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EFFECTS OF PRESCRIBED PHYSICAL THERAPY EXERCISES ON BLOOD GLUCOSE, METABOLIC AND HbA1C PROFILES IN PRE-DIABETES AT MOI TEACHING AND REFERRAL HOSPITAL IN UASIN GISHU COUNTY, KENYA

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H. M. Muroki, N. Magak, M. G. Owiti and K. Onyango

ABSTRACT

Objectives: **To investigate the metabolic parameters of pre-diabetes and to provide evidence of prescribed physical therapy exercises that can be quantified and reproduced.**

Design: **A controlled experimental study**

Setting: **Moi Teaching and Referral Hospital and physical therapy gymnasium of Moi University orthopaedics and rehabilitation department in Uasin Gishu County, Kenya.**

Subjects: **Two comparison groups, Experimental Group (EG) and Control Group (CG) with each group having the same size of subjects (17 each).**

Results: **Exercise reduces Fasting Blood Glucose (FBG) by 5% and 13%, in 6 and 12 weeks, respectively. It also showed High Density Lipoprotein (HDL) were significantly higher in the experimental than in the control group during post-training (z= -3.20.17, p=0.001). On the other hand, the level of Low-Density Lipoprotein (LDL) decreased in the experimental group during both mid-training and post-training period relative to pre-training (z= -2.908.18, p=0.001). There was a significant reduction of HbA1c (of 3%) after six weeks and an even more marked drop (8%) after 12 weeks in EG compared to CG in which there was no drop in HbA1c levels. High correlation was found between FBG and HbA1c(r=0.95). All parameters at pre, mid and post training were not significantly different between males and females.**

Conclusion: **Prescribed Physical Therapy Exercises (PPTE) exerted improvement on FBG, metabolic and HbA1c profiles in pre-diabetes. The knowledge of how**

much exercise is needed to impact change in disease progression would inform the prescription of exercise by physiotherapists to their clients.

INTRODUCTION

Pre-diabetes is characterized by plasma glucose above the normal range (3-6mmol/L) but below that of clinical diabetes (>9.0mmol/L) American Diabetes Association (ADA)(1). In Kenya the estimated prevalence of diabetes is 3.3% and is a threat to social and economic development (2). Undetected and untreated complications of diabetes lead to huge socio-economic costs that result from premature morbidity and mortality (3). Apart from diabetes being the leading cause of blindness, they also lead to renal failure and triggers cardiovascular disease, which is the leading cause of deaths in diabetes patients (4).

People with pre-diabetes have an increased risk of Type 2 diabetes. Around to 10% of people with pre-diabetes become diabetic every year (5). An estimated 34% of adults have pre-diabetes and the lifestyle risk factors for this condition include overweight and physical inactivity (6). The International Diabetes Federation (IDF) Diabetes Atlas has now recognized pre-diabetes as a reversible condition that increases an individual's risk for development of diabetes (7).

International Diabetes Federation (IDF), Diabetes Atlas has estimated that in 2017, 425 million people around the world had diabetes and one in every two adults with diabetes is undiagnosed approximating to 212 million people. Almost 30% of people with diabetes go undiagnosed, and nearly 25% of them have micro-vascular complications by the time their diabetes is diagnosed (8). In Africa, a disproportionate increase in pre-diabetes is anticipated in low- and middle-income countries, many of which are expected to experience several-fold increase in the number of diabetics.

In Kenya, diabetic epidemic is similar to other developing countries because of a dramatic change in living standards, urbanization and demographic changes (9). According to the Kenya Ministry of health, division of Non-communicable diseases (DNCD) current prevalence is estimated to be 10% which the World Diabetes Foundation (WDF) claims to be an underestimate (10). Physical activity and even exercises at moderate intensities such as walking significantly reduces the risk of developing type 2diabetes.

MATERIALS AND METHODS

Design: Randomized Controlled Trial assigning participants into an experimental and a control group.

Settings: The Moi Teaching and Referral Hospital in Uasin Gishu County. MTRH was purposively selected because of large number of patients and its proximity to the experimental lab and Physical Therapy Department at Moi University.

