Society of Medical Education & Research

2021, Volume 1, Page No: 32-40

Annals of Pharmacy Education, Safety, and Public Health Advocacy Specialty

Lifestyle Modifications Help Lower the Likelihood of Developing Cardiovascular Diseases and Type II Diabetes in Adults with Prediabetes

Sang Ngoc Nguyen[1]*, Van Dinh Tran[2], Trinh Thi Mai Le[3], Hoang Thu Nga[3], Nguyen Thi Thi Tho[2]

[1]Department of Pediatrics, Hai Phong University of Medicine and Pharmacy, Hai Phong, Vietnam.
[2]Department of Non-Communicable Disease Control, National Institute of Hygiene and Epidemiology, Hanoi, Vietnam.
[3]Institute for Preventive Medicine and Public Health, Hanoi Medical University, Hanoi, Vietnam.

***E-mail** ✉ nnsang@hpmu.edu.vn

Abstract

This study assessed the impact of a community-centered program focusing on nutrition and physical activity on physical activity levels, dietary habits, blood glucose, and various metabolic markers in pre-diabetic adults aged 50-65 years after six months. Participants, all pre-diabetic and with at least two components of metabolic syndrome, were recruited from Hanam province, Vietnam, and randomly assigned to an intervention group (n = 44) or a control group (n = 49). The intervention group participated in a comprehensive health promotion program, while the control group participated in a standard counseling session over the same period. The findings showed significant improvements in the intervention group for physical activity measures, such as increased walking time, moderate activity, overall physical activity, and decreased average sitting time. Post-intervention comparisons showed significant differences between the intervention and control groups in total physical activity, walking time, and sitting duration. Analysis of dietary behavior showed a significant reduction in the frequency of salt consumption in both groups, while the intervention group also showed a significant reduction in the frequency of cooking oil use. After six months, fasting glucose levels decreased in the intervention group but increased in the control group. In addition, the intervention group showed a significant increase in HDL-C levels and diastolic blood pressure compared to the control group. Weight loss was also significantly greater in the intervention group than in the control group. Overall, this program demonstrated success in improving physical activity, dietary behaviors, fasting glucose levels, and cardiovascular risk factors among pre-diabetic adults in Vietnam.

Keywords: Physical activity, Diet, Diabetes, Cardiovascular diseases, Lifestyle intervention, Vietnam

Introduction

Type II diabetes (T2D) [1] and cardiovascular diseases (CVDs) [2] represent significant health challenges both globally and in Vietnam. In 2016, CVDs accounted for 31% of all deaths in Vietnam, making them the leading cause of mortality [3]. Concerning T2D, an estimated 6% of the Vietnamese population, or nearly 6 million individuals, were living with diabetes in 2017 [4, 5]. Projections indicate a rising prevalence of CVDs and T2D in Vietnam, highlighting the need for enhanced efforts within the healthcare system to address and mitigate associated risk factors [4].

Access this article online

Website: https://smerpub.com/ **E-ISSN: 3108-4850**

Received: 12 August 2021; **Revised:** 26 October 2021; **Accepted:** 28 October 2021

How to cite this article: Nguyen SN, Tran VD, Le TTM, Nga HT, Tho NTT. Lifestyle Modifications Help Lower the Likelihood of Developing Cardiovascular Diseases and Type II Diabetes in Adults with Prediabetes. Ann Pharm Educ Saf Public Health Advocacy Spec. 2021;1:32-40. https://doi.org/10.51847/vmQt7JDlwi

Metabolic Syndrome (MetS) refers to a collection of risk factors that contribute to CVD, T2D, and increased all-cause mortality. These factors include abdominal obesity, hypertension, elevated fasting glucose levels, high triglycerides, and decreased HDL-C [6]. Studies have shown that MetS doubles the likelihood of cardiovascular events, increases all-cause mortality by 1.5 times, and raises the risk of developing T2D by 5 to 6 times [7]. Globally, it is estimated that 25% of adults are affected by MetS, though the actual figure may be higher due to underdiagnosis [8]. In Vietnam, nearly two-fifths of middle-aged adults are affected by MetS, with the prevalence rising to 27% among individuals aged 55–64 years [9].

