Regular swimming session improves metabolic syndrome risk factors in women and men from Palestine: Quasi-experimental study

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Abstract

Background: Swimming and other aquatic fitness are important aerobic exercises that have been proposed as an effective nonpharmacological approach in the management of type 2 diabetes (T2DM), hyperlipidemia, and hypertension (HTN). The current study aimed to assess the effect of long-term swimming sessions on glycemic and lipidemic parameters, body composition, and hemodynamic responses for patients with metabolic risk factors.

Methods: Forty participants from both genders with T2DM and HTN (aged 52.4±5.5 yrs) agreed to take part in this quasi-experimental study and were divided into two groups. The first group included the participants who performed long-term swimming sessions and the second group served as the reference. The first group exercised for 2 h, 3 times/week in 29-33 ∘C swimming pool for 16 weeks. While the reference group did not participate in any kind of exercise and advised to keep on with their normal lifestyle. All the obtained metabolic syndrome risk factors data were analyzed using a paired *t*-test which was applied to separately determine the differences between pre- and post-tests for both genders and groups, and the percentage of change (Δ %) was computed. Independent *t*-test was applied to determine the differences in the post-tests (Exp. vs Ref) in men patients as well as for women separately.

Results: The results showed that there were statistically significant differences at $p \leq 0.05$ between pre- and post- exercise concerning Total Cholesterol (TC), High-Density Lipoproteins (HDL), Low-Density Lipoproteins (LDL), Triglycerides (TG), glycemic parameters, systolic and diastolic blood pressures, body mass index (BMI) and fat mass percent in favor of posttests in the experimental group for both genders. Whereas, no significant differences were found at $p \leq 0.05$ between pre- and post-tests for all studied variables in the reference group for both genders. Significant differences were found at $p \leq 0.05$ on the post-tests in favor of the experimental for both genders.

Conclusion: Findings of the current study suggested that the regular 16 weeks of the conducted swimming sessions could be considered as nonpharmacological approaches in the management of T2DM and HTN.

Background

Diabetes mellitus (DM) is a chronic metabolic disorder that is characterized by long-lasting hyperglycemia, which mainly occurs due to disturbances in insulin action, insulin secretion, or both (1). Long-lasting hyperglycemia has been associated with harmful damages, dysfunction, and failure of different body organs like blood vessels, heart, nerves, kidneys, retina of eyes, among others (2). According to the World Health Organization (WHO), the number of diabetic patients has been quadruplicated in the last four decades (3). Unfortunately, the prevalence of DM among the Palestinian population (East Jerusalem, Gaza, and West Bank) is about two to three times higher than in the rest of the world (4).

Hypertension (HTN) is another chronic metabolic disorder, which is characterized by the elevation of systolic and/or diastolic blood pressure, that can be associated with lethal complications such as heart failure and stroke (5). The WHO estimated that about 1.13 billion of the world population reported HTN. Moreover, two-thirds of people living in middle- and low-income countries have HTN as reported in the same study. Despite the severity of HTN, which can cause premature death worldwide, about 20% of patients with this disease are keeping it under control (6).

Another metabolic disease that is threatening humanity is hyperlipidemia, in which lipids, fibrous plaques, calcium, and cholesterol can accumulate on the walls of the blood vessels. Lipid deposits can build up and result in narrowing and hardening of the arteries. Consequently, tissues and organs would not receive enough blood to function properly. If arteries that supply the heart with blood are affected, this accumulation can narrow the blood vessel and reduce blood flow and oxygen to the muscle of the heart, which can cause angina pectoris (7). While the complete blockage of the artery can cause myocardial infarction which commonly known as a heart attack. Besides, if the fatty matters build up in the brain arteries that can lead to stroke if a blood clot blocks blood flow in the cervical circulation (8).