Sample Size

Zhong (2009) provides a formula for calculating sample size in a randomized controlled trial having two comparison groups with both groups having the same size of subjects as:

$$N = 2 \times \left[\frac{z_{1-\alpha} + z_{1-\beta}}{\delta - \delta_0}\right]^2 \times s^2$$

Where

N is the size per group

$z_{\alpha}$is the standard normal deviate for a one sided

$\delta$is the hypothesized mean difference between the two groups

δ_0 is the clinically admissible margin of superiority

$s^2$is the pooled variance of both comparison groups

Power standard to set this at 80% requiring a greater sample size

For this study HbA1c was used to compute the sample size. We have

: 0.05 , : 0.20 , : 0.3 , = 0.1 , = 0.2 . Hence

$$N = 2 \times \left[\frac{1.645 + 0.845}{\delta - \delta_0}\right]^2 \times 0.2 = 17$$

Each arm was having 17 participants

Inclusion criteria: All overweight patients attending outpatient clinic at MTRH aged 18 to 60 years during study period, Secondly Participants with HbA1c of between 5.7% to 6.7% and Fasting Plasma Glucose of between 5.6mmol/L to 6.9mmol/L.

Exclusion criteria: Patient already on treatment for dyslipidemia, Secondly, Diabetic patients and Persons with disabilities

Data collection: Data were collected using a laboratory-based experiment where by blood samples were taken by a medical laboratory scientist at the end of every six weeks after administration of prescribed physical therapy exercise regimen. During the day of the laboratory tests, the identified participants were instructed to fast for 8 – 12 hours prior to the tests.

Data Analysis: All experimental results were evaluated and analysis of variance (ANOVA) was used to investigate associations between variables (relationship between physical therapy exercises and metabolic components). Presentation was done by use of charts, tables and Figures.

Ethical considerations: Approval was sought from Institutional Research and Ethics Committee (IREC) at Moi Teaching and Referral hospital, there after permission was sought from the Moi University administration. Informed consent was given by the study participant before the commencement of the study and data collected from the participant were treated with outmost confidentiality.

RESULTS

The study collected data from 34 respondents (17 each for the experimental and control groups). Data were collected from the participants at three time-periods: pre-training, mid-training (at end of 6 weeks), and post-training (at end of 12 weeks).

Table 1

Biographic information of respondents

Bio-graphic information	Overall (n=34)	Experimental group (n=17)	Control group (n=17)
Respondents' gender			
1. Male (%)	19 (55.9)	9 (52.9)	10 (58.8)
2. Female (%)	15 (44.1)	8 (47.1)	7 (41.2)
3. Total (%)	34 (100.0)	17 (100.0)	17 (100.0)
Highest education level			
1. Primary (%)	6 (17.6)	3 (17.6)	3 (17.6)
2. Secondary (%)	18 (52.9)	8 (47.1)	10 (58.8)
3. Tertiary (%)	10 (29.4)	6 (35.3)	4 (23.5)
4. Total (%)	34 (100.0)	17 (100.0)	17 (100.0)
Respondents' age			
Mean years + SD	35.94±9.35	34.59±9.53	37.29±9.25

Key: SD = standard deviation; n = number of respondents

Descriptive results in Table 1 showed that the study sampled slightly more males (56%) compared to female (44%) participants.

Metabolic profiles of pre-diabetes: Table 2 presents the metabolic profiles of the pre-diabetes enrolled in the study at the baseline (pre-training period).

