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Original Article

Effects of vitamin D supplementation along with endurance physical activity on lipid profile in metabolic syndrome patients: A randomized controlled trial

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Background and objectives: This study was conducted to determine the effects of vitamin D supplementation along with endurance physical activity on lipid profile among metabolic syndrome patients.
Materials and methods: In a parallel randomized placebo controlled trial, 70 metabolic syndrome patients, were randomly assigned into three groups. Biochemical tests were assessed as baseline and after 12 weeks of intervention. Statistical analysis was performed using SPSS version 20.
Results: The mean vitamin D levels was increased significantly in both vitamin D and vitamin D plus physical activity groups (P value < 0.05). No significant change was observed in the placebo group. Additionally, there was a significant decrease in total cholesterol and LDL-C in vitamin D plus physical activity group (P value < 0.05). No significant differences in changes of triglycerides and HDL-C among the three groups (P value > 0.05). While, in vitamin D group a decreased in total cholesterol, HDL-C, LDL-C and increase in triglycerides were observed, but did not reach a statistically significant.
Conclusion: Daily supplementation of vitamin D for 12 weeks, along with moderate endurance physical activity, significantly increase vitamin D concentration and induce a significant reduction in lipid profile in metabolic syndrome patients.

1. Introduction

Cardiovascular diseases (CVD) are disorders of the heart and blood vessels and include coronary heart disease, cerebrovascular disease, rheumatic heart disease and other conditions [1]. Globally, four out of five CVD deaths are due to heart attacks and strokes [2]. Individuals at risk of CVD may demonstrate raised blood pressure, glucose, and lipids as well as overweight and obesity [3]. Metabolic syndrome (MetS) is a cluster of the most dangerous heart attack risk factors: diabetes, raised fasting plasma glucose, abdominal obesity, high cholesterol and high blood pressure [1,2]. In addition, people with MetS carry a much higher risk of CVD [3]. MetS is a major health problem worldwide; based on reports, around 20–25% of the world's adult population have the MetS, and mortality rate among these people is twice as likely from heart attack, and three times as likely from stroke compared with people without MetS [4]. On the other hand, there is now increasing evidence that vitamin D, beyond its well-known effects on bone metabolism, it is also plays an important role in the development of CVD [5]. Epidemiologic studies have shown that vitamin D deficiency was closely associated with increased risk of major adverse CVD events [6,7]. Furthermore, some of previous cross-sectional analyses have revealed that vitamin D deficiency is associated with an unfavorable lipid profile [8,9]. However, adequate intake might not translate into clinically meaningful changes in lipid concentrations [10]. Further data from intervention trials are required to confirm if vitamin D may play a role in the improvement of lipid profile. Globally the World Health Organization

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identified physical inactivity as the fourth leading risk factor for mortality [11]. In addition, engaging in physical activity (PA) for at least 30 min every day of the week will help to prevent heart attacks and strokes [12]. Besides, there is strong epidemiological evidence indicating that regular PA is associated with reduced rates of all-cause mortality, oxidative stress, improvements in metabolism of glucose, vitamin D and decline of body weight by increasing lipolysis [13,14]. The clear relationship between PA and vitamin D metabolism or its outcome are confusing because the relationship between PA and body fat or sun exposure are not definite [15]. More data are needed to clarify the biases for this variation. As serum lipid levels, are among the real hazard factors for CVD, if there is a relationship between vitamin D and CVD, one clear clarification could be the impact of vitamin D along with endurance PA on serum lipid levels. In the present investigation, we inspected the impact of 2000 IU daily vitamin D supplementation along with endurance PA on lipid profile in MetS patients.

2. Materials and methods

2.1. Study design and study population

A Randomized Controlled Trial (RCT), was performed to examine the association and effects between vitamin D, and PA on lipid profile. Baseline and follow up information was performed and collected, in two different stages, baseline and end stage. In the present study, the subjects underwent a 12 weeks treatment program (From 01 March 2016 to 23 May 2016). Based on suggested formula of this model, the study participants were recruited on the foundation of developed inclusion/exclusion criteria [16]. Participants were randomly assigned into three groups: A) Vitamin D group, participants who took only 2000 IU/day vitamin D supplements (Morning time), and did not participated in 30 min/day of endurance PA (n = 30). B) Vitamin D plus PA group, participants who took 2000 IU/day vitamin D supplements plus 30 min/day of endurance PA (Either at the morning, 7:30 a.m. or afternoon, after 3:00 p.m.) (n = 30). C) Placebo group, participants who took only placebo (Morning time), and did not participated in 30 min/day of endurance PA (n = 30). Both vitamins and placebo were obtained from Osweh manufacture Iran-Tehran and was prepared to feature the same shape, odor and size of the supplements.