Due to the harmful complications of DM on blood vessels, HTN may occur in many diabetic patients, especially those suffering from uncontrolled blood glucose levels (9). Therefore, it has been demonstrated that there are substantial overlaps between DM and HTN in the disease’s mechanisms and etiology (10). Actually, HTN is documented in 2 out of 3 patients with T2DM, and its development occurs simultaneously with the development of hyperglycemia. This association underlies many pathophysiological mechanisms including the excitatory effect of hyperglycemia on the renin-angiotensin-aldosterone system, the stimulatory effect of hyperinsulinemia on the sympathetic nervous system, smooth muscle growth, sodium, and fluid retention, and insulin resistance in the nitric oxide pathway. In patients with T2DM and HTN usually increases the risk of many cardiovascular diseases. According to recent guidelines, blood pressure of lower than 140/85 mm Hg is a rational therapeutic goal in patients with T2DM, and patients with controlled diabetes have the same cardiovascular risk to patients with hypertension but without diabetes (11). In fact, T2DM and HTN tend to occur in the same patients who may have also other disorders, such as high body mass index, high-fat percentages, high plasma concentrations of insulin, and triglycerides (TG) and low serum concentrations of high-density lipoproteins (HDL) and others (12).

Accordingly, these chronic diseases must be carefully treated and the related medical conditions require appropriate management because pathological and mental health problems may increase the risk of developing many major public health diseases which may contribute to premature death. Lifestyle modification along with glucose- and blood pressure-lowering medications are provided to keep glucose and atrial blood pressure levels as close to normal (13).

One of the important points for improving lifestyle is the continuous practice of physical exercises that significantly improve blood circulation, metabolic processes, and other physiological functions (14). Regular physical exercises also associated with a decrease in mortality and the risk of developing various types of cardiovascular diseases. Moreover, various types of physical exercises have been found to slow aging, reduce physiological dysfunctions, and decrease the complications of DM by improving endurance, metabolism, muscle strength, circulation, and decreasing body fat mass (15, 16). In addition, physically active individuals have higher insulin sensitivity, lower blood pressure, and a more favorable plasma lipoprotein profile (17).

Moreover, the regular long term of different types of aerobic exercises has been shown to benefit many physiological and psychological disorders and diseases. Thus, can help in the treatment of obesity, overweight, reducing the risks of metabolic disorders, normalizing blood glucose and lipids profiles, helping with cancer-related side effects, and many other positive effects. While the endurance exercise on land has many adverse effects including gastrointestinal tract discomfort, burnout, eating disorders, and the risk of injury. While water exercises have fewer side effects such as dry skin, muscle spasm, and muscle pain (18-20).

Swimming is one of the safest and gratifying methods of aerobic physical exercise (21). In the regular form of swimming, people can burn a lot of calories, improve their skeletomuscular and other physiological functions with minimal negative effects on joints, heart, and other organs, especially in elderly people when swimming carried out at a moderate or low speed (22). Besides, moderate-intensity types of aerobic exercises, are promising lifestyle interventions to improve the cognitive function of patients with mild cognitive impairment who have a heightened risk of developing dementia (23). Moreover, regular aerobic exercises have a positive effect on improving symptoms of attention deficit hyperactivity disorder, anxiety, depression, and other mental health disorders (24, 25).

Many of the scientific data described the effects of swimming and other types of aerobic physical fitness on diabetes, cardiovascular, and respiratory systems responses, also their effects on the serum lipid profile, body fat percentage, muscle mass in subjects with T2DM (26-30).

To the best of our knowledge, investigations that describe the effects of long-term swimming sessions among patients suffering from T2DM and HTN as comorbid in Palestine are missing from the literature. Therefore, more information to evaluate the effects of regular long-term swimming procedures on glycemic and blood pressure parameters in T2DM and HTN patients is required.

Therefore, this study aims to investigate the outcomes of 16 weeks of swimming sessions on blood pressure levels, glycemic responses, lipid profiles, body mass index, and body fat percent in patients with T2DM and HTN compared with a reference group suffering from these disorders without swimming sessions.

Methods

Participants

Forty patients (twenty women and twenty men with age 52.35±5.5 yrs) who were diagnosed with T2DM and HTN from the employees of An-Najah National University were included in the current study. The study was conducted on a purposive sample consisting of two groups (experimental and reference(of 20 patients each. Both groups included patients of both genders evenly split between males and females. The men (n = 20) were divided equally into two groups, experimental and reference, as well as for women. The first group included the participants who performed long-term swimming sessions and the second group served as the reference. The reference group did not participate in any kind of exercises and advised to keep on with their normal lifestyle.

The experimental group underwent swimming as a recreational and sports program. The intensity of the swimming was moderate and below average and did not require high efforts such as walking in the water like free swimming for short distances also without looking at speed like standing in the water like swimming using rafts and fins. While in the reference group, they did not participate in any sports program throughout conducting this study and all the participants in the current study are persons who are athletically inactive and have normal skill level in swimming.

