Original Article

Fasting plasma glucose and lipid profiles of diabetic patients improve with aerobic exercise training

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SUMMARY

Objective: This study presents the effects of aerobic exercise training on fasting plasma glucose and lipid profiles (FPG/LP) of diabetic patients in Kumasi.

Design: A randomised experimental with control design.

Setting: The study was conducted at the diabetic unit of KATH in Kumasi, Ghana.

Participants: Twelve diabetic patients [grouped into intervention (IG) and control (CG)] attending the diabetic unit of KATH with diabetes diagnosis durations less than fifty years, ambulant status/age of 20-68years, sedentary and free from complications.

Interventions: Eight weeks aerobic exercise training between August 2015 and March 2016

Main outcome measures: Body weight (BW), Body mass index (BMI), fasting plasma glucose (FPG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), triglycerides (T) and total cholesterol (TC).

Results: Body weight (4.85kg, 7.0%), body mass index (4.08kg/m^2, 7.3%), FPG (5.28mmol/L, 43.5%), LDL-C (.33mmol/l, 11.9%), TC (.47 mmol/l, 5.3%) and T (.48mmol/l, 29.4%) profiles of the patients in IG declined while HDL-C (.11mmol/l, 7.1%) increased. IG patients improved significantly in FPG [6.27 ± 0.91 < 8.00 ± 0.96; t=-52.00, P = 0.000], BW [58.60 ± 15.34 < 75.35 ± 22.00; t= 3.29, P = 0.040] and BMI [23.45 ±5.03<27.04 ±4.78, t=4.24, P = .050] compared to CG.

Conclusion: Patients in IG, in addition to conventional care, experienced non-significant decline in LDL-C, TC, T, increase in HDL-C and significant reduction in FPG, BW, and BMI over those receiving conventional care only. Exercise Scientists are recommended to handle exercise sessions for healthcare prevention and management routines of diabetic patients.

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Keywords: Diabetic patients, Aerobic exercise training, Fasting plasma glucose, Lipoprotein, Triglycerides, Total cholesterol

INTRODUCTION

Diabetes Mellitus (DM) is a global health problem and one of the leading causes of morbidity and mortality for 90-95% of all chronic diseases.[1] According to estimated reports, the number of patients with DM worldwide is expected to rise to 300 million by 2035.[2] Diabetes mellitus is associated with severe long-term complications including microvascular complications such as retinopathy and nephropathy, macrovascular complications such as coronary artery disease and stroke, with an increased risk of premature death.[3–5]

The increase in DM prevalence can partly be attributed to the increasing prevalence of obesity and sedentary lifestyle[6], insulin resistance, beta-cell dysfunction, environmental and genetic factors.[7] Uncontrolled hyperglycemia and insulin resistance in patients with diabetes results in lipid abnormalities.[8]

Treatment of DM is solely centered on healthcare management using prescribed medication and dietary lifestyle modifications.[9]

Healthcare cost of managing individuals with DM is however a huge financial burden for individuals hence the need for support from family members and other donors.[10]

Exercise has been considered a cornerstone of diabetic management, along with diet and medication.[4,5]
The American Diabetes Association (ADA) recommends at least 150minutes per week of moderate intensity aerobic physical activity or at least 90minutes per week vigorous aerobic exercise distributed over at least 3 days per week and with no more than 2 consecutive days without physical activity.[11]

Studies have shown aerobic exercise training as a convenient, cheap, effective and efficient technique in diabetes management in some countries.[3,9,11] It has also been reported that regular aerobic exercise reduces the indices of cardiovascular and all-cause mortality, increases skeletal muscle capitalization and blood flow, muscular glucose transporter type 4 (GLUT4) levels, hexokinase and glycogen synthase activities.[12,13]

Kubuga et al reported an estimation credited to Ghana Diabetes Association that a Ghanaian dies of diabetes every 10 seconds.[14] These deaths occur as a result of potentially life-threatening complications that include stroke, heart attack, diabetic ketoacidosis, retinopathy and nephropathy.[15,16,17]Kumi-Ampofo researched into the household cost of seeking diabetic healthcare of 424 diabetic patients aged 12 and 80 years in the Tano North District of the Brong Ahafo region of Ghana with the conclusion that both financial and non- financial cost of diabetes mellitus accounts for more than two- thirds of the household's income.[18]

