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Effects of Aerobic Exercise on Fasting Blood Glucose and Blood Pressure Levels of Diabetic-Hypertensive Clients at a Diabetes Clinic in Accra, Ghana

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Abstract

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Background: Hypertension and diabetes are associated with an increased risk of cardiovascular diseases. Effective interventions are therefore relevant in reducing the morbidity and mortality associated with hypertension and diabetes. We set out to determine the effect of aerobic exercise on type-2 diabetic-hypertensive clients at a diabetes clinic in Accra.

Method: Twenty-one participants were recruited from the National Diabetes Management and Research Center in Korle-Bu in Accra. Participants undertook 30 minutes of aerobic exercise comprising, warm up, ergonomic cycling and cool down, three times a week for a period of eight weeks. Fasting blood glucose and blood pressure levels were measured and changes with respect to exercise were analysed. The mixed model ANOVA was used to test for the differences in the weekly blood pressure and blood glucose levels while the paired t-test was used to compare the baseline and final readings of blood pressure and blood glucose levels. Pearson's correlation test was used to determine the relationship between age and change in blood pressure and blood glucose levels after eight weeks of exercise.

Results: Mean systolic blood pressure reduced from 142mmHg to 135mmHg while the mean diastolic blood pressure also reduced from 89mmHg to 84mmHg post exercises. The baseline and eighth week post exercise average blood glucose level were 8.0 mmol/L and 5.2 mmol/L respectively. There were significant differences in baseline and week eight systolic ($p = 0.0017$), and diastolic ($p = 0.006$) blood pressure as well as blood glucose ($p=0.0027$) levels. There was also a significant positive correlation between age and change in blood glucose level ($p = 0.036$).

Conclusion: Aerobic exercise reduces the fasting blood glucose level and blood pressure in type-2 diabetic-hypertensives. Diabetic-hypertensives should therefore be encouraged to participate in aerobic exercises.

Keywords: *aerobic exercise, blood glucose level, diabetic-hypertensive, blood pressure, clients.*

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INTRODUCTION

Hypertension is a common cardiovascular disease responsible for 9.4 million deaths each year, or 16.5% of all deaths worldwide and it is defined as persistent elevation of systolic blood pressure of 140mmHg or greater and/or diastolic blood pressure of 90mmHg or greater [1]. As of 2000, nearly one billion people or approximately 26% of the adult population of the world were living with hypertension [2]. Aerobic exercise is almost completely free of secondary effects and is a useful adjunct therapy for treating hypertension [3]. An immediate (acute) reduction in blood pressure following exercise has been termed 'post-exercise hypotension' and is caused by reductions in vascular resistance [4]. There is evidence that aerobic exercises help to reduce blood pressure. Molmen-Hansen *et al.* [5] in their study of 39 women with essential hypertension randomized for aerobic interval training indicated that the blood pressure reducing effect of exercise is intensity dependent and hence, the exercise mode used is an effective method to lower blood pressure and improve other cardiovascular risk factors.

Diabetes mellitus is characterized by abnormalities in insulin production and action or both, and its prevalence in UK varies from 2.7 % to 4.1 % of the population [6]. Living with diabetes means coping with a regimen of dietary management, physical exercise and periodic testing [6]. Exercise as a key prevention strategy for diabetes is commonly accepted and recommended throughout the world [7]. Unfortunately, not all individuals profit to the same extent as some exhibit exercise resistance [7]. Aerobic exercise, with cardiovascular equipment like treadmill, improves the blood glucose level and decreases the free radicals in patients with diabetes mellitus [8]. Reduction in blood glucose levels during exercise may be due to the conversion of blood glucose to glycogen to produce energy during aerobic exercise [9]. Moderate-intensity exercise improves blood glucose (BG), but most people fail to achieve the required exercise volume [10]. Although, high-intensity exercise (HIE) protocols may vary, very brief HIE improves blood glucose one to three days post exercise in both diabetics and non-diabetics [10].