The study participants were instructed not to change their medications, diet, water intake, behavior, and sleep-rest patterns. Patients were also asked not to perform any other type of physical exercise during this experiment. T2DM and HTN medications had to be stable during the swimming sessions for all the participants.

Patients with a history of chronic pulmonary, stroke, and peripheral artery diseases also participants suffering from nephropathy, infections, peripheral ulcers, or problems with glycemic control were excluded from the current study. The participants were assigned for a 120 min swimming session, three times weekly for 16 weeks in the pool temperature of 29 to 33°C. Clarification of the benefits, possible risks and adverse effects of long-term swimming sessions of participating in this study were established before the participants signing the informed consent forms. The study complied with the Declaration of Helsinki. The Ethics committee of An-Najah National University approved the current study protocol under the archive number (3.7.2019). The biomedical tests were taken before starting the current study and repeated after sixteen weeks. The participants could stop the swimming sessions at any time they experienced the uncomfortable feeling.

Procedures

The instructions of swimming sessions were given to the participants during 16 weeks of this study by qualified physical education researchers. Glucose levels were measured using a glucometer (OneTouch Ultra®, USA), while blood pressure was measured utilizing a mercury sphygmomanometer (Diamond BPMR120 Deluxe Conventional Mercurial Type BP Instrument, India). While the body mass index and fat mass percent were calculated by the researchers before and after finishing the current study. The serum glucose and blood pressure measurements were taken before and after 10 min of each swimming session. All participants provided the researchers with their biomedical laboratory analysis data, which were analyzed by a certified clinical laboratory for TG, TC, LDL, and HDL before starting and after finishing the current experiment.

Statistical Analyses

Means and standard deviations were utilized as descriptive statistics. A paired *t*-test was applied to determine separately the differences between pre- and post- tests for both genders and groups, and the percentage of change (Δ %) was computed. Independent *t*-test was applied to determine the differences in the post-tests (Exp. vs Ref) in men patients as well as for women separately. No abnormal distributions were noticed in pretests according to Shapiro- Wilk results for both genders and groups. In the men group as well as for women group, the experimental and reference groups were equivalent in pre-tests according to independent *t*-test results and no significant differences were found. The data were analyzed by Statistical Package for the Social Sciences (SPSS) version 20 (IBM SPSS® software, USA) program and the level of significance was fixed at $p \leq 0.05$.

Results

The results of paired t-test shown in Table 1. revealed that there were statistically significant differences at $p \leq 0.05$ between pre- and post-tests of (TC, HDL, LDL, TG, glycemic parameters, systolic blood pressure, diastolic blood pressure, BMI, and fat) in favor of posttests in the experimental group for both genders. Whereas, no significant differences were found at $p \leq 0.05$ between pre- and post-tests for all studied variables in the reference group for both genders as illustrated in Table 2.

Table 1. The effect of participation in swimming sessions on chronic diseases: hyperlipidemia, diabetes and hypertension, BMI, and fat in the experimental group (men & women).

Groups		Men (n=10)			Women (n=10)		
iables	(Units)	Pre M±SD	Post M±SD	Δ %	Pre M±SD	Post M±SD	Δ %
	(mg/dl)	227.60±18.88	177.30± 7.04*	-22.1	224.30±22.14	169.40±12.59*	-24.47
L	(mg/dl)	31.80±2.89	38.60±2.50*	21.38	34.90±2.51	42.50±0.84*	21.77
L	(mg/dl)	160.98±19.92	111.90±13.95*	-30.48	154±23.13	99.52±13.09*	-35.37
	(mg/dl)	174.10±13.42	134±11.29*	-23.03	177±13.24	136.90±11.02*	-22.65
I	(kg/m^2)	29.20±1.71	26.82±1.64*	-8.15	28.90±1.71	25.56±1.89*	-11.55
	(%)	24.62±0.71	20.19±0.84*	-17.99	29.17±1.85	23.63±2.16*	-18.99
cose els	(mg/dl)	237.90±26.53	148.77±20.29*	-37.46	177.20±13.87	132.90±14.69*	-25
P	(mmHg)	151±10.61	125±8.36*	-17.21	164.90±10.64	143.20±11.73*	-13.15
P	(mmHg)	99.60±4.81	87.60±5.64*	-12.04	97.70±2.66	87.50±4.32*	-9.92

Note values are: M±SD= Mean± Standard Deviation; Δ % = percentage of change; TC= Total Cholesterol; HDL= High Density of Lipoprotein; LDL= Low Density of Lipoprotein; TG= Triglycerides; SBP=Systolic Blood Pressure; DBP= Diastolic Blood Pressure; *Significant effects (pre *vs*. post) differences at $p \le 0.05$.