She further reiterated that the adverse effect of the cost has implications on the healthcare and quality of life of the diabetic patients and their household; hereby calling for intervention treatment.[18] Kubuga et al's study also found that diabetic patients suffer the risk of post-traumatic stress disorder where psychological treatment was recommended.[14] A recent study on the qualitative information about current food knowledge, attitudes and practices among type 2 diabetes mellitus (T2DM) patients and their caregivers in the region of Kumasi, Ghana, endorsed educational intervention as preventive measure.[19]

Although there are many studies in Ghana[20–27] on diabetes management, study on the use of exercise intervention as vital tool in the management of diabetic patients, trending diabetes healthcare management technique of developed countries[28–32] cannot be overemphasised.

This study therefore examined the effects of aerobic exercise training on fasting plasma glucose and lipid profiles (FPG/LP) of diabetic patients in Komfo Anokye Teaching Hospital (KATH), Kumasi.

METHODS

Study design and population

A randomised experimental pre-posttest design was used in the study. This was considered appropriate for explaining the variation of result hypothesized and abide by the rules that is generally associated with true experiments.[33] The population was made up of Ghanaian diabetic patients who attend the diabetes unit of KATH, Kumasi, Ghana.

Sample

The participants were twelve out-patients from the KATH diabetes unit admitted between January and December 2015. The participants were patients with a diagnosis of diabetes with varied years but more than ten, ambulant status/age 20-68years, who do not meet the standard physical activity guidelines of 150 minutes per week of moderate physical activity[34] and free from complications (e.g. nephropathy, neuropathy, cataracts, glaucoma, heart diseases, stroke and hypertension) ascertained through medical records.

Participants were excluded if both systolic and diastolic blood pressure were more than 140 and 90 mmHg respectively, existence of bilateral or unilateral lower or upper limbs amputation and patients using insulin pump. Twenty patients who met the inclusion criteria were contacted and taken through the objectives of the study. Twelve (60.0%) out of the twenty who voluntarily consented to participate in the study were given informed consent form to read and sign. On the subsequent visit to the participants, the signed informed consent forms were retrieved.

Thereafter participants were randomly assigned to the intervention or control group by ballot (choose a folded pre-engraved paper of intervention or control in a box, without replacement).[35] Of the twelve subjects used, seven were in the eight weeks intervention group (IG) while five were in the control group (CG).

Study setting

The study was conducted at the diabetic unit of the KATH in Kumasi, Ghana. KATH is one of the most accessible tertiary healthcare facilities in the country. The hospital receives referrals from all the northern regions (namely, Northern, Upper East and Upper West Regions), Brong Ahafo, Central, Western, Eastern and part of the Volta Region.

A number of patients also come in from the neighbouring countries. The hospital is equipped with state of the art health facilities and equipment needed for this project.

The diabetic center of KATH is situated beneath the medicine block (D Block), between the chest clinic and diagnostic center and behind the emergency unit of the hospital.

Assessment Procedure

Assessment of weight (kg) and height (m), and calculation of body mass index (kg/m^2) were in accordance with standardized anthropometric protocol.[34] Fasting plasma glucose and lipid profiles also followed ethical protocol[34].

Fasting Plasma Glucose and Lipid Profiles

Subject's pre and post training FPG/LP profiles were measured early in the morning (7:00AM) with the following methods and procedures: 5ml of venous blood sample was taken from the subjects after cleaning the venipuncture site with 70% alcohol, 3ml of the blood sample (whole blood) was dispensed into fluoride oxalate tube for the fasting plasma glucose test and 2ml into a gel separator sample tube for lipid test. The samples were centrifuged using the centrifuge SM80-2 to separate the plasma (for the fasting plasma glucose) and serum (for the lipid studies) from the red blood cells.

The samples were then analyzed using the BA-88A Chemistry Analyzer manufactured by Mindray Bio-Medical Electronics Co. Ltd, China. Pre-post training HDL-C, LDL-C, TC, T, BW and FPG were conducted as earlier described in the testing procedure section using standardized protocols, techniques and methods. The choice of FPG as a marker of glycemic control in this study was based on the report that it is clinically acceptable and affordable within Ghana.[23] All pre and post-test measurements were recorded for analysis.