Table 2

Baseline values of metabolic profiles of pre-diabetes

Variable	Overall Mean ± SD	Experimental Mean ± SD	Control Mean ± SD	t-value	p
BMI (Kg/m^2)	28.62±2.49	28.47±2.37	28.77±2.66	-0.34	0.74
FBG (mmol/L)	6.15±0.51	6.11±0.47	6.19±0.55	-0.42	0.68
TC (mg/dL)	211.35±24.33	206.29±27.56	216.41±20.17	-1.22	0.23
HDL (mg/dL)	45.53±8.99	48.00±9.68	43.06±7.73	1.64	0.11
TRI (mg/dL)	141.32±32.64	138.47±34.72	144.18±31.21	-0.50	0.62
LDL (mg/dL)	138.06±25.91	131.12±29.30	145.00±20.59	-1.59	0.12
HbA1c (%)	5.96±0.25	5.93±0.23	5.97±0.28	-0.42	0.68

***Key**. BMI: body mass index, FBG: fasting blood glucose, TC: total cholesterol, HDL: high-density lipoprotein, TRI: triglycerides, LDL: low-density lipoprotein, HbA1c: glycosylated haemoglobin,*
SD: standard deviation

Exercise Regimen required to change Pre-diabetes Metabolic Profiles: Table 3 shows the metabolic profiles of pre-diabetes recorded at pre-training, mid-training and post-training.

Table 3

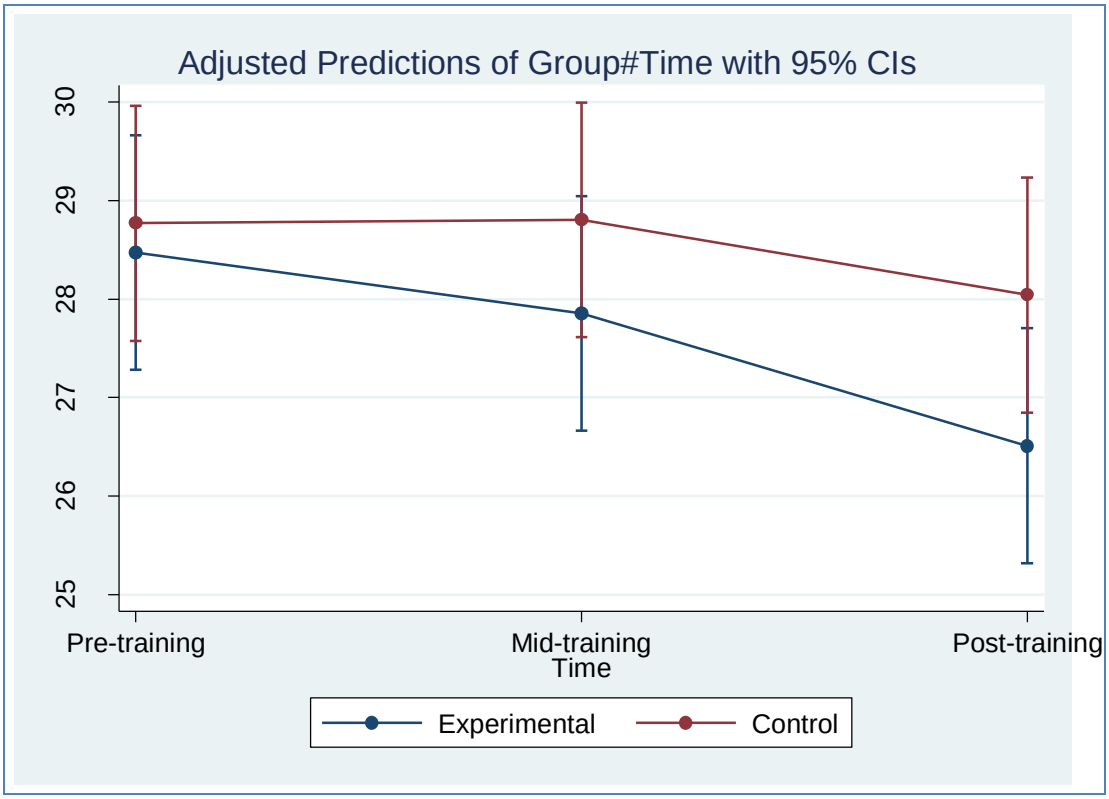
Metabolic profiles of pre-diabetes at pre-, mid-, and post-training