Lifestyle interventions that combine physical activity (PA) with dietary changes have been identified as essential strategies for reducing the risk of CVDs and T2D [10]. Research has demonstrated that structured lifestyle programs effectively reduce risk factors for CVDs, such as triglycerides, blood pressure, LDL-C, HDL-C, and total cholesterol [10, 11]. Furthermore, evidence supports the efficacy of these interventions in encouraging participants to adopt healthier behaviors and manage weight to control MetS [12].

The Vietnam Physical Activity and Nutrition (VPAN) program is a lifestyle intervention targeting adults aged 50–65 years with MetS in Hanam province, located in northern Vietnam. This cluster randomized controlled trial is registered with the Australia and New Zealand Clinical Trials Registry (ACTRN12614000811606). Comprehensive details regarding the intervention have been outlined in a previous publication [13].

The purpose of this study was to evaluate the impact of the VPAN program on pre-diabetic participants by assessing changes in physical activity levels, dietary habits, fasting glucose levels, and selected metabolic parameters following the six-month intervention.

Materials and Methods

Study design

This community-based intervention was designed as a 6-month cluster-randomized controlled trial, focusing on individuals aged 50 to 65 years with MetS in Hanam province, northern Vietnam. Detailed information regarding the program has been reported in a separate publication [13].

Studied participants

This study examined 93 pre-diabetic adults between the ages of 50 and 65 and they completed the 6-month intervention, including 44 individuals in the intervention group and 49 in the control group.

Inclusion criteria

The participants were classified as pre-diabetic, defined by fasting plasma glucose levels (≥ 6.1 mmol/L), and exhibited at least 2 components of MetS based on the modified criteria of the National Cholesterol Education Program Adult Treatment Panel III [14], outlined as follows: 1) abdominal obesity (waist circumference ≥ 80 cm for women and ≥ 90 cm for men in the Asian population (4); 2) elevated triglycerides (≥ 150 mg/dL or ≥ 1.7 mmol/L); 3) decreased HDL-C (less than 50 mg/dL or < 1.29 mmol/L for women and less than 40 mg/dL or < 1.03 mmol/L for men); and 4) high blood pressure (systolic ≥ 130 mmHg or diastolic ≥ 85 mmHg).

Exclusion criteria

Individuals suspected of having T2D (fasting plasma glucose ≥ 7.1 mmol/L), those receiving treatment for T2D, dyslipidemia, CVD, hypertension, or hyperglycemia, as well as those who had participated in a PA or dietary program in the previous year, were not included in the study.

Interventions

The specifics of the interventions were outlined in a previous publication [13]. Briefly, the intervention was grounded in Social Cognitive Theory [15], aimed at encouraging participants to sustain a healthy diet and engage in physical activity. The VPAN program consisted of four 2-hour educational sessions, walking groups, resistance bands, and a booklet.

Instruments

Personal and demographic data, including marital status, gender, occupation, alcohol consumption, age, and smoking habits, were collected through a questionnaire administered to participants during an in-person interview at the start of the study.

Physical activity

Physical activity levels, including moderate-intensity exercise, sitting, vigorous-intensity exercise, and walking time, were assessed using the International Physical Activity Questionnaire-Short Form, which has been validated for Vietnamese adults [16].

Diet

We adapted the brief dietary habits questionnaire from the STEPs questionnaire created by the World Health Organization [17] to collect data on the frequency of using salt and cooking oil in meal preparation, intake of animal internal organs, and vegetable and fruit consumption.

Metabolic outcomes

Metabolic outcomes included blood parameters and blood pressure, which were assessed at both baseline and post-test. A phlebotomist collected fasting blood samples at commune health stations. The concentrations of fasting plasma glucose, HDL-C, total cholesterol, and triglycerides were measured, while LDL-C and non-HDL-C levels were calculated afterward [18]. Anthropometric measurements and Blood pressure were recorded by trained program staff according to WHO guidelines [17]. Diastolic and Systolic blood pressure measurements were averaged after taking three consecutive readings.