Training Procedure

The participants continued with their regular medical/clinical routines during the period of the study.

Intervention Group

Blood pressure and heart rate were measured each day before exercise training while physicians were always available during training. The intervention group participated in walking aerobic exercise sessions without using treadmill. After a 10-minutes warm up, subjects walked for 30- minutes at a moderate intensity of between 50% - 60% of their maximum heart rate (obtained during exercise session with pulse oximeter-version 803, China and online Pace Calculator application). The starting workload was slow pace (3.5m/s, 3.95miles) which was increased to a faster pace (4.0m/s, 4.5miles) to obtain HR max 60%. The initial exercise session was increased from 30-minutes in the first two weeks of training to 45-minutes (2.35m/s, 3.95miles - 2.68m/s, 4.5miles) throughout the remaining part of the training. After each of the aerobic exercise training session, 10-minutes cool down was established. The aerobic exercise session of three times per week was maintained throughout the eight weeks training period.

Control Group: Participants in the control group were instructed not to engage in any organized/ structured physical activity apart from the activity of daily living and monitored during the 8 weeks period of study.

Data Analysis

Data analysis was performed using statistical package for social science (SPSS) for window program version 23.0. Descriptive statistics of means and standard deviations were recorded and within-group comparisons were performed to test for differences in these parameters before and after the exercise programme with paired t-test analysis ($P<0.05$ was considered statistically significant).

Ethical issues

The study received approval of the KATH Research and Development Unit (R&D) and clearance was sought from the Committee on Human Research, Publications and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana [Ref. CHRPE/AP/209/16]. All the participants signed consent of participation form after attaining personal understanding of the rationale of the study.

RESULTS

Out of the 12 participants that participated in the study, majority of them were females (10, 83. %) and the rest were males (2, 17%). The modal age range of the participants was 46-55years (10, 83%). Ten participants were type II and 2 were type I. 8 (80%) were female type II, 2 (20%) were male type II while all the type I (2, 100%) were female. The ranges of the duration of diagnosed of the participants were 1-5years (25%), 6-10years (50%), 11-15years (8%), 16-20years (8%) and 21-25years (9%). Descriptive results obtained are presented in table 1 while tables 2 and 3 are for pre-post intervention group as well as between intervention and control group respectively.

Table 1 Descriptive Distribution of Pre-post FPG/LP among Groups

VARIABLES	INTERVENTION GROUP		CONTROL GROUP	
	PRETEST MEAN ±SD	POSTTEST MEAN ±SD	PRETEST MEAN ±SD	POSTTEST MEAN ±SD
HEIGHT(M)	1.62 ± 0.09	1.62 ±0.09	1.65 ±0.11	1.65 ± 0.11
BODY WEIGHT (KG)	65.95 ± 16.13	61.31 ±12.05	69.58 ±14.08	75.35 ± 21.99
BMI(KG/M^{-2})	25.31 ± 6.63	23.45 ±5.03	25.39 ±2.91	27.04 ±4.78
FPG (MMOL/L)	9.56 ± 5.04	5.40 ±1.52	9.10 ±6.41	8.00 ± 0.96
HDL-C (MMOL/L)	1.56 ± 0.27	1.67 ±0.23	1.15 ±0.36	1.02 ± 0.38
LDL-C (MMOL/L)	2.19 ± 0.71	1.93± 0.44	2.73 ±1.56	1.82 ±0.48
TC (MMOL/L)	4.15 ± 0.80	3.93 ±0.33	4.76±2.14	3.53 ± 0.45
T (MMOL/L)	1.02 ± 0.51	0.72 ±0.12	2.02 ±1.08	1.52 ± 0.47

Key: *body mass index (BMI), fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (T), high density lipoprotein (HDL-C), low density lipoprotein (LDL-C)*. There are no statistically significant differences ($p > 0.05$) in the baseline values between pre-test of both IG and CG.