2.2. Sample size and sample determination

In the present study, the sample size was calculated using a previously described formula for parallel clinical trials n = 2 [(z1-α/2 + z1-β) 2. s2]/d2 [17]. In this formula, n is number of participants in each group. For estimating sample size, we considered type one (α) and type two errors (β) of 0.05 and 0.20 (Power = 80%) respectively, and fasting plasma glucose levels as a key variable. Based on a previous study [17], standard deviation (SD) of plasma glucose levels was 8 mg/dL and the difference in mean (d) was considered to be 5 mg/dL. Where α = 0.95, β = 20%, study power = 80%, d = 5, and SD = 8.

$$n = \frac{2\ (1.96 + 0.85)^2\ (8)^2}{(7)^2} = 21$$

We reached the sample size of 21 subjects for each group. In addition, to consider probable dropouts, 30 patients were included in each group. At the end, a total of 90 patients with MetS were included in the present study. Participants were distributed into three groups.

2.3. Inclusion and exclusion criteria

Eligibility criteria for participants having MetS, according to International diabetes federation (IDF) criteria [18], aged (30–50 years), both gender, living in Halabja (Kurdistan Region of Iraq), for at least three years. Individuals who were using any kind of minerals, vitamins and medications were not included in this study. Participants with type I or type II diabetes, heart failure, renal problems, malabsorption syndrome, history of bariatric surgery, participants who were taking weight loss medications, smoker, alcohol intake, pregnant or lactation, postmenopausal women, those with high triglycerides (TG) levels more than 400 mg/dl, high blood pressure 140/90 mmHg, and finally those with raised fasting plasma glucose (FPG) levels more than 150 mg/dl were excluded from the study. Furthermore, eligible individuals who were not follow the recommended time for PA (Approximately 6 h per week), were also excluded from the study.

2.4. Data collection

Data collection was performed in Halabja hospital, Kurdistan Region of Iraq. During the study visit, a standardized questioner was filled to get information from the subjects. In addition, information regarding demographic and medical history variables was obtained with an interview-based questionnaire. Past history and any previous treatment for certain disease including hypertension, diabetes, high cholesterol, supplement used, family history of obesity, family history of diabetes, family history of hypertension as well as PA patterns were also recorded.

2.5. Biochemical assessments

Fasting blood samples were collected at baseline and 12 weeks of intervention after 12 h overnight fasting to quantify serum levels of total cholesterol (TC) mg/dl, TG mg/dl, low-density lipoprotein cholesterol (LDL-C) mg/dl, high-density lipoprotein cholesterol (HDL-C) mg/dl, and serum vitamin D (25(OH)D) ng/ml. Serum Vitamin D was measured by the clinical laboratory at the Slemani Hospital, Iraq, using the Model-vidas analyser (Biomerux, Italy). Serum TC and TG concentration were assayed using enzymatic colorimetric tests with cholesterol esterase and cholesterol oxidase and glycerol phosphate oxidase, respectively, by using standard kits. HDL-C was measured after precipitation of the apolipoprotein B containing lipoproteins with phosphotungistic acid. LDL-C was calculated from serum TC, TG and HDL-C based on relevant formula [19]. Vitamin D insufficiency was defined as a 25(OH) D serum levels below than 30 ng/ml whereas deficiency was defined when the 25(OH) D levels was below than 15 ng/ml.

2.6. Anthropometric measurements

Weight (kg) was measured using standard scale (Seca); the scale was placed on a hard floor surface; patients were asked to remove their heavy outer garments and weight was measured and recorded to the nearest 0.1 kg. Height (m) was measured in all patients (Patients barefooted and head upright) with a measuring rod attached to the balanced beam scale; the height was reported to the nearest 0.5 cm. Furthermore, a stretch-resistant tape was used for measuring waist circumference (WC); WC (cm) was measured at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest. The body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters.