Anthropometric outcomes

Trained staff measured the waist and hip circumferences and calculated the waist-to-hip ratio. Weight was measured to the nearest 0.01 kg, and height was measured to the nearest 0.1 cm.

Statistical analysis

Descriptive statistics were initially used to summarize the traits of the participants based on group status. Comparisons between the two groups at both time points were made using independent sample tests and chi-square tests for dichotomous outcomes, and paired t-tests for continuous outcomes. We also employed the Wilcoxon signed-rank test and Mann-Whitney U test for variables with skewed distributions.

Results and Discussion

This study implemented a community-based intervention program aimed at improving dietary habits and PA levels to evaluate its effectiveness in adults at high risk for CVDs and T2D. The findings demonstrated notable improvements in nutrition and PA outcomes among those in the intervention group compared to the control group, aligning with results from similar studies using comparable approaches [19]. Additionally, significant changes in MetS components and anthropometric measures were observed in both groups.

Table 1. Initial characteristics of participants in the intervention and control groups

Variable	Intervention (n = 44) n (%)	Control (n = 49) n (%)	P-value
Age: mean (SD) years	58.6 (4.6%)	56.7 (4.4%)	0.053
Gender			
Female	35 (79.5%)	32 (65.3%)	0.127
Male	9 (20.5%)	17 (34.7%)	
Education level			0.124
Primary school or below	2 (4.5%)	6 (12.2%)	
Secondary school	22 (50.0%)	29 (59.2%)	
High school	17 (38.6%)	8 (16.3%)	
College/University	3 (6.8%)	6 (12.2%)	
Occupation			0.132
Farmer/worker	6 (13.6%)	16 (32.6%)	
Office job	0 (0%)	2 (4.1%)	
Retired	16 (36.4%)	12 (24.5%)	
Business	6 (13.6%)	5 (10.2%)	
Home duties and others	16 (36.4%)	14 (28.5%)	
Smoking status			0.825
Never	38 (86.4%)	40 (81.6%)	
Former	4 (9.1%)	6 (12.2%)	
Current smoker	2 (4.5%)	3 (6.1%)	
Alcohol drinking			0.212

No	37 (84.1%)	36 (73.5%)
Yes	7 (15.9%)	13 (26.5%)

Table 1 outlines the characteristics of participants in the 6-month intervention. There were no significant differences between the 2 groups (P > 0.05) regarding baseline characteristics. The average age was 56.8 years (SD = 4.6) in the intervention group and 56.7 years (SD = 4.4) in the control group, with a majority of participants being female. A high proportion of participants (90%) had completed higher education or secondary school. Approximately 35% of the participants were retired. Among the participants,73.5% in the control group and 84.1% in the intervention group were non-smokers. The majority of individuals in both groups did not smoke (86.4% in the intervention group and 81.6% in the control group).

Table 2. Comparing physical activity results over time and between the control and intervention groups

Outcomes	Intervention (n = 44)		P^1	Control (n = 49)		P^2	P^3	P^4
	Baseline	Post		Baseline	Post			
Vigorous activity[a]	4 (9.1%)	8 (18.2%)	0.214	5 (10.2%)	11 (22.4%)	0.101	0.569	0.610
Moderate activity[a]	12 (27.3%)	21 (47.7%)	0.048	12 (24.5%)	18 (36.7%)	0.188	0.759	0.283
Walking time: mean (SD)[b]	395.2 (554.2)	630.6 (539.4)	0.015	333.6 (394.3)	326.7 (355.0)	0.680	0.567	0.002
Total physical activity: mean (SD)[b]	545.7 (666.3)	773.3 (557.1)	0.018	448.4 (447.9)	502.9 (496.6)	0.260	0.951	0.009
Sitting time: mean (SD) min/week	2,529.9 (656.7)	1,902.7 (934.1)	< 0.001	2,568.9 (831.0)	2499.4 (940.7)	0.697	0.494	0.007

1: From baseline to post-test for the intervention group
2: From baseline to post-test for the control group
3: Between the intervention and control groups at baseline
4: Between the intervention and control groups at post-test
a: Participation lasting at least 10 minutes
b: Nonparametric test applied to MET-min/week