Variable	Treat.	Pre-training	Mid-training	Post-training	Main effects (F values)		Interaction (F value)
		Mean±SD	Mean±SD	Mean±SD	Group	Time	Group*Time
BMI (Kg/m²)	Exp.	$28.47\pm2.37^{a,k}$	$27.85\pm2.17^{a,k}$	$26.51\pm2.26^{b,k}$			
	Cont.	$28.77\pm2.66^{a,k}$	$28.80\pm2.77^{a,k}$	$28.04\pm2.74^{b,l}$	1.28^{ns}	18.27^{**}	3.49^{*}
FBG	Exp.	$6.11\pm0.47^{a,k}$	$5.81\pm0.53^{b,k}$	$5.30\pm0.46^{c,k}$			
(mmol/L)	Cont.	$6.19\pm0.55^{a,k}$	$6.28\pm0.48^{a,l}$	$5.99\pm0.76^{a,l}$	7.22^{*}	15.20^{**}	5.05^{*}
	Exp.	$206.29\pm27.56^{a,k}$	$203.41\pm26.06^{a,k}$	$194.35\pm32.77^{b,k}$			
TC (mg/dL)	Cont.	$216.41\pm20.17^{a,k}$	$208.65\pm21.80^{b,k}$	$209.88\pm20.32^{a,k}$	0.22^{ns}	7.27^{**}	2.24^{ns}
	Exp.	$48.00\pm9.68^{a,k}$	$49.53\pm7.69^{a,k}$	$51.47\pm6.77^{b,k}$			
HDL (mg/dL)	Cont.	$43.06\pm7.73^{a,k}$	$43.18\pm7.73^{a,k}$	$43.53\pm4.06^{a,l}$	8.17^{**}	2.32^{**}	1.33^{ns}
	Exp.	$138.47\pm34.72^{a,k}$	$134.29\pm34.61^{a,k}$	$123.24\pm25.03^{b,k}$			
TRI (mg/dL)	Cont.	$144.18\pm31.21^{a,k}$	$146.47\pm30.59^{a,k}$	$139.59\pm25.03^{a,k}$	1.38^{ns}	5.41^{*}	1.30^{ns}
	Exp.	$131.12\pm29.30^{a,k}$	$128.26\pm25.59^{a,k}$	$118.15\pm33.91^{b,k}$			
LDL (mg/dL)	Cont.	$145.00\pm20.59^{a,k}$	$136.04\pm24.20^{a,k}$	$138.44\pm22.10^{a,l}$	2.71^{ns}	6.91^{**}	2.79^{*}
	Exp.	$5.93\pm0.23^{a,k}$	$5.78\pm0.30^{b,k}$	$5.46\pm0.25^{c,k}$			
HbA1c (%)	Cont.	$5.97\pm0.28^{a,k}$	$6.00\pm0.28^{a,k}$	$5.80\pm0.41^{b,l}$	6.18^{**}	21.00^{**}	4.02^{*}

Key *BMI: body mass index, FBG: fasting blood glucose, TC: total cholesterol, HDL: high-density lipoprotein, TRI: triglycerides, LDL: low-density lipoprotein, HbA1c: glycosylated haemoglobin, SD: standard deviation, Treat: Treatment, Exp.: experimental, Cont.: Control. For every group, means with similar letters in a row (a, b, and c) and for every variable, means with similar letters in a column (k and l) are not significantly different by Tukey HSD test.* **, * *: significant at 99% and 95% significance levels, respectively.*