2.7. Assessment of PA

Endurance PA with sun exposure without sun protective was eligible for participants. Two a week around 2 h each time for climbing and two times of running a week around 1 h at the afternoon between 2 p.m. and 5 p.m. Overall, approximately 6 h per week.

2.8. Assessment of blood pressure

Blood pressure was measured from the left arm (mmHg) by mercury sphygmomanometer during each interview (From baseline and end of study), while the patient was seated after relaxing for at least 15 min in a quiet environment, empty bladder. The average of the measurements was recorded.

2.9. Follow-up

Follow-up and monitoring of all participants was done monthly at the health center. In every visit, participants were asked about health and/or any problem that may have during the study. In term of ethics as well as to avoid any confounding effects from dietary changes throughout the study, dietary recommendations were given to all participants after final intervention.

2.10. Statistical analysis

All statistical analyses were done using SPSS version 20. Following baseline randomness of allocation of participants in intervention groups by looking at their demographic and medical history characteristics were tested using Chi-square test and ANOVA. After this by student's t-test and paired *t*-test the difference of variables under study (Change due to intervention), were investigated by adjusting for effects of baseline measures. P value < 0.05 was considered as statistically significant.

3. Results

In the present study, 90 patients with MetS aged 30–50 years old were recruited: Vitamin D (n = 30), "vitamin D plus 30 min/day of PA" (n = 30) and placebo (n = 30) groups. Finally, 70 patients successfully finished the study (60.0% females, 40.0% males), vitamin D (n = 24), "vitamin D plus 30 min/day of PA" (n = 21) and placebo (n = 25). The baseline characteristics of study participants are provided in Table 1. To be confident participants age distribution, BMI, WC, family history of obesity, family history of diabetes mellitus and family history of hypertension was not significantly different among groups (P value > 0.05 for all). In addition, Table 1 show that, the baseline lipid profile of study participants revealed no significant differences in TC and LDL-C levels among the three groups (P value > 0.05 for all). However, participants who received vitamin D supplements had higher serum levels of TG compared with those who received placebo (P value < 0.05), and participants in the "vitamin D plus 30 min/day of PA" group had higher values of HDL-C and compared with those in the placebo group (P value < 0.05). Furthermore, the baseline characteristics of study participants show no significant differences in vitamin D levels among the study groups (P value > 0.05). On the other hand, the difference of the measured variables between the study groups after 12 weeks of intervention was shown in Table 2. As shown in Table 2 we observed a significant increase in mean serum vitamin D concentrations in participants who received either vitamin D or "vitamin D plus 30 min/day of PA" (P value < 0.05 for all). In addition, vitamin D plus 30 min/day of PA resulted a significant decrease in TC and LDL-C (P value = 0.002 and 0.017 respectively). No significant changes in serum levels of vitamin D were seen in the placebo group (P value > 0.05). Moreover, the end of trial means of biochemical indicators across the study groups are shown in Table 3. After intervention, subjects in vitamin D group had lower serum levels of TC compared with the placebo and "vitamin D plus 30 min/day of PA" groups (P value = 0.002). In terms of TG, vitamin D intake resulted in higher serum levels of TG compared with the "vitamin D plus 30 min/day of PA" and placebo groups (P

Table 1
Baseline characteristics of study participants.[a]