The generally high prevalence of hypertension is currently driven by two phenomena: the increased age of the population and the growing prevalence of obesity, which is seen in developing as well as developed countries [11]. With current research that relates the occurrence of hypertension with diabetes and the beneficial effects of exercises in both diseases [12, 13], it has become imperative to know or ascertain how aerobic exercises specifically affect diabetic-hypertensive patients. Diabetic-hypertensive patient is an individual diagnosed with both type 2 diabetes and hypertension.

Empirical evidence shows that physiotherapy has not been fully involved in the management of diabetic-hypertensive patients in Ghana. The practice of referral of such patients for physiotherapy is minimal in spite of documented potential benefits of aerobic exercise on both diabetes and hypertension and promotion of overall health indicate this. Moreover, there is a paucity of literature in Ghana on the effects of aerobic exercise on fasting blood glucose and blood pressure levels in diabetic- hypertensives. Thus, in view of the renewed concern to improve health conditions of people living with both diabetes and hypertension through the most cost-effective means, this study was designed to determine the effects of aerobic exercise on such people (type-2 diabetic-hypertensive clients).

METHODS AND MATERIALS

This quasi experimental pilot research was conducted at the National Diabetes Management and Research Center (NDMRC), Korle-Bu Teaching Hospital, Accra, Ghana. All ambulant individuals between 45 and 65 years, diagnosed with type-2 diabetes and hypertension referred to NDMRC were recruited via the simple random sampling method with participants for each day selected by picking one of two letters (A or B) to be included in the study or otherwise. At least two participants were recruited on each of the three clinic days in a week over a three-week period. A total of 25 individuals who agreed to participate in the study were recruited. The sample size was determined by the formula:

n =2 (Z1 +Z2) 2. δ 2 /d 2 [14], where n = sample size, Z1= z-value at α= 0.005 =1 .96, Z2= β = 0.20 = 0.84, δ = standard deviation, estimated to be 5 and d = change in score was estimated at 4.8 due to the clinical significance of such studies as showed by Maggard et al [14]. Thus, n = 2 (1.96 + 0.84) 2 * 52 / 4.82 = 17.01. A minimum sample size of 17 was therefore determined. Patients with gestational diabetes and or communication and cognitive impairments such as Aphasia were excluded from this study. Patients with co-morbidities such as cancer that may be contraindicated to exercise were also excluded from the study.

The instruments used for data collection were a mercury sphygmomanometer

(PARAMED brand), stethoscope (Littmann Classic brand), ergometric cycle (ERG 910 Plus brand) and blood glucose meter (Freestyle Lite brand). The sphygmomanometer and a stethoscope were used to measure participants' blood pressure in millimetres of mercury (mmHg) and the ergometric cycle used for aerobic exercises on eligible clients. The blood glucose meter was used to measure the amount of glucose in blood millimoles per litre (mmol/L).

Demographic data and other information (age, gender, medications, time of last meal [onset of the study] and acute illnesses) relating to their condition was obtained from their medical folders through the Head of the NDMRC. A biomedical laboratory scientist assisted in training the researchers to measure fasting blood glucose level using a glucometer. The blood pressure was measured with a stethoscope and sphygmomanometer. Data collection commenced in August 2013 and ended in February 2014.

Baseline tests were measured on the first day of assessment by the researchers before engaging the patients in the exercise protocol. On each day of exercise, the blood pressure and blood glucose levels were established before exercises began. Patients' medications were continued throughout.

Participants were taken through 30 minutes of exercise (aerobics and ergometric cycling) for eight (8) weeks uninterrupted with an intensity of approximately 25% of VO2 max (the highest oxygen delivered and utilized during exercise) [15], which included warm-ups and cool downs, relative to the patients' abilities three times a week. Participants were required in consultation with the physicians in charge to continue their medications throughout the data collection period. The exercises were carried out in the gymnasium of the Physiotherapy Department of Korle-Bu Teaching Hospital. Patients fasting blood glucose and blood pressure levels were measured after exercising for every visit until the 8th week.