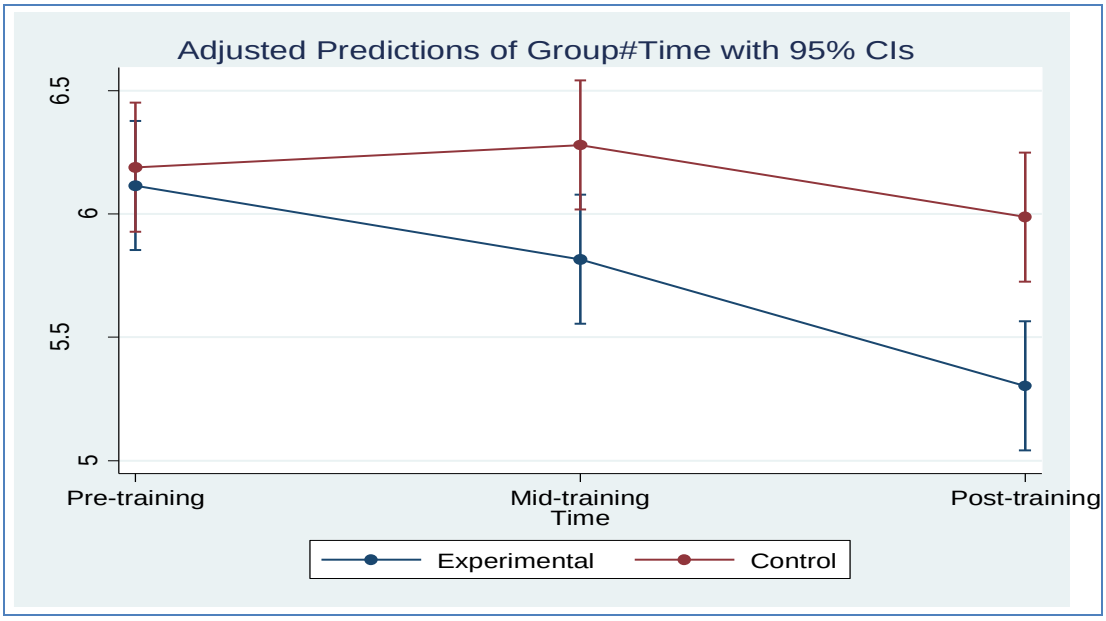
The levels of BMI decreased in the experimental group during both the mid-training and post-training period. A mixed-design (repeated-measures) ANOVA with a within-subjects factor of time of training (pre-, mid-, and post-training) and a between-subject factor of treatment type (experimental and control groups) was run to determine the effects of these factors. There were no outliers in the data, as assessed by inspection of a boxplot. BMI scores for each level of treatment were normally distributed, as assessed by Shapiro-Wilks test ($p > 0.05$) whereas the Levene's Test indicated error variance to be equal across the groups (all $p > 0.05$). The results showed that over time, BMI levels, significantly reduced in both groups. However, the most substantial decrease was recorded in the experimental group relative to the control group (Figure 1).

Figure 1: Predicted BMI interactions between group and time



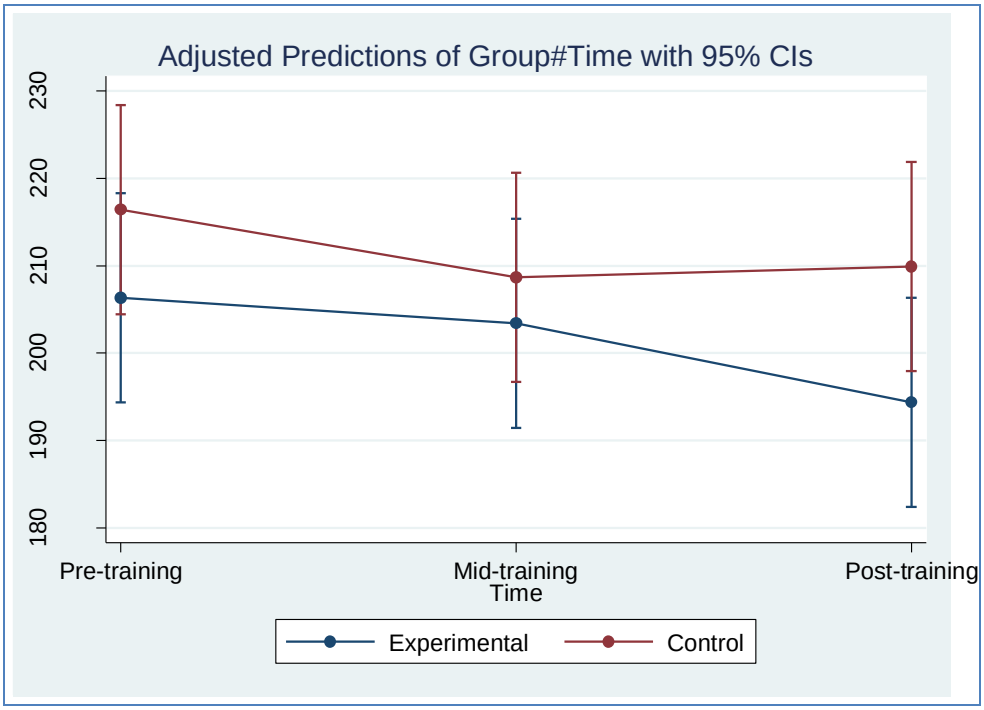
Post-hoc pair wise comparisons of adjusted predictions revealed that BMI levels did no significantly differ between mid-training and pre-training in both the experimental and control groups (Table3).