PA levels for both groups at baseline and post-test are presented in **Table 2**. No important differences were found between baseline and post-test for the control group, nor between the intervention and control groups at baseline. The intervention group showed important improvements in moderate activity, total PA, walking, and sitting time at post-test. Research indicates that excessive sitting has negative metabolic and cardiovascular effects on adults, regardless of whether PA guidelines are followed [20, 21]. Therefore, future intervention programs should focus on both increasing PA levels and reducing sitting time. We observed important differences between the intervention and control groups at post-test in total PA, walking time, and sitting time (P < 0.05), while no significant changes were noted in vigorous or moderate activities. The increase in PA levels in this research adds to the growing evidence supporting the effectiveness of PA interventions, as seen in other research [21, 22]. However, variations in intervention strategies pose challenges in determining the most effective approach for specific groups. Our study followed the WHO's Recommendations for physical activity [23], adapted the program to meet individual needs and goals, and fostered a motivating environment to enhance participant adherence. Walking was the primary PA in this study, as it is the most common and safest form of exercise, particularly for older adults [24]. These factors likely contributed to the positive changes in PA behaviors observed in the intervention group.

Table 3. Dietary habits result over time and between the intervention and control groups

Outcome	Intervention (n = 44)		P^1	Control (n = 49)		P^2	P^3	P^4
	Baseline n (%)	Post n (%)		Baseline n (%)	Post n (%)			
Frequent vegetable intake[a]	39 (88.6%)	37 (84.1%)	0.534	44 (89.8%)	36 (73.5%)	0.037	0.559	0.213

Frequent fruit intake[a]	17 (38.6%)	17 (38.6%)	1.000	8 (16.3%)	12 (24.5%)	0.316	0.015	0.141
Frequent use of cooking oil[a]	13 (29.5%)	5 (11.4%)	0.034	14 (28.6%)	12 (24.5%)	0.647	0.918	0.116
Frequent use of salt[a]	40 (90.9%)	15 (34.1%)	< 0.001	48 (98.0%)	31 (63.3%)	< 0.001	0.186	0.005
Frequent intake of animal internal organs[b]	35 (79.5%)	35 (79.5%)	1.000	35 (71.4%)	29 (59,2%)	0.203	0.365	0.034

[1]: From baseline to post-test for the intervention group
[2]: From baseline to post-test for the control group
[3]: Between the intervention and control groups at baseline
[4]: Between the intervention and control groups at post-test
[a]: At a minimum of once a day
[b]: More than two times a month

Table 3 presents the dietary behavior outcomes. The healthy eating guidelines included in this intervention program were aligned with the Food-Based Dietary Guidelines of Vietnam [25], emphasizing increased vegetable and fruit consumption while reducing intake of salt, red meat, and fats. No significant differences were observed between the intervention and control groups at baseline. Both groups showed a significant reduction in the frequent use of salt for meal preparation from baseline to post-test ($P < 0.001$). Additionally, the intervention group significantly reduced their daily cooking oil usage ($P = 0.034$). These improvements reinforce the importance of nutrition programs targeting individuals at high risk for CVD, particularly due to the links between dietary fat intake [26] and salt intake [27] with MetS components. However, no important changes were observed in daily vegetable and fruit consumption in either group. This outcome contrasts with a study showing increased fruit and vegetable intake following a 10-week nutrition education program [28, 29]. The "ceiling effect" may explain this lack of improvement, as participants were already consuming these foods at least once a day. A noticeable difference in the intake of animal internal organs was found between the 2 groups, with a higher prevalence in the intervention group (79.5%) compared to the control group (59.2%) at the post-test. This difference may be linked to participants' dietary habits, but further discussion on this aspect was not possible due to data limitations.