Variables	Group (n = 70)			
	Vitamin D[b] (n = 24)	Vitamin D + PA[c] (n = 21)	Placebo[d] (n = 25)	P value[e]
Age (years)	40.54 ± 5.94	40.42 ± 5.89	42.6 ± 5.62	0.352
Male (%)	8.0 (33.3)	7.0 (33.3)	13.0 (52.0)	0.557
Female (%)	16.0 (66.7)	14.0 (66.7)	12.0 (48.0)	0.322
Weight (kg)	84.21 ± 16.72	81.73 ± 9.6	82.34 ± 13.98	0.826
Height (m)	1.59 ± 0.1	1.56 ± 0.07	1.58 ± 0.08	0.553
Body mass index (kg/m[b])	33.12 ± 5.92	33.43 ± 4.26	32.81 ± 4.32	0.915
Waist circumference (cm)	109.16 ± 8..03	108.47 ± 7.7	107.64 ± 9.6	0.825
Family history of obesity (%)	18.0 (75.0)	17.0 (80.9)	19.0 (76.0)	0.882
Family history of diabetes mellitus (%)	12.0 (50.0)	14.0 (66.6)	15.0 (60.0)	0.534
Family history of hypertension (%)	14.0 (58.3)	13.0 (61.9)	15.0 (60.0)	0.973
Fasting plasma glucose (mg/dl)	108 ± 17.05	106.04 ± 11.84	110.64 ± 17.21	0.611
Systolic blood pressure (mmHg)	127.08 ± 11.5	129.04 ± 12.71	125.6 ± 14.52	0.675
Diastolic blood pressure (mmHg)	79.79 ± 9.49	83.57 ± 9.37	80 ± 6.92	0.274
Total cholesterol (mg/dl)	173.5 ± 60.8	194.7 ± 32.2	185.9 ± 39	0.322
Triglycerides (mg/dl)	229.3 ± 113.8*	184.5 ± 98.5	147.3 ± 43	0.008
LDL-C (mg/dl)	120.7 ± 64.4	149.9 ± 35.8	150.4 ± 39.9	0.062
HDL-C (mg/dl)	34.9 ± 17.3	40.9 ± 14.4*	30 ± 8.5	0.031
Vitamin D (ng/ml)	10.75 ± 2.79	10.42 ± 3.24	12.16 ± 3.95	0.182

*P < 0.05 are significant.
PA: physical activity.
[a] Data are mean ± standard deviation (SD).
[b] Receiving 2000 IU vitamin D per day.
[c] Receiving 2000 IU vitamin D per day plus 30 min endurance physical activity.
[d] Receiving one placebo per day.
[e] Obtained from ANOVA or chi-square test, where appropriate.

Table 2
Difference of the measured variables between the groups at 12 weeks of intervention.[a].

Variables	Vitamin D[b] (n = 24)		P value[e]	Vitamin D + PA[c] (n = 21)		P value[e]	Placebo[d] (n = 25)		P value[e]
	Before Mean ± SD	After Mean ± SD		Before Mean ± SD	After Mean ± SD		Before Mean ± SD	After Mean ± SD	
TC (mg/dl)	173.5 ± 60.8	160.5 ± 33.4	0.155	194.7 ± 32.2	181.7 ± 31.3	0.002*	185.9 ± 39	196.8 ± 39.4	0.114
TG (mg/dl)	229.3 ± 113.8	233.8 ± 97	0.547	184.5 ± 98.5	178.1 ± 80.8	0.331	174.4 ± 43	158.6 ± 35.4	0.072
LDL-C (mg/dl)	120.7 ± 64.4	107 ± 36.6	0.142	149.6 ± 35.8	138.3 ± 31.4	0.017*	150.4 ± 39.8	158.8 ± 39	0.214
HDL-C (mg/dl)	34.9 ± 17.3	33.7 ± 10.6	0.631	40.9 ± 14.4	39 ± 10	0.053	30.04 ± 8.5	31.7 ± 7	0.248
Vit D (ng/ml)	10.7 ± 2.8	23.2 ± 4.9	0.001*	10.4 ± 3.2	29 ± 5.5	0.001*	12.1 ± 3.9	12.6 ± 4	0.095

*P < 0.05 are significant.
PA: physical activity; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; Vit D: vitamin D.
[a] Data are means ± standard deviation (SD).
[b] Receiving 2000 IU vitamin D per day.
[c] Receiving 2000 IU vitamin D per day plus 30 min' endurance physical activity.
[d] Receiving one placebo per day.
[e] Obtained from paired sample T test.

Table 3
End of trial means of biochemical indicators across study groups.[a].

Variables	After 12 weeks of intervention			
	Vitamin D[b] (n = 24) Mean ± SD	Vitamin D + PA[c] (n = 21) Mean ± SD	Placebo[d] (n = 25) Mean ± SD	P Value[e]
TC (mg/dl)	160.5 ± 33.4*	181.7 ± 31.2	196.8 ± 39.4	0.002
TG (mg/dl)	233.8 ± 97*	178 ± 80.8	158.6 ± 35.4	0.003
LDL-C (mg/dl)	107 ± 36.6†	138.3 ± 31.4	158.8 ± 39	0.001
HDL-C (mg/dl)	33.7 ± 10.6	39 ± 10†	31.8 ± 7	0.029
Vitamin D (ng/ml)	23.2 ± 4.9	29 ± 5.5†	12.7 ± 4	0.001