Data was analyzed using SPSS. Descriptive statistics of means and standard deviations were used to represent changes in blood glucose and blood pressure levels. The mixed model ANOVA was used to test for the differences in the weekly blood pressure and blood glucose levels. The paired t-test was used to compare the baseline and final readings of blood pressure and glucose levels. Pearson's correlation test was used to determine the relationship between age and change in blood pressure and glucose levels after eight weeks of exercise. The level of significance was set at $p = 0.05$.

RESULTS

Twenty-five participants were recruited for the study of which 21 participated actively giving a response rate of 84%. Some of the 21 participants skipped some sessions due to high glucose or BP levels or inability to turn up due to genuine reasons. However, these participants completed the eight-week exercise programme which gave rise to some missing values. Expectation maximization (EM) analysis was used to construct and analyze the missing values. The parameter of interest was estimated in each dataset separately, and combined. Imputed values compared reasonably to observed values and results using the complete case analysis were similar to EM. Eight (38.1%) participants were females and 13 (61.9%) were males. Majority 15 (71.4%) of participants were between the ages of 45 and 58 years with a mean age of 55 (□7) years.

There was reduction of 7mmHg (from 142mmHg to 135mmHg) in mean systolic pressure with a spurt (128mmHg and 132mmHg) in average systolic blood pressure between the sixth and seventh weeks followed by a reduction to 129mmHg. There was also a reduction of 5mmHg (from 89mmHg to 84mmHg) in mean diastolic blood pressure. There was however a decreasing and increasing trend in average diastolic blood pressure from baseline to last measurements with a spurt (79mmHg to 85mmHg) between the seventh and eighth measurement before it dropped to 84mmHg at the final measurement.

The baseline and eight weeks post exercise average blood glucose level of participants was 8.0 mmol/L and 5.2 mmol/L respectively. A mean reduction of 1.4 mmol/L (□ 1.4) over the eight-week period was observed as shown in Table 1.

Table 1: Distribution of mean blood glucose levels from baseline to week eight

	Complete case analysis							Expectation maximization analysis			
Week	N	min	max	Mean	Std		N	Min	max	Mean	std
Baseline	21	4.3	13.6	8.0	2.8		21	4.3	13.6	8.0	2.8
1	21	4.5	13.0	7.4	2.1		21	4.5	13.0	7.4	2.1
2	21	4.9	11.0	7.1	1.7		21	4.9	11.0	7.1	1.7
3	14	4.9	8.0	6.1	1.0		21	4.9	8.0	6.1	0.8
4	13	4.5	9.3	6.5	1.6		21	4.5	9.3	6.5	1.2
5	18	4.2	9.0	5.9	1.2		21	4.2	9.0	5.9	1.1
6	18	4.2	8.4	5.6	1.1		21	4.2	8.4	5.6	1.0
7	15	4.2	8.2	5.5	1.0		21	4.2	8.2	5.5	0.8
8	5	4.0	7.5	5.2	1.4		21	4.0	7.5	5.2	0.6

N = Number of participants

There was a significant change of the weekly effect on systolic (p=0.011) and diastolic (p=0.042) blood pressure of the weekly differences in blood pressure levels on performing the aerobic exercises and ergometric cycling as shown in Table 2.

Table 2: Weekly effect of exercises on blood pressure levels

Systolic blood pressure			Diastolic blood pressure	
Source	F	P-value	F	P-value
Intercept	12971.421	0.000	12551.797	0.000
Week	2.597	0.011*	1.917	0.042*

* =statistically significant

The systolic blood pressure has an upper and lower bound of 148mmHg and 137mmHg respectively for baseline measurement while the week eight upper and lower bound measurements are 140mmHg and 118mmHg respectively as shown in Table 3.