Table 4. Comparison of variations in glucose levels and other metabolic parameters between the intervention and control groups

Outcome	Intervention (n = 44)		P^1	Control (n = 49)		P^2	P^3	P^4
	Baseline Mean (SD)	Post-test Mean (SD)		Baseline Mean (SD)	Post-test Mean (SD)			
Glucose (mM)	6.6 (0.36)	6.4 (1.77)	0.518	6.6 (0.32)	7.3 (2.75)	0.120	0.450	0.117
HDL-C (mM)	1.4 (0.20)	1.6 (0.67)	0.116	1.6 (0.38)	1.4 (0.26)	0.004	0.171	0.025
Total cholesterol (mM)	5.1 (0.94)	5.8 (1.28)	0.017	5.3 (0.84)	5.5 (0.95)	0.128	0.259	0.344
Triglycerides (mM)[a]	2.1 (1.3)	2.3 (1.2)	0.420	2.5 (1.6)	2.7 (2.2)	0.490	0.113	0.783
Non-HDL-C (mM)	3.6 (0.95)	4.1 (1.52)	0.125	3.7 (0.87)	4.1 (0.85)	0.012	0.502	0.997
LDL-C (mM)	2.7 (0.78)	3.1 (1.44)	0.163	2.4 (1.34)	2.9 (1.30)	0.113	0.733	0.546
Systolic blood pressure (mmHg)	134.4 (17.14)	131.4 (18.10)	0.363	133.9 (15.61)	135.5 (20.59)	0.604	0.864	0.369
Diastolic blood pressure (mmHg)	82.2 (10.41)	80.1 (10.78)	0.362	85.3 (12.71)	89.6 (12.2)	0.032	0.258	0.001

[1]: From baseline to post-test for the intervention group
[2]: From baseline to post-test for the control group
[3]: Between the intervention and control groups at baseline
[4]: Between the intervention and control groups at post-test
[a]: Non-parametric tests were used because of skewed distributions.

Table 4 illustrates the changes in glucose levels and other metabolic parameters for both the intervention and control groups following the 6-month intervention. In the intervention group, fasting plasma glucose decreased by -0.2 mM ($P = 0.518$) at the post-test, while the control group saw an increase of +0.7 mM ($P = 0.12$). However, no important differences were found between the groups in the post-test. These findings align with a study by

Oldroyd *et al*. [30], which also displayed an insignificant reduction in glucose levels in individuals with impaired glucose tolerance following lifestyle modifications (-0.11 mM, P = 0.63). Similarly, a 10-week daily walking intervention did not result in an important decrease in fasting plasma glucose levels [31]. This suggests that the effectiveness of lifestyle changes for diabetes prevention may depend on pre-diabetic conditions such as impaired glucose tolerance and/or fasting glucose, each linked to distinct pathophysiological mechanisms, including insulin resistance [32, 33]. Despite this, the changes in glucose levels were promising, and a longer intervention period may lead to more significant improvements in glucose levels among high-risk individuals.

Unexpectedly, the intervention group experienced an increase in total cholesterol (+0.7 mM, P = 0.017), while other metabolic parameters showed no significant changes. In contrast, other studies have demonstrated the positive effects of exercise in lowering total cholesterol, blood pressure, triglycerides, and LDL-C levels [34, 35]. The control group exhibited notable changes, including a decrease in HDL-C levels (-0.2 mM, P = 0.004) and an increase in diastolic blood pressure (+4.3 mM, P = 0.032). Statistically significant differences were observed between the groups at the post-test, with higher mean HDL-C (+0.2 mM, P = 0.025) and increased diastolic blood pressure (+9.5 mmHg, P = 0.001) in the intervention group. The mixed results regarding the effectiveness of the intervention on MetS components could be attributed to the high-risk nature of the participants for CVD and T2D, the limited duration of the intervention, and the insufficient intensity of physical activities, all of which may have hindered improvements. Additionally, factors like the frequency and the type of the exercise must also be considered for future interventions.