*P < 0.05 compared with the placebo and vitamin D plus physical activity groups.
†P < 0.05 compared to placebo groups.
PA: physical activity; TC: total cholesterol; TG: triglycerides; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol.
[a] Data are means ± standard deviation (SD).
[b] Receiving 2000 IU vitamin D per day.
[c] Receiving 2000 IU vitamin D per day plus 30 min endurance physical activity.
[d] Receiving one placebo per day.
[e] Obtained from ANOVA.

value = 0.003). After vitamin D supplementation, participants in vitamin D plus 30 min/day of PA group had higher serum levels of HDL-C compared to vitamin D and placebo groups (P value = 0.029). End of trial means of serum levels of LDL-C was significantly lower in the vitamin D group compared with other two groups (P value < 0.001). Additionally, Table 3 show that, serum vitamin D levels were significantly high among “vitamin D plus 30 min/day of PA” group compared with other two groups (P value < 0.001). Finally, the changes in biochemical indicators across study groups are presented in Table 4. A significant changes in serum levels of TC and LDL-C were seen following “vitamin D plus 30 min/day of PA” than that in the placebo group (P value = 0.021 and 0.049 respectively). There were no significant differences in changes of TG and HDL-C among the three groups (P value > 0.05).

4. Discussion

To the best of our knowledge, this is the first randomized controlled trial, which describes the effects of vitamin D supplementation along with endurance PA on lipid profile among MetS patients in Iraq. The main findings of the present study indicate that, after 12 weeks of intervention, the mean vitamin D levels was increased significantly in both vitamin D and vitamin D plus 30 min/day of PA groups. No significant change was observed in the placebo group. In addition, there was a significant decrease in TC and LDL-C in vitamin D plus 30 min/day of PA group. Furthermore, no significant differences in changes of TG and HDL-C among the three groups. Babaei et al. [20] study the interaction effects of aerobic exercise training and vitamin D supplementation on plasma

Table 4
Changes in biochemical indicators across study groups.[a].

Variables	Vitamin D[b] (n = 24) Mean ± SD	Vitamin D + PA[c] (n = 21) Mean ± SD	Placebo[d] (n = 25) Mean ± SD	P value[e]
TC (mg/dl)	−13 ± 42.3	−12.9 ± 16.7*	10.9 ± 32.8	0.021
TG (mg/dl)	4.6 ± 32.9	−6.4 ± 29.4	11.2 ± 29.8	0.165
LDL-C (mg/dl)	−13.7 ± 43.8	−11.3 ± 19.8*	8.3 ± 30.9	0.049
HDL-C (mg/dl)	−1.3 ± 12.9	−1.9 ± 13.4	1.7 ± 7.2	0.513
Vitamin D (ng/ml)	12.4 ± 4.3*	18.6 ± 6.8*	0.5 ± 1.3	0.001

*P < 0.05 compared with the placebo group.
PA: physical activity; TC: total cholesterol; TG: triglycerides; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol.
[a] Data are means ± standard deviation (SD).
[b] Receiving 2000 IU vitamin D per day.
[c] Receiving 2000 IU vitamin D per day plus 30 min' endurance physical activity.
[d] Receiving one placebo per day.
[e] Obtained from ANOVA.

lipid profiles and insulin resistance in ovariectomized rats, and the author concluded that, the TC, and LDL-C levels were significantly decreased with increased aerobic training and vitamin D intake. In addition, few studies have investigated the relationship between serum levels of vitamin D and lipid profiles. Major et al. [21] reported that, in obese middle-aged women taking 200 IU of vitamin D per day for 15 weeks, TC, and LDL-C concentrations were significantly reduced. The results of our study support these findings. Furthermore, from results of cross-sectional data used for meta-analysis where the majority of the study results indicated that serum vitamin D is directly associated with serum HDL-C and inversely related to TC, LDL-C, and TG, it is important to highlight that higher serum vitamin D is related to a more favorable lipid profile in the pediatric age groups [22]. In contrary, Jorde et al. [23] in a cross sectional study show that, there were highly significant positive associations between serum vitamin D and serum TC, HDL-C and LDL-C, and significant negative associations between serum vitamin D and both LDL-C/HDL-C ratio and TG after adjustment for gender, age, BMI and month of blood sampling. Moreover, Saeidlou et al. [24] in a cross sectional study of the seasonal variations of vitamin D and its relation to lipid profile in children and adults. The author concluded that, vitamin D is different between the two seasons (winter and summer) regardless of gender variations. Its status showed some significant relationship with some lipid profiles (TC, LDL-C, and HDL-C) during the two seasons [24]. On the other hand, the results of the present study revealed that, in vitamin D group a decreased in TC, HDL-C, LDL-C and increase in TG were observed, but did not reach a statistically significant. Hao Wang et al. [25] in a meta-analysis show that, controlled trials indicated that vitamin D supplementation does not appear to significantly affect TC, HDL-C and TG. The results of our study support these findings.