Table 3: Systolic blood pressure distribution from baseline to week-eight

	Complete case analysis				Expectation maximization analysis		
	Systolic blood pressure				Systolic blood pressure		
Week	N	Mean ± SD	95% CI		N	Mean ± SD	95% CI
Baseline	21	142±20	137-148		21	142±20	137-148
1	21	140±14	134-145		21	140±14	134-145
2	21	138±9	132-143		21	138±9	132-143
3	21	137±12	130-144		21	137±12	130-144
4	14	132±14	125-139		21	132±11	125-139
5	13	130±10	124-136		21	130±9	124-136
6	18	128±11	122-134		21	128±10	122-134
7	18	132±9	125-138		21	132±8	125-138
8	15	129±5	118-140		21	129±5	118-140

The diastolic blood pressure shows an upper and lower bound of 93mmHg and 85mmHg respectively for baseline measurement while week eight shows an upper and lower bound measurement are 91mmHg and 77mmHg respectively which are all shown in Table 4.

Table 4: Diastolic blood pressure distribution from baseline to week 8

	Complete case analysis				Expectation maximization analysis		
	Diastolic blood pressure				Diastolic blood pressure		
Week	N	Mean±SD	95% CI		N	Mean ±SD	95% CI
Baseline	21	97±3	82-111		21	97±3	82-111
1	21	93±3	79-107		21	93±3	79-107
2	21	93±3	79-107		21	93±3	79-107
3	21	87±9	48-124		21	81±2	78-85
4	14	87±3	72-101		21	85±1	82-87
5	13	87±3	72-101		21	84±1	82-87
6	18	83±3	67-98		21	79±1	76-82
7	18	87±3	72-101		21	85±2	81-88
8	15	83±3	67-98		21	84±1	82-85

There were significant differences in baseline and final (week eight) systolic (p = 0.0017), diastolic (p = 0.006) blood pressure as well as blood glucose (p=0.0027) levels as shown in Table 5.

Table 5: Comparison of baseline and week eight differences in blood pressure and glucose levels

Item	Paired Differences Mean	Std. Deviation	Std. Error Mean	T	Sig (2-tailed)
Systolic blood pressure:	12.047	21.214	4.629	2.602	**0.017***
Diastolic blood pressure:	7.142	10.555	2.303	3.101	**0.006***
Blood glucose Level:	2.366	2.972	0.648	3.649	**0.002***

* = statistically significant Std = Standard Sig = Significant

There was a significant correlation between age and change in blood glucose level (p = 0.036). However, there was no correlation between age and change in systolic blood pressure (p = 0.453) as well as age and change in diastolic blood pressure (p = 0.453) as shown in Table 6.

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Table 6: Relationship between age and change in blood glucose and pressure levels

		Week 1- 8 Overall mean change in SBP	Week 1- 8 Overall mean change in DBP	Week 1- 8 Overall mean change in Glucose Level
Age	Pearson Correlation	-0.173	-0.143	-0.460
	P-value	0.453	0.535	0.036
	N	21	21	21

SBP = Systolic blood pressure; DBP= Diastolic blood pressure; N= Number of participants