Table 5. Comparison of changes in anthropometric measurements between the intervention and control groups

Outcomes	Intervention (n = 44)		P[1]	Control (n = 49)		P[2]	P[3]	P[4]
	Baseline Mean (SD)	Post-test Mean (SD)		Baseline Mean (SD)	Post-test Mean (SD)			
Waist circumference (cm)	87.0 (6.04)	86.0 (6.36)	0.104	88.7 (8.14)	87.8 (7.51)	0.133	0.864	0.264
Hip (cm)	93.4 (4.33)	93.4 (4.49)	0.944	97.7 (6.78)	94.6 (6.89)	0.157	0.838	0.393
WHR	0.93 (0.05)	0.91 (0.04)	0.132	0.93 (0.05)	0.92 (0.04)	0.192	0.973	0.407
Weight (kg) [a]	60.6 (8.2)	58.5 (8.5)	0.001	61.4 (9.0)	62.4 (9.1)	0.473	0.776	0.039
BMI [a]	25.1 (2.1)	24.2 (2.3)	0.001	25.1 (2.3)	25.1 (2.4)	0.577	0.929	0.068

[1]: Differences between the baseline and post-test results for the intervention group.
[2]: Differences between the baseline and post-test results for the control group.
[3]: Comparison between the intervention and control groups at baseline.
[4]: Comparison between the intervention and control groups at post-test. a. Non-parametric tests were used due to the skewed distributions.

Table 5 presents the changes in anthropometric measures after a six-month intervention in both the control and intervention groups. At baseline, no important differences were observed either within the control group or between the 2 groups. However, after the intervention, the intervention group showed significant reductions in both weight (-2.1 kg, P = 0.001) and BMI (-0.9 kg/m², P = 0.001). A notable difference in weight (3.9 kg, P = 0.039) was also observed between the control and intervention groups at post-test. The beneficial effects of physical activity and nutrition interventions on reducing the risks of type 2 diabetes (T2D) and cardiovascular diseases (CVDs) have been well-documented [11]. Obesity increases the risk of T2D by twenty times compared to individuals with normal weight [36] and raises mortality risk from cardiovascular diseases [37]. Therefore, weight loss is a critical goal in lifestyle interventions aimed at high-risk populations. In this study, the significant reduction in weight and BMI in the intervention group aligns with findings from other studies [38]. As the control group did not participate in walking sessions, the differences between the groups suggest that the combined effects of physical activity and changes in dietary habits may offer more benefits than nutrition interventions alone.

Health promotion, which fosters increased awareness and self-regulation of health, is an essential approach [39]. It includes a broad range of environmental and social interventions. As previously noted, health promotion programs targeting lifestyle changes are effective in lowering the risk of CVDs and T2D, though maintaining these benefits over the long term can be challenging [12, 40]. Nevertheless, the significance of these interventions in preventing non-communicable diseases (NCDs) remains clear and underscores the need for ongoing development and implementation [41]. The growing prevalence of NCDs, like diabetes, hypertension, and CVDs, in Vietnam [4] is largely due to the country's rapid economic growth, an aging population, and lifestyle shifts that have increased the health burden from NCDs [42]. Consequently, large-scale lifestyle interventions, particularly those focused on long-term changes, can significantly reduce the burden of these diseases, ultimately preventing morbidity and mortality in high-risk populations.

Conclusion

The prescribed physical activity and nutrition intervention proved effective in enhancing physical activity and dietary behaviors, lowering fasting glucose levels, and improving certain metabolic parameters among pre-diabetic adults in Vietnam.

Acknowledgments: We express our gratitude to the residents of Hanam province for their participation in the study. We also appreciate the Hanam Provincial Preventive Medicine Centre for assisting with participant recruitment and providing support throughout the trial.

Conflict of Interest: None

Financial Support: This study received partial financial support from Curtin University, Western Australia.

Ethics Statement: The study protocol was approved by the Curtin University Human Research Ethics Committee (approval number: HR139/2014).