Table 2 Mean differences of pre-post FPG/LP mean values in the intervention group

VARIABLES	PAIRED DIFFERENCES						T	DF	P-VALUE
	MEAN	SD	% DIFF.	STD. ERROR MEAN	99% CI LOWER	99% CI UPPER			
BW	4.85	14.23	7.0	6.37	-12.82	22.53	0.76	4	.490
BMI	4.08	2.15	7.3	1.24	-9.41	1.25	-3.29	2	.080
FPG	5.28	4.79	43.5	2.14	-4.58	15.14	2.47	4	.069
HDL-C	0.11	.48	7.1	0.24	-.84	0.69	-.31	3	.780
LDL-C	0.33	.43	11.9	0.21	-.35	1.01	1.56	3	.220
TC	0.47	.79	5.3	0.39	-.78	1.73	1.20	3	.320
T	0.48	.50	29.4	0.25	-.32	1.28	1.90	3	.150

*Difference is significant at 0.05 alpha levels

Table 3 Mean differences of Pre-Post FPG/LP Mean Values in the Control Group

VARIABLES	PAIRED DIFFERENCES					T	DF	P-VALUE
	MEAN	SD	STD. ERROR MEAN	99% CI LOWER	99% CI UPPER			
BW	-9.82	27.29	15.75	-77.61	57.97	-0.62	2	.595
BMI	-3.13	4.52	2.61	-14.37	8.11	-1.20	2	.353
FPG	2.57	7.11	4.10	-15.09	20.22	0.63	2	.595
HDL-C	-0.01	0.22	0.12	-0.54	0.53	-0.05	2	.962
LDL-C	-0.08	0.42	0.24	-1.11	0.96	-0.32	2	.780
TC	-0.20	0.61	0.35	-1.71	1.31	-0.57	2	.626
T	-0.26	0.53	0.30	-1.57	1.05	-0.85	2	.483

There is no statistically significant difference in all the pre-post FPG/LP in the control group at 0.05 alpha level.

Table 4 Mean differences of post FPG/LP between intervention and control groups

VARIABLES	PAIRED DIFFERENCES					T	DF	P-VALUE
	MEAN	SD	STD. ERROR MEAN	99%CI LOWER	99%CI UPPER			
BW	4.08	2.15	1.24	-9.41	1.25	-3.29	2	0.040*
BMI	16.75	6.84	3.94	-33.76	0.25	-4.24	2	0.050*
FPG	1.73	0.05	0.033	-1.88	-1.59	-52.00	2	0.000*
HDL-C	0.68	0.53	0.30	-0.63	1.99	2.23	2	0.160
LDL-C	0.22	0.76	0.44	-1.66	2.11	0.50	2	0.660
TC	0.53	0.46	0.27	-0.61	1.68	2.00	2	0.180
T	0.82	0.41	0.24	-1.80	0.20	-3.48	2	0.070

*Difference is significant at 0.05 alpha level.

DISCUSSION

The aim of the study was to examine the effects of aerobic exercise training on fasting plasma glucose and lipid profiles (FGP/LP) of diabetic patients in Komfo Anokye Teaching Hospital (KATH), Kumasi. The participants in IG experienced 4.85kg (7.0%) body weight loss after eight weeks aerobic exercise training. This supports Okada et al's work that showed significant weight loss in the intervention group programme that included exercise plus nutrition classes (which may have an additional positive effect, confirming this study).[39]

This is however contrary to some previous studies that showed no weight loss.[40–42] The discrepancies in these studies could be attributed to varying factors ranging

from differences in study design to socioeconomic and socio-demographic factors and the sample size. A significant 4.08kg/m^2 (7.3%) decrease was observed in the BMI of the participants as reported in previous studies with the same principles but longer duration.[43,44]

This study shows that FPG reduced by 43.5% (5.28mmol/l) after eight weeks aerobic exercise training which is significantly different from the FPG of the control group (tables 2 & 3). This is in line with earlier studies where six months continuous aerobic exercise training were reported to significantly reduce the mean of FPG as compared to non-exercisers.[45,46] Other studies concluded that since working muscles are more sensitive to insulin, aerobic exercise facilitates glucose uptake by the muscles, and can thus be a definitive tool in blood glucose control.[47,39,44] These findings imply that aerobic exercise could serve as therapeutic and defensive antidotes to FPG in patients with diabetes mellitus.