Figure 2: Predicted FBG interactions between group and time



Pair wise comparisons showed that in the experimental group, training significantly lowered the level of FBG in six weeks compared to pre-training period. In addition, training significantly lowered the FBG value in 12 weeks compared to week six (Table 3 and Figure 2).

Figure 3: Predicted TC interactions between group and time



Concordance between Pre-diabetes Metabolic Parameters: Table 4 presents the Pearson's correlation amongst the pre-diabetes metabolic parameters measured among the participants of the study.

Table 4

Pearson's correlations between pre-diabetes metabolic parameters

Parameter		BMI	FBG	TC	HDL	TRI	LDL	HbA1c
BMI	r	1						
FBG	r	0.47**	1					
TC	r	0.43**	0.40**	1				
HDL	r	-0.39**	-0.52**	-0.49**	1			
TRI	r	0.35**	0.29**	0.56**	-0.34**	1		
LDL	r	0.44**	0.45**	0.95**	-0.67**	0.38**	1	
HbA1c	r	0.49**	0.95**	0.37**	-0.46**	0.32**	0.40**	1

Key: *r = Pearson correlation coefficient; ** = correlation significant at .01 level (2-tailed)*

Gender differences in Metabolic Profiles after administration of Exercises: The study recorded gender differences in metabolic profiles after the administration of training. Table 5 shows the parameters recorded during baseline. Independent samples t-tests were conducted to determine gender differences in metabolic profiles of pre-diabetes.

Table 5

Baseline values of metabolic profiles grouped according to respondents' gender

Variable	Male Mean ± SD	Female Mean ± SD	t-value	p
BMI (Kg/m²)	28.73±2.69	28.48±2.27	0.29	0.77
FBG (mmol/L)	6.16±0.48	6.14±0.55	0.06	0.95
TC (mg/dL)	209.58±24.53	213.60±24.74	-0.47	0.64
HDL (mg/dL)	44.16±6.91	47.27±11.10	-1.00	0.32
TRI (mg/dL)	137.47±35.95	146.20±28.35	-0.77	0.45
LDL (mg/dL)	138.42±23.99	137.60±29.01	0.09	0.93
HbA1c (%)	5.95±0.25	5.96±0.26	-0.07	0.95

Table 6 presents the metabolic profiles recorded in male and female participants during the mid-training period. TC and LDL were higher in males than in females whereas HDL and TRI reversely distributed.

Table 6

Metabolic profiles segregated according to respondents' gender at mid-training

Variable	Male Mean ± SD	Female Mean ± SD	t-value	p
BMI (Kg/m²)	28.35±2.79	28.30±2.17	0.04	0.97
FBG (mmol/L)	6.05±0.52	6.05±0.60	0.02	0.98
TC (mg/dL)	207.53±24.83	204.13±23.15	0.41	0.68
HDL (mg/dL)	45.53±6.64	47.40±8.82	-0.71	0.48
TRI (mg/dL)	134.95±33.47	147.27±31.58	-1.09	0.28
LDL (mg/dL)	136.13±23.38	127.12±26.53	1.05	0.30
HbA1c (%)	5.89±0.30	5.89±0.32	0.03	0.97

Independent samples t-tests were run to determine the effect of gender of the levels of the parameters and all were found (Table 6) to be non-significant (all had P>0.05). The results showed that the response of participants to training was not affected by their gender.