References

1. Kanjikar AP. On anti-diabetic potential of phyto-nanoparticles comparison with hormonal therapy and medicinal plants. Int J Pharm Phytopharmacol Res. 2019;9(1):103-11.
2. Alzahrani S, Alosaimi ME, Oways FF, Hamdan AO, Suqati AT, Alhazmi FS, et al. Knowledge of cardiovascular diseases and their risk factors among the public in Saudi Arabia. Arch Pharm Pract. 2019;10(3):47-51.
3. WHO. Cardiovascular diseases (CVD) in Viet Nam. 2021 [cited 2021 25 May]; Available from: https://www.who.int/vietnam/health-topics/cardiovascular-diseases.
4. Ngoc NB, Lin ZL, Ahmed W. Diabetes: what challenges lie ahead for Vietnam? Ann Glob Health. 2020;86(1):1.
5. Nguyen CT, Pham NM, Lee AH, Binns CW. Prevalence of and risk factors for type 2 diabetes mellitus in Vietnam: a systematic review. Asia Pac J Public Health. 2015;27(6):588-600.
6. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009;120(16):1640-5.
7. Dragsbæk K, Neergaard JS, Laursen JM, Hansen HB, Christiansen C, Beck-Nielsen H, et al. Metabolic syndrome and subsequent risk of type 2 diabetes and cardiovascular disease in elderly women: challenging the current definition. Medicine. 2016;95(36):e4806.
8. Saklayen MG. The global epidemic of the metabolic syndrome. Curr Hypertens Rep. 2018;20(2):12.
9. Binh TQ, Phuong PT, Nhung BT. Metabolic syndrome among a middle-aged population in the Red River Delta region of Vietnam. BMC Endocr Disord. 2014;14(1):1-9.
10. Zhang X, Devlin HM, Smith B, Imperatore G, Thomas W, Lobelo F, et al. Effect of lifestyle interventions on cardiovascular risk factors among adults without impaired glucose tolerance or diabetes: a systematic review and meta-analysis. PloS one. 2017;12(5):e0176436.
11. Rintamäki R, Rautio N, Peltonen M, Jokelainen J, Keinänen-Kiukaanniemi S, Oksa H, et al. Long-term outcomes of lifestyle intervention to prevent type 2 diabetes in people at high risk in primary health care. Prim Care Diabetes. 2021;15(3):444-50.
12. Jancey J, Lee AH, James AP, Howat P, Hills AP, Anderson AS, et al. Long-term sustainability of a physical activity and nutrition intervention for rural

adults with or at risk of metabolic syndrome. Aust N Z J Public Health. 2020;44(5):421-6.

13. Lee AH, Jancey J, James AP, Howat P. Community-based physical activity and nutrition programme for adults with metabolic syndrome in Vietnam: study protocol for a cluster-randomised controlled trial. BMJ Open. 2016;6(6):e011532.
14. National Cholesterol Education Program (US). Expert Panel on Detection, Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation. 2002;106(25):3143-421.
15. Shamizadeh T, Jahangiry L, Sarbakhsh P, Ponnet K. Social cognitive theory-based intervention to promote physical activity among prediabetic rural people: a cluster randomized controlled trial. Trials. 2019;20(1):1-0.
16. Tran VD, Do VV, Pham NM, Nguyen CT, Xuong NT, Jancey J, et al. Validity of the international physical activity questionnaire–short form for application in Asian countries: a study in Vietnam. Eval Health Prof. 2020;43(2):105-9.
17. World Health Organization (WHO). WHO STEPS Surveillance Manual. Geneva: World Health Organization; 2008.
18. Kathariya G, Aggarwal J, Garg P, Singh S, Manzoor S. Is evaluation of non-HDL-C better than calculated LDL-C in CAD patients? MMIMSR experiences. Indian Heart J. 2020;72(3):189-91.
19. Burke L, Lee AH, Jancey J, Xiang L, Kerr DA, Howat PA, et al. Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomized controlled trial. Int J Behav Nutr Phys Act. 2013;10(1):1-8.
20. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior. Curr Cardiovasc Risk Rep. 2008;2(4):292-8.
21. Muellmann S, Forberger S, Möllers T, Bröring E, Zeeb H, Pischke CR. Effectiveness of eHealth interventions for the promotion of physical activity in older adults: a systematic review protocol. Syst Rev. 2016;5:47.
22. Ribeiro EH, Garcia LM, Salvador EP, Costa EF, Andrade DR, Latorre MD, et al. Assessment of the effectiveness of physical activity interventions in the Brazilian Unified Health System. Rev Saude Publica. 2017;51:56.
23. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO Press; 2010.
24. Valenti G, Bonomi AG, Westerterp KR. Walking as a contributor to physical activity in healthy older adults: 2 week longitudinal study using accelerometry and the doubly labeled water method. JMIR Mhealth Uhealth. 2016;4(2):e5445.
25. National Institute of Nutrition of Vietnam. Food-based dietary guildelines - Vietnam. 2021 [cited 2021 03 May]; Available from: http://viendinhduong.vn/news/en/714/123/food-based-dietary-guidelines---viet-nam.aspx.
26. Julibert A, del Mar Bibiloni M, Tur JA. Dietary fat intake and metabolic syndrome in adults: a systematic review. Nutr Metab Cardiovasc Dis. 2019;29(9):887-905.
27. Sarebanhassanabadi M, Mirhosseini SJ, Mirzaei M, Namayandeh SM, Soltani MH, Pakseresht M, et al. Effect of dietary habits on the risk of metabolic syndrome: Yazd healthy heart project. Public Health Nutr. 2018;21(6):1139-46.
28. Wagner MG, Rhee Y, Honrath K, Salafia EH, Terbizan D. Nutrition education effective in increasing fruit and vegetable consumption among overweight and obese adults. Appetite. 2016;100:94-101.
29. de Vreede PL, van Meeteren NL, Samson MM, Wittink HM, Duursma SA, Verhaar HJ. The effect of functional tasks exercise and resistance exercise on health-related quality of life and physical activity. Gerontology. 2007;53(1):12-20.
30. Oldroyd JC, Unwin NC, White M, Mathers JC, Alberti KG. Randomised controlled trial evaluating lifestyle interventions in people with impaired glucose tolerance. Diabetes Res Clin Pract. 2006;72(2):117-27.
31. Jesmin S, Sohael F, Rahman MA, Maqbool A, Islam MM, Shima T, et al. Short-term lifestyle intervention program through daily walking improves circulatory low HDL level in rural Bangladeshi women. J Phys Fit Sports Med. 2020;9(4):181-90.