The positive decline in the LDL-C (.33mmol/l, 11.9%), TC (.47mmol/l, 5.3%) and T (.48mmol/l, 29.4%) profiles of the patients in IG and increase in HDL-C-C (.11mmol/l, 7.1%), although not significant, indicate the value inherent in aerobic exercise training. In addition, positive changes were also evident in a three-week walking programme reported in the study of Goldhaber-Fiebert et al although insignificantly small.[48,49]

The percentage decline in LDL-C (11.9%) observed in this study is greater than the value in the meta-analysis conducted by Kelly and Kelly which indicated a significant reduction by 5% for LDL-C.[50] The improvement in TC, T, HDL-C-C and LDL-C exhibits clear evidence of reduction in atherogenic traits of risk factors[51,52] and better quality of life[53–55] of the sample studied. Authors observed that there are variations in the findings associated with this study in literature which are attributed to intensity, duration and frequency of exercise trainings and sample sizes.

LIMITATION

This study is limited on the fact that it is an experimental study with a sample size of only twelve patients and duration of the aerobic exercise programme was 8 weeks. The dietary lifestyle of the participants was not controlled which could also be a limitation.

CONCLUSION

Based on the findings of this study after 8 weeks of aerobic exercise programme in addition to conventional care of patients with diabetes mellitus, we concluded that there is non-significant decline in LDL-C, TC and T, increase in HDL-C and significant improvements in BW, BMI and FPG over those receiving conventional care only. The inclusion of aerobic exercise programme in the healthcare prevention and management routine of diabetic patients would be beneficial in the long run. Hence a scheduled aerobic exercise training programme handled by Exercise Scientists is recommended to be emphasized by physicians as part of healthcare prevention and management routines of diabetic patients.

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REFERENCES

1. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2008;31(SUPPL. 1):S62–7.
2. Guariguata L, Whiting DR, Hambleton I, Beagley J, Linnenkamp U, Shaw JE. Global estimates of diabetes prevalence for 2013 and projections for 2035. *Diabetes Res Clin Pract.* 2014;103(2):137–49.
3. Kwon HR, Min KW, Ahn HJ, Seok HG, Lee JH, Park GS, et al. Effects of Aerobic Exercise vs. Resistance Training on Endothelial Function in Women with Type 2 Diabetes Mellitus. *Diabetes Metab J.* 2011;35(4):364–73.
4. Yavari A, Najafipoor F, Aliasgharzadeh A, Niafar M, Mobasseri M. Effect of Aerobic Exercise, Resistance Training Or Combined Training on Glycaemic Control and Cardiovascular Risk Factors in Patients with Type 2 Diabetes. *Biol Sport.* 2012;29(2):135–43.
5. Egger A, Niederseer D, Diem G, Finkenzeller T, Ledl-Kurkowski E, Forstner R, et al. Different types of resistance training in type 2 diabetes mellitus: effects on glycaemic control, muscle mass and strength. *Eur J Prev Cardiol.* 2013;20(6):1051–60.
6. Kootte RS, Vrieze a, Holleman F, Dallinga-Thie GM, Zoetendal EG, de Vos WM, et al. The therapeutic potential of manipulating gut microbiota in obesity and type 2 diabetes mellitus. *Diabetes Obes Metab.* 2012;14(2):112–20.
7. Wu Y, Ding Y, Tanaka Y, Zhang W. Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. *International journal of medical sciences.* 2014; 11:1185–200.