The metabolic profiles recorded in male and female participants during the end of the experiment are presented in Table 7. TC and LDL were higher in males than in females whereas FBG, HbA1c, HDL and TRI were slightly higher in females than in males.

Table 7

Metabolic profiles segregated according to respondents' gender at post-training

Variable	Male Mean ± SD	Female Mean ± SD	t-value	P
BMI (Kg/m²)	27.04±2.73	27.57±2.47	-0.59	0.56
FBG (mmol/L)	5.57±0.64	5.73±0.79	-0.66	0.51
TC (mg/dL)	204.11±33.07	199.60±20.66	0.46	0.65
HDL (mg/dL)	47.53±6.09	47.47±7.86	0.02	0.98
TRI (mg/dL)	125.47±22.31	138.93±29.09	-1.53	0.14
LDL (mg/dL)	131.48±34.29	124.25±24.05	0.69	0.49
HbA1c (%)	5.61±0.33	5.65±0.44	-0.27	0.78

Independent samples t-tests were conducted to determine the effect of gender of the levels of the parameters and all tests were found not to be significant (Table 7). Overall, gender was found to have no significant influence on the respondent's ability to respond to training regime with respect to metabolic parameters (Figure 4).

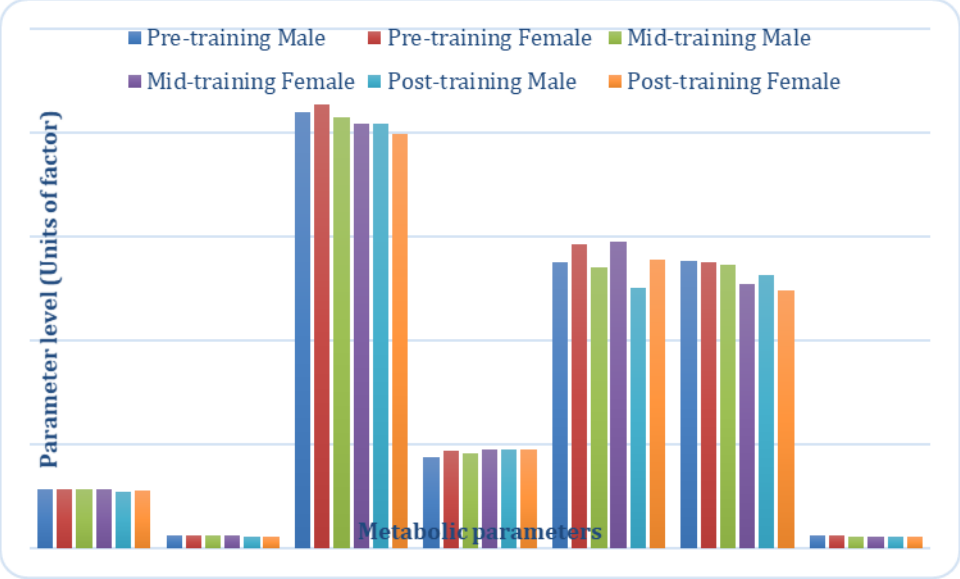


Figure 4: Levels of metabolic parameters:

Units of factors: BMI: body mass index (kg/m²), FBG: fasting blood glucose (mmol/L), TC: total cholesterol, HDL: high-density lipoprotein, TRI: triglycerides, LDL: and low-density lipoprotein (all in mg/dL), HbA1c: glycosylated haemoglobin (%).

DISCUSSION

Physiologically increase or decrease in BMI is determined by the balance between energy intake and energy expenditure (11). Where there is increase in BMI physiologically it is perceived as an adaptation to lack of physical activity and down regulation of metabolic processes geared towards energy and macronutrients expenditure. On the other hand, a reduction in BMI results from induction of an overall body energy deficit or prevention of a positive energy balance (12). Data from the present study revealed that over time BMI levels, substantially decreased in the experimental group compared to the control group. Studies have reported that regular physical activity induces multiple adaptations within the skeletal muscles and the cardiovascular system all of which provide positive outcomes for the prevention and treatment of metabolic disorders. Prescribed physical therapy exercises in enhancing burning of calories in the study participants probably also induced a more pronounced enhancing effects on the oxidation potential of skeletal muscles. Skeletal muscles are usually more active in metabolism in any exercise since they are involved in moving the body parts. Our findings are similar to the findings by Mora et al in the US where lower levels of physical activity and higher levels of BMI were independently associated (P for trend <.001) (13).