32. Campbell MD, Sathish T, Zimmet PZ, Thankappan KR, Oldenburg B, Owens DR, et al. Benefit of lifestyle-based T2DM prevention is influenced by prediabetes phenotype. Nat Rev Endocrinol. 2020;16(7):395-400.
33. Guess ND. Dietary interventions for the prevention of type 2 diabetes in high-risk groups: current state of evidence and future research needs. Nutrients. 2018;10(9):1245.
34. Bajer B, Rádiková Ž, Havranová A, Žitňanová I, Vlček M, Imrich R, et al. Effect of 8-weeks intensive lifestyle intervention on LDL and HDL subfractions. Obes Res Clin Pract. 2019;13(6):586-93.
35. Lin WY. A large-scale observational study linking various kinds of physical exercise to lipoprotein-lipid profile. J Int Soc Sports Nutr. 2021;18(1):35.
36. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC Public Health. 2009;9(1):1-20.
37. Afshin A, Forouzanfar MH, Reitsma, MB, Sur P, Estep K, Lee A, et al. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2017;377(1):3-27.
38. Webb VL, Wadden TA. Intensive lifestyle intervention for obesity: principles, practices, and results. Gastroenterology. 2017;152(7):1752-64.
39. Ngigi S, Busolo DN. Behaviour change communication in health promotion: appropriate practices and promising approaches. Int J Innov Res Dev. 2018;7(9):84-93.
40. Saboya PP, Bodanese LC, Zimmermann PR, Gustavo AD, Macagnan FE, Feoli AP, et al. Lifestyle intervention on metabolic syndrome and its impact on quality of life: a randomized controlled trial. Arq Bras Cardiol. 2016;108(1):60-9.
41. Arena R, Guazzi M, Lianov L, Whitsel L, Berra K, Lavie CJ, et al. Healthy lifestyle interventions to combat noncommunicable disease—a novel nonhierarchical connectivity model for key stakeholders: a policy statement from the American Heart Association, European Society of Cardiology, European Association for Cardiovascular Prevention and Rehabilitation, and American College of Preventive Medicine. Eur Heart J. 2015;36(31):2097-109.
42. Nguyen TT, Trevisan M. Vietnam a country in transition: health challenges. BMJ Nutr Prev Health. 2020;3(1):60.