DISCUSSION

This study revealed that there were more men than women. The findings of this study corroborate findings of Siddiqi *et al.* [6], who reported that diabetes was more prevalent in males than in females but contrary to findings of Kearney *et al.* [2] who indicated that the prevalence of diabetes and hypertension in women was more than men. This indicates a prevalence of the combination of diabetes and hypertension in men although this was is inconsequential for the design of this study. Although the difference in gender regarding the number of diabetic-hypertensives in this study was not huge, the reason for a contrary outcome with Keaney *et al.* [2], may be attributed to the sample size of this study and the fact that this study was conducted among diabetic-hypertensives whereas Keaney *et al.* conducted theirs with diabetic and hypertensive patients. Aerobic exercise is and can be performed by both male and female thus did not impose any form of restriction to participants. The study was rather meant to inform or direct the use of aerobic exercise as an intervention for diabetic-hypertensives irrespective of gender. Patients also reported a significant increase in general body strength and mood, which may be considered an added benefit of aerobic exercise. The increase in general body strength may also be due to increased blood circulation to the musculoskeletal system, which helps in muscle nutrition and contractility [16]. This may be attributed to the general effect of exercise especially cycling which includes increased general body strength, energy and increased level of endorphins, which are natural mood lifters [17]. Cardoso *et al*. [18] reported improved cardiorespiratory fitness, concomitant with increased participation in physical activity and decreased fatigue severity, following an aerobic exercise-training regimen which included treadmill walking for 30-45 minutes per session over 10-weeks. Specific characteristics of the exercise itself might also be important in determining post-exercise hypotension and general body strength. However, the effect of exercise intensity still remains controversial [16]. For example, in this study participants in this study, participants went through. Although the exercise regimen (30 minutes of aerobics and ergometric cycling for eight weeks uninterrupted with an intensity of approximately 25% of VO2 max) used in this study may have different characteristics and intensity similar results were achieved as in other studies with relatively different exercise regimen as reported by Cardoso *et al*. [18].

The reduced blood pressure levels of all participants after eight weeks of aerobic exercise compared to values obtained at baseline corroborate the outcomes of Molmen *et al.* [5] who reported that aerobic interval training was an effective method that lowers blood pressure and improves other cardiovascular risk factors. The extent of exercise-induced reduction of blood pressure varies from 5 to 15mmHg among studies [19] while in older hypertensives such as participants of this study, the effect is not as pronounced in younger individuals and is reported to be 5 to 6mmHg. Thus, the present study's systolic blood pressure reduction of 7mmHg in diabetic-hypertensives is not lower than the anticipated range for hypertension. Radhakrishnan and Ekambaram [19] revealed that acute aerobic exercise is able to reduce ambulatory blood pressure levels when these levels are already elevated, whereas chronic aerobic exercise can reduce ambulatory blood pressures in normotensive and especially hypertensive subjects. Thus, aerobic training is a very useful tool for the prevention and treatment of hypertension. This may be due to an immediate (acute) reduction in blood pressure termed 'post-exercise hypotension' which is caused by reductions in vascular resistance [17]. In order to be clinically relevant, post-exercise hypotension must have a significant magnitude and be sustained for a long period of time under ambulatory conditions [19].

The significant difference observed among the weekly average glucose levels and the reduction in the upper and lower bound levels after eight weeks may be due to the conversion of blood glucose to glycogen to produce energy during the prescribed aerobic exercise [9] which corroborates outcomes by Anja *et al.* [7] who reported that there was significant reduction in fasting blood glucose levels in patients with type-2 diabetes who undertook aerobic exercise. Since muscle contraction increases glucose uptake in skeletal muscles, physical activity has been suggested in type-2 diabetes mellitus [20]. Moderate levels of aerobic exercises were performed by participants of this study since it affects a large group of muscles over time, which led to reduction in fasting blood sugar, after the eight weeks of exercise intervention. This effect is related to the promotion of glucose uptake in the skeletal muscles and loss of body fat in the body central part during exercise [24]. Yang *et al.* [16] reported decreases in glucose level and insulin resistance index after 12 weeks of aerobic exercise, resistance exercise and combined exercise in women with type 2 diabetes mellitus. However, these changes were bigger among the participants in the combined exercise group. Aminilari *et al.* [20] confirms that both resistance and aerobic exercises are effective in diabetes control by decreasing fasting blood sugar and glycosylated haemoglobin.

The comparison of baseline and final systolic blood pressure of this study was significantly different as also found by Ruivo and Alcântara [3]. A decrease of 7mmHg in systolic and 5mmHg in diastolic blood pressures as reported in this study, is of clinical relevance with regard to cardiovascular risk as demonstrated by Dimeo [21]. Mohan *et al*. [22] showed that aerobic exercise significantly decreased systolic and diastolic daytime ambulatory blood pressure by 6±12 and 3±7mmHg, respectively among resistant hypertensives and concluded that physical exercise is able to decrease blood pressure even in persons with low responsiveness to medical treatment. Post-exercise hypotension" may be the reason for reduction in systolic blood pressure. This is because during exercise, there is a decrease in the peripheral vascular resistance and thus an overall reduction in blood pressure [23].