High plasma concentrations of LDL-C and TG and low HDL-C levels are risk factors for CVD [26]. In addition to reducing the risk for CVD [27,28], an increase in HDL can halt the progression or even cause the regression of atherosclerotic plaques [29]. Observational and experimental studies have shown that regular practice PA induces desirable changes in plasma lipid levels [30], especially HDL-C increase and TG decrease, in addition to triggering beneficial effects on TC and its low-density and very-low density fractions (LDL and VLDL, respectively) [31,32]. Despite the well-known benefits resulting from PA practice, there are controversies about which PA characteristic would be more important to improve lipid profile: exercise intensity [33], frequency [34], duration [35] combination of frequency and intensity [36]. In fact, the mechanism of exercise induced lipid changes is unclear; exercise itself may increase blood lipid consumption hence to decrease lipids levels [37]. Furthermore, observational studies have shown that high serum vitamin D concentrations are associated with a favorable lipid profile [38]. Hao Wang et al. [25] in a meta-analysis show that, the effect of vitamin D supplement on serum LDL-C levels seemed more significant in obese subjects and in studies with relatively shorter durations, while studies with longer durations only showed a significant reduction in HDL-C levels; and the author concluded that, subgroup analyses by duration of intervention revealed that vitamin D treatment has a more obvious effect on LDL-C in the shorter duration studies. Actually, the effects of vitamin D supplementation along with endurance PA on lipid profile in MetS patients need more studies in the future; and a preferable impression of the mechanism included is required, as it will give novel perception in to clinical guidance of patients.

The main limitations of this study is its small sample size and duration is short. Moreover, our study not adjusted for other confounding variables such as genetics factors, and environmental factors, such as exposure to ultraviolet light and consumption of foods rich in fat-soluble vitamin D staples (e.g., oily sea fish, meat, and eggs) which limits the generalizability of our results. However, studies with a larger sample size and longer intervention period together may yield more meaningful data on the effects of vitamin D supplementation along with endurance PA on lipid profile in MetS patients. Finally, individuals with habits of exercising outside frequently and eating nutritious food, which would elevate serum vitamin D levels, may have other healthy habits which could favorably affect lipid profiles and reduce the risk for CVD.

In conclusion, daily supplementation of vitamin D (2000 IU) for 12 weeks, along with moderate endurance PA, significantly increase vitamin D concentration and induce a significant reduction in lipid profile in MetS patients.

Declarations

Ethics approval and consent to participate

The Ethics Committee of Tehran University of Medical Sciences approved the study protocol, and the trial was registered at the World Health Organization, International Clinical Trails Registry Platform (Code: IRCT20161110030823N2). In addition, written informed consent was also obtained from each participant.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing of interest statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (Such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (Such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Authors' contributions

HAF, MJH, BAM and AHB participated in the design of the study, data collection, performed the statistical analysis and drafted the manuscript. MJH, AE and AHB supervising the study and participated in draft review. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Trial registration

WHO-ICTRP IRCT20161110030823N2. Registered 01 February 2018. http://apps.who.int/trialsearch/Trial2.aspx?TrialID=IRCT20161110030823N2.

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List of abbreviations

LDL-C	Low-density lipoprotein cholesterol
HDL-C	High-density lipoprotein cholesterol
IU	International unit
CVD	Cardiovascular disease
MetS	Metabolic syndrome
PA	Physical activity
RCT	Randomized controlled trial
SD	Standard deviation
IDF	International diabetes federation
TG	Triglyceride;
FPG	Fasting plasma glucose
TC	Total cholesterol
WC	Waist circumference
BMI	Body mass index

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.01.029.

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