A study done by Aspray *et al*. in Cameroon found that physical inactivity was associated with obesity, diabetes and hypertension among individuals studied in rural settings (14). A qualitative study done in Cameroon by Treloar *et al*., explained that the higher rate of obesity observed in people with these sedentary occupations in the cities was associated with reduced physical activity (15). On the other hand, Steyn *et al*. in a study conducted in a poor, peri-urban community near Cape Town showed an independent association between low levels of physical activity and having diabetes (16).

The results lead to a similar conclusion in a study done by Peyoosha & Rajan that demonstrated passive static stretching and Resistance exercises being effective treatment in reducing blood sugar levels (17). The recovery of insulin sensitivity is boosted by high-intensity aerobic exercises. Benefits from weight management, blood glucose control, and insulin sensitivity on tissues exercise are generally recommended for the treatment of pre- diabetes (Diabetes Prevention Program Research Group, 2002. Physiological studies have shown that, lowering blood glucose through exercise prolong the onset and progression of long-term complications of symptomatic cardio-vascular disease in diabetes. Modification of lifestyle in regular physical activity has also shown a protective effect against the development of diabetes independent of age, obesity, parental history of diabetes and history of hypertension Erikson et al., (18).

Physical exercise increases glucose uptake by the muscles and enhances storage of glucose. Level of FBG diminishes during the exercise because muscle contraction stimulates glucose uptake into the muscle even in the absence of insulin.

These findings were in agreement to other previous studies also done in Canada; Dunn *et al*. assessed effects of a 6-month aerobic exercise training program (18). The exercise progressed from 50 to 85 % of maximum aerobic power for 20–60 min three times weekly. It was reported that there was a

significant decreases in total cholesterol (-0.3 mmol/L, p\0.001) and in the total: HDL cholesterol ratio (-0.3, p\0.001). In this case, the set period for intervention was relatively long and the magnitude was relatively high.

Physiologically exercise can help lower HbA1C levels over time. Exercise increases the effectiveness of insulin, which results in more glucose entering cells and lower levels in the blood. Our study findings indicated that HbA1c decreased in the experimental group during both mid-training and post-training period compared to pre-training. The decrease in HbA1c in our study is of clinical importance in positively affecting the management of pre-diabetes as well as in reducing the potential for development of complications from the disease. It is therefore important to interpret the findings that exercise regimen is effective in reducing hemoglobin HbA1c.

Similar findings were seen in Cauza *et al*, in China showing a greater improvement in FBG control following 4 months of strength training as opposed to endurance exercise (18). In the current study the highest correlation was found between FBG and HbA1c (r=0.95) suggesting a high level of concordance between the two parameters. Our findings have the same opinions like those results from Solomon *et al.* who found that improvements of glycaemic control were positively caused by increasing the training before when sugars are elevated for period of 3-4 months doing aerobic exercise period in client with T2DM (19). Recently in meta-analysis done in Spain by Ishiguro *et al.* (20) findings were shown that resistance training using increased numbers had the most effective magnitude strategy of training to reduce glycosylated haemoglobin (HbA1c) in pre-diabetes.

CONCLUSION AND RECOMMENDATIONS

We found that the data provides evidence that there is a significant relationship between physical exercise and metabolic profiles of pre-diabetes. Prescribed exercises reduce FBG and training increases HDL. Exercise regime reduces BMI, TC, TRI, LDL levels but after a long time of training. Increase in BMI leads to increase in FBG, TC, TRI, LDL, and HbA1c and the vice versa.

We recommend that regular screening of metabolic profile be incorporated in the daily clinical profiles in our health institutions to help pick the abnormalities early for effective prevention measures. We also recommend that the Kenyan health sector develop clinical guidelines for Health practitioners on how to identify and manage patients with pre-diabetes.

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