8. Ozder A. Lipid profile abnormalities seen in T2DM patients in primary healthcare in Turkey : a cross-sectional study. *Lipids Health Dis.* 2014;13(1):1–6.
9. Zanuso S, Jimenez A, Pugliese G, Corigliano G, Balducci S. Exercise for the management of type 2 diabetes: A review of the evidence. *Acta Diabetologica*. 2010; 47: 15–22.
10. Shuyu Ng C, Toh MPHS, Ko Y, Lee Yu-Chia J. Direct Medical Cost of Type 2 Diabetes in Singapore. *PLoS One.* 2015;10(3):e0122795.
11. Lessard SJ, Rivas DA, Alves-Wagner AB, Hirshman MF, Gallagher IJ, Constantin-Teodosiu D, et al. Resistance to aerobic exercise training causes metabolic dysfunction and reveals novel exercise-regulated signaling networks. *Diabetes.* 2013;62(8):2717–27.
12. Bello AI, Owusu-Boakye E, Adegoke BO, Adjei DN. Effects of aerobic exercise on selected physiological parameters and quality of life in patients with type 2 diabetes mellitus. *Int J Gen Med* [Internet]. 2011;4:723–7. Available from: https://www.dovepress.com/effects-of-aerobic-exercise-on-selected-physiological-parameters-and-q-peer-reviewed-article-IJGM
13. Stanford KI, Goodyear LJ. Exercise and type 2 diabetes: molecular mechanisms regulating glucose uptake in skeletal muscle. *Advances in physiology education,* 2014; 38: 308–14.
14. Kubuga, Clement Kubreziga MM, Osei G, Osei SO, Abugre D. Nutritional and Psychological Impact of Diabetes on Diabetics : Case Study in the Tamale Teaching Hospital - Ghana. *Eur Sci J.* 2013;9(30):212–35.
15. Soumya D, Srilatha B. Diabetes & Metabolism Late Stage Complications of Diabetes and Insulin Resistance. *J Diabetes Metab.* 2011;2(9):1–7.
16. Diabetes.co.uk. Diabetes alert in Ghana. 2007; Available from: http://www.diabetes.co.uk/news/2007/Oct/diabetes-alert-in-ghana.html
17. Kweku D. Alert: B/A records more new cases of Diabetes and Hypertension. 2012; Available from: http://gocreatestudio.com/healthnest/2012/08/20/alert-ba-records-more-new-cases-of-diabetes-and-hypertension/
18. Kumi-Ampofo G. Household Cost of Seeking Diabetic Healthcare in the Tano North District of the Brong Ahafo Region, Ghana [Internet]. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana; 2014. Available from: http://ir.knust.edu.gh/bitstream/123456789/6870/1/GIFTY KUMI-AMPOFO.pdf
19. Doherty ML, Owusu-Dabo E, Kantanka OS, Brawer RO, Plumb JD. Type 2 diabetes in a rapidly urbanizing region of Ghana, West Africa: a qualitative study of dietary preferences, knowledge and practices. *BMC Public Health* [Internet]. 2014;14(1):1069. Available from: http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-1069%5Cnhttp://www.scopus.com/inward/record.url?eid=2-s2.0-84928725727&partnerID=tZOtx3y1
20. Steyl T, Phillips J. Management of type 2 diabetes mellitus: adherence challenges in environments of low socio-economic status. *African J Prim Heal care Fam Med* [Internet]. 2014;6(1):E1-7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26245413%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4502898
21. Tuakli-Wosornu, Y A Rowan, M Gittelsohn, J Tuakli-Wosornu YA. Perceptions of Physical Activity, Activity Preferences and Health Among a Group of Adult Women in Urban Ghana: a Pilot Study. *Ghana Med J.* 2014;48(1):3–13.
22. Danquah I, Bedu-Addo G, Terpe K-J, Micah F, Amoako Y a, Awuku Y a, et al. Diabetes mellitus type 2 in urban Ghana: characteristics and associated factors. *BMC Public Health* [Internet]. 2012;12(1):210. Available from: http://www.biomedcentral.com/1471-2458/12/210
23. Sunwiale SS. Prevalence of Prediabetes and Diabetes Mellitus among Children and Young Adults in the Kassena Nankana District of Ghana. Kwame Nkrumah University of Science and Technology; 2014.
24. Kratzer J. Structural barriers to coping with type 1 diabetes mellitus in Ghana: experiences of diabetic youth and their families. *Ghana Med J* [Internet]. 2012;46(2 Suppl):39–45. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3645143&tool=pmcentrez&rendertype=abstract
25. Saleh A, Amanatidis S, Samman S, Samman S. the Effect of Migration on Dietary Intake, Type 2 Diabetes and Obesity: the Ghanaian Health and Nutrition Analysis in Sydney, Australia (Ghanaisa). *Ecol Food Nutr.* 2002;41:255–70.
26. Mogre V, Apala P, Nsoh JA, Wanaba P. Adiposity, hypertension and weight management behaviours in Ghanaian type 2 diabetes mellitus patients aged 20-70 years. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews.* 2015;
27. Mogre V, Abedandi R, Salifu ZS. Prevalence of obesity and systemic hypertension among diabetes mellitus patients attending an out-patient diabetes clinic in a Ghanaian Teaching Hospital. Diabetes Metab Syndr Clin Res Rev. 2014;8(2):67–71.
28. Padayachee C, Coombes JS. Exercise guidelines for gestational diabetes mellitus. *World J Diabetes,* [Internet]. 2015;25(68):1033–44. Available from:

http://www.wjgnet.com/esps/%5Cnhttp://www.wjgnet.com/esps/helpdesk.aspx
29. Cadore EL, Izquierdo M. Exercise interventions in polypathological aging patients that coexist with diabetes mellitus: improving functional status and quality of life. Age (Omaha) [Internet]. 2015;37(64):DOI 10.1007/s11357-015-9800-2. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26054595
30. Boulé NG, Haddad E, Kenny GP, Wells GA, Sigal RJ. Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *JAMA* [Internet]. 2001;286(10):1218–27. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=mnh&AN=11559268&site=ehost-live
31. Orozco LJ, Buchleitner AM, Gimenez-Perez G, Roqué I Figuls M, Richter B, Mauricio D. Exercise or exercise and diet for preventing type 2 diabetes mellitus. *Cochrane database Syst Rev* [Internet]. 2008;(3):CD003054. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18646086
32. Bain E, Crane M, Tieu J, Han S, Crowther CA, Middleton P. Diet and exercise interventions for preventing gestational diabetes mellitus. *Cochrane database Syst Rev*. 2015;4:CD010443.
33. Gribbons B and Herman J. True and Quasi-Experimental Designs. *J Pract Assesment, Res Eval*. 1997;1–7.
34. Pescatello LS and AC of SM. ACSM Guidelines for Exercise Testing and Prescription. 9th ed. Pescatello LS, editor. Medicine & Science in Sports & Exercise. Philadelphia: Wolters Kluwer; 2014.
35. Wing RR, Bolin P, Brancati FL, Bray G a, Clark JM, Coday M, et al. Cardiovascular effects of intensive lifestyle intervention in type 2 diabetes. *N Engl J Med*. 2013;369(2):145–54.
36. Arthur FKN, Yeboah FA, Nsiah K, Nkrumah PKN, Afreh KA. Fasting Blood Glucose and Glycosylated Haemoglobin Levels in Randomly Selected Ghanaian Diabetic Patients – The Clinical Implications. *J Sci Technol*. 2005;25(2):13–7.
37. Ghazanfari Zahra, Haghdoost Ali Akbar, Alizadeh Sakineh Mohammad, Atapour Jamileh and ZF. A Comparison of HbA1c and Fasting Blood Sugar Tests in General Population. *Int J Prev Med*. 2010;1(3):187–94.
38. World Health Organisation (WHO). Use of Glycated Haemoglobin (HbA1c) in the Diagnosis of Diabetes Mellitus [Internet]. Geneva; 2011. Available from: http://www.who.int/diabetes/publications/report-hba1c_2011.pdf
39. Okada S, Hiuge A, Makino H, Nagumo A, Takaki H, Konishi H, et al. Effect of exercise intervention on endothelial function and incidence of cardiovascular disease in patients with type 2 diabetes. *J Atheroscler Thromb*. 2010;17(8):828–33.
40. Goldhaber-Fiebert JD, Goldhaber-Fiebert SN, Tristán ML, Nathan DM. Randomized controlled community-based nutrition and exercise intervention improves glycemia and cardiovascular risk factors in type 2 diabetic patients in rural Costa Rica. *Diabetes Care*. 2003;26(1):24–9.
41. Barnard ND, Cohen J, Jenkins DJA, Turner-McGrievy G, Gloede L, Jaster B, et al. A Low-Fat Vegan Diet Improves Glycemic Control and Cardiovascular Risk Factors in a Randomized Clinical Trial in Individuals With Type 2 Diabetes. *Diabetes Care*. 2006;29(8):1777–83.
42. Elhayany a, Lustman a, Abel R, Attal-Singer J, Vinker S. A low carbohydrate Mediterranean diet improves cardiovascular risk factors and diabetes control among overweight patients with type 2 diabetes mellitus: a 1-year prospective randomized intervention study. *Diabetes Obes Metab*. 2010;12(3):204–9.
43. Tjønna AE, Stølen TO, Bye A, Volden M, Slørdahl S a, Odegård R, et al. Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clin Sci (Lond)*. 2009;116(4):317–26.
44. Ho SS, Dhaliwal SS, Hills A, Pal S. Acute exercise improves postprandial cardiovascular risk factors in overweight and obese individuals. *Atherosclerosis*. 2011;214(1):178–84.
45. Alam S, Stolinski M, Pentecost C, Boroujerdi MA, Jones RH, Sonksen PH, et al. The Effect of a Six-Month Exercise Program on Very Low-Density Lipoprotein Apolipoprotein B Secretion in Type 2 Diabetes. *J Clin Endocrinol Metab*. 2004;89(2):688–94.
46. Stolinski M, Alam S, Jackson NC, Shojaee-Moradie F, Pentecost C, Jefferson W, et al. Effect of 6-month supervised exercise on low-density lipoprotein apolipoprotein B kinetics in patients with type 2 diabetes mellitus. *Metabolism*. 2008;57(11):1608–14.
47. Khandouzi N, Shidfar F, Rajab A, Rahideh T, Hosseini P, Taheri MM. The effects of ginger on fasting blood sugar, hemoglobin A1c, apolipoprotein B, apolipoprotein A-I and malondialdehyde in type 2 diabetic patients. *Iran J Pharm Res*. 2015;14(1):131–40.
48. Goldhaber-Fiebert JD, Goldhaber-Fiebert SN, Tristán ML, Nathan DM. Randomized controlled community-based nutrition and exercise intervention improves glycemia and cardiovascular risk factors in type 2 diabetic patients in rural Costa Rica. *Diabetes Care*. 2003;26(1):24.
49. Gibala MJ, Little JP, van Essen M, Wilkin GP, Burgomaster KA, Safdar A, et al. Short-term sprint

interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. *J Physiol.* 2006;575(Pt 3):901–11.
50. Kelley GA, Kelley KS, Roberts S, Haskell W. Comparison of aerobic exercise, diet or both on lipids and lipoproteins in adults: a meta-analysis of randomized controlled trials. *Clin Nutr.* 2012;31(2):156–67.
51. Krauss RM. Lipids and Lipoproteins in Patients With Type 2 Diabetes. *Diabetes Care*. 2004;27(6):1496–504.
52. Schwartz EA, Koska J, Mullin MP, Syoufi I, Schwenke DC, Reaven PD. Exenatide suppresses postprandial elevations in lipids and lipoproteins in individuals with impaired glucose tolerance and recent onset type 2 diabetes mellitus. *Atherosclerosis*. 2010;212(1):217–22.
53. Rizos C V, Elisaf MS, Liberopoulos EN. Effects of Thyroid Dysfunction on Lipid Profile. *Open Cardiovasc Med J*. 2011;5:76–84.
54. Yang W, Zhuang X, Li Y, Wang Q, Bian R, Shen J, et al. Improvements in quality of life associated with biphasic insulin aspart 30 in type 2 diabetes patients in China : results from the A 1 chieve ® observational study. *Health Qual Life Outcomes*. 2014;12(1):1–7.
55. Giordano, Roberta, Guaraldi Federica, Marinazzo Elisa, Fumarola Federica, Rampino Alessia, Berardelli Rita, Karamouzis Ioannis, Lucchiari Manuela, Manetta Tilde, Mengozzi Giulio, Arvat Emanuela GE. Improvement of anthropometric and metabolic parameters, and quality of life following treatment with dual-release hydrocortisone in patients with Addison's disease. *Endocrine* [Internet]. 2016;51(2):360–8. Available from: http://link.springer.com/article/10.1007/s12020-015-0681-z ✪