes the significant genetic predisposition to T2DM among Indians, revealing that the condition tends to emerge at younger ages and even in individuals with a normal body mass index (BMI). [10,11].

Numerous studies have established that post-prandial glucose levels contribute not only to overall blood glucose control but also serve as an independent risk factor for cardiovascular disease and mortality [12].

This highlights the urgent need to identify the vulnerable population at risk for type 2 diabetes and take action to reduce the early onset of the disease in young individuals.

In this study, it was observed that acute bouts of moderate-intensity continuous exercise significantly lowered post-prandial glucose levels across all groups except for the normal-weight offspring of non-diabetic parents (Figure 1). This observation aligns with previous studies, which demonstrate that during moderate-intensity exercise in nondiabetic individuals, the increase in peripheral glucose uptake corresponds with a similar rise in hepatic glucose production, thus maintaining stable blood glucose levels unless during extended, glycogen-depleting activities. In individuals with type 2 diabetes engaging in moderate exercise, muscle glucose utilization typically exceeds hepatic glucose production, causing blood glucose levels to decrease. [13].

It's essential to recognize that just 20 minutes of moderate exercise can lower blood glucose levels. Therefore, in a young population with hectic schedules that may lead to a future risk of developing type 2 diabetes mellitus (T2DM), even a single session of moderate exercise can provide protective benefits and serve as a key preventive measure against type 2 DM.

According to the U.S. 2018 Physical Activity Guidelines Advisory Committee, it is now recognized that even 10 minutes of exercise can bring positive health benefits, which diminishes the emphasis on exercise duration. [14].

Current research primarily targets adults diagnosed with T2DM or those with prediabetes, emphasizing exercise as a crucial non-pharmacological method for managing blood glucose levels. [15]. Exercise is most effective for those who need its ability to lower blood glucose the most. Clinicians must be aware that patients, as well as the general population referred to targeted exercise programs, should gain advantages from these interventions. This study focuses on the offspring of individuals with type 2 diabetes mellitus (T2DM), rather than those with clinically diagnosed T2DM, to better identify who benefits the most from exercise. The goal is to highlight postprandial glucose levels and cardiovascular reactivity as crucial preventive measures, in addition to being a non-pharmacological approach to preventing or delaying the onset of T2DM. The findings indicate that offspring of T2DM parents, who are at higher risk for developing T2DM, may experience greater benefits from even a single session of moderate-intensity continuous exercise (MICE), as evidenced by improvements in postprandial glucose levels and cardiovascular reactivity, compared to the offspring of non-diabetic parents.

A significant rise in heart rate reactivity, systolic blood pressure reactivity, and diastolic pressure reactivity was noted in overweight children of diabetic parents, in contrast to their normal weight and overweight counterparts from non-diabetic parents (see Figure 2, Figure 3, Figure 4). Numerous studies have shown that elevated cardiovascular reactivity increases the likelihood of developing atherosclerosis, hypertension, and a higher risk of heart diseases. [16].

As mentioned earlier, the leading cause of death in type 2 diabetes mellitus (T2DM) is silent myocardial infarction, with cardiac complications representing the primary chronic issues associated with T2DM [17]. This indicates a need for early intervention, ideally even before prediabetes sets in, to prevent the progression of cardiac complications.

Thus, identifying individuals at high risk for developing T2DM early is crucial. There is a pressing need for effective strategies and lifestyle interventions that can halt diabetes progression among young people. In developing nations like India, a significant rise in prediabetes prevalence is anticipated over the next 25 years. Immediate implementation of targeted exercise routines and dietary changes is essential to mitigate the diabetes epidemic in India. Raising awareness about maintaining a healthy weight for age, along with continuous growth monitoring by pediatricians during childhood, and establishing strong connections between healthcare providers and community prevention programs are vital to prevent young individuals from transitioning from being overweight to obese and eventually to T2DM.

This investigation concluded that the increase in post-prandial glucose levels in both normal weight and overweight offspring of T2DM may be related to the genetic predisposition to T2DM. The present study supports the acute bout of moderate exercise as a crucial non-pharmacologic line of defense in delaying the development of T2DM. It would be suggested to do several periods of moderate exercise interspersed throughout the day.

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