There was no correlation between age and change in systolic blood pressure which suggest that older persons probably tend to have small or decreased changes in systolic blood pressure. Weinstein *et al.* [17] reported no correlation between age and hypertension but on the contrary, Weber *et al.* [11] revealed an increased systolic blood pressure after age 50 or 60 years. The difference in findings may be attributed to the category of participants used for the studies. This study was conducted among diabetic-hypertensives while Webber *et al.* [11] used apparently healthy individuals. Moreover, age probably represents an accumulation of environmental influences and the effect of genetically programmed senescence in body systems [21]. There was a negative correlation between age and change regarding diastolic blood pressure, thus older persons tend to have small changes (decrease) in diastolic blood pressure, which tends to corroborate reports by Weber et al [11]. Although, diastolic blood pressure values fluctuated a bit over the eight-week period, there was an overall 5mmHg reduction at the end. This could be considered remarkable because it buttresses the success of exercise in reducing blood pressure.

There was a negative but significant correlation between age and change in glucose levels, similar to findings by Adams [10] and Aminilari *et al.* [16] where high-intensity exercise caused a reduction in fasting blood sugar of diabetics. The outcomes of this study probably indicate that the effect of exercises depends on various factors such as the type, intensity and frequency. In this study, the maximum effect of aerobic exercise on blood glucose appeared after 8 weeks although there were minute reductions in blood glucose weekly. For instance, Oberbach *et al.* [24] reported improvement in glucose metabolism and insulin resistance after four-week training aerobic training protocol which included 60 minutes of swimming. Bello *et al.* [24] also indicated that the therapeutic benefits of aerobic exercise include regulation of body weight, reduction of insulin resistance, enhancement of insulin sensitivity and glycaemic control after they found no significant difference in mean age and duration of type 2 diabetes mellitus patients.

LIMITATIONS

The referral of diabetic-hypertensive patients to physiotherapy for aerobic exercises appears minimal in Ghana in spite of its documented potential benefits and promotion of overall health. However, the outcomes of this study may be not be exactly attributable to the effect of the exercises due to the small sample size and lack of a control group for appropriate comparison of indices measured under similar conditions asides age-matching. Changes in dietary habits, the continued use of their medication and possible changes with medication were also not controlled in this study.

CONCLUSION

This study reiterates reported outcomes of studies in other countries. This study showed that half an hour of aerobic exercises three times a week for eight weeks probably caused a mean reduction of 1.4 mmol/L in fasting blood glucose levels as well as marginal reduction in systolic and diastolic blood pressure in ambulant type-2 diabetic-hypertensives clients. Type-2 diabetic-hypertensives clients should therefore be encouraged to participate in at least half an hour of aerobic exercise thrice a week in conjunction with consistent education on their condition.

DECLARATION

Contributors Conceptualization: The concept and study design were developed by EL and JQ. EL, SK, TM, BO, JQ and HL, were involved in data collection. EL, SK, and JQ provided advice on statistical analysis. EL, JQ, and HL contributed on the interpretation of results. The manuscript was written by EL, JQ and SK while TM, BO and HL provided substantial amounts of references. ES, SK, TM, BO, JQ and HL contributed towards the draft and approved the final manuscript.

Competing interests There were no competing interests from all authors in this study.

Ethics approval
Ethical clearance (ET. /10306805/AA/21A/2012-2013) was sought and obtained from the Ethics and Protocol Review Committee of the School of Allied Health Sciences, University of Ghana. Appropriate permissions and informed consent of the participants were obtained before recruitment into the study.

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