Table 2. The differences between pre- and post-tests of hyperlipidemia, diabetes, hypertension, BMI, and fat in the reference group (men & women).

	Men (n=10)			Women(n=10)		
(Units)	Pre M±SD	Post M±SD	Δ %	Pre M±SD	Post M±SD	Δ %
(mg/dl)	223.70±21.92	227.80±24.53	1.83	239±15.20	237.30±15.88	-0.71
(mg/dl)	32.80±2.39	33.10±2.37	0.91	35±3.29	35.10±3.10	0.28
(mg/dl)	155.84±22.03	159.60±25.02	2.41	167.76±16.01	166±16.92	-1.04
(mg/dl)	175.30±6.48	175.50±7.10	0.11	181.20±8.50	181.50±10.33	0.16
(kg/m^2)	28.85±1.83	28.83±1.89	-	28.84±1.42	28.78±1.68	-0.2
(%)	24.29±0.84	24.22±0.90	-	28.37±1.27	28.10±1.26	-0.95
(mg/dl)	210.50±32.68	191.20±29.46	9.02	187.90±14.18	185.50±10.84	-1.27
(mmHg)	157.20±9.82	156.30±10.03	-0.57	157.80±13.21	151.30±3.86	-4.11
(mmHg)	102.40±5.42	100.20±4.34	-2.14	94.30±4.85	92.80±4.36	-1.59

Note values are: M±SD= Mean± Standard Deviation; Δ % = percentage of change; TC= Total Cholesterol; HDL= High Density of Lipoprotein; LDL= Low Density of Lipoprotein; TG= Triglycerides; SBP=Systolic Blood Pressure; DBP= Diastolic Blood Pressure; *Significant effects (pre vs. post) differences at $p \leq 0.05$.

Comparing with post-tests (Exp. *vs* Ref.) groups in men patients, the results of the independent *t*-test are shown in Table 3. Which indicated that there were statistically significant differences at $p \leq 0.05$ on all post-tests of (TC, HDL, LDL, TG, glycemic parameters, systolic blood pressure, diastolic blood pressure, BMI and fat) in favor of experimental group as illustrated in (Fig. 1). Concerning the comparison with the post-tests (Exp. *vs* Ref.) groups in women patients, the results of the independent *t*-test are shown in Table 4, which indicated that there were statistically significant differences at $p \leq 0.05$ in the variables of (TC, HDL, LDL, TG, glycemic parameters, diastolic blood pressure, diastolic blood pressure, BMI and fat) in favor of experimental group as illustrated in (Fig. 2). No significant differences were found at $p \leq 0.05$ for the systolic blood pressure variable.

Table 3. Independent *t*-test results for the differences in post-tests between experimental and reference groups in men patients.

Groups		Experimental (n= 10)	Reference (n=10)	*T*- value	*P* ≤
Variables	**Units**	**M ± SD**	**M ± SD**		
TC	(mg/dl)	177.30±17.04	227.80±24.53	- 5.649	0.001*
HDL	(mg/dl)	38.60±2.50	33.10±2.37	5.037	0.001*
LDL	(mg/dl)	111.90±13.95	159.60±25.02	- 5.265	0.001*
TG	(mg/dl)	134±11.29	175.50±7.10	- 9.935	0.001*
BMI	(kg/m^2)	26.82±1.64	28.83±1.89	- 2.532	0.021*
Fat	(%)	20.19±0.84	24.22±0.90	- 10.327	0.001*
Glucose levels	(mg/dl)	148.77±20.29	191.20±29.46	- 3.756	0.001*
SBP	(mmHg)	125±8.36	156.30±10.03	- 7.578	0.001*
DBP	(mmHg)	87.60±5.64	100.20±4.34	- 5.598	0.001*

Note values are: M±SD= Mean ± Standard Deviation; TC= Total Cholesterol; HDL= High Density of Lipoprotein; LDL= Low Density of Lipoprotein; TG= Triglycerides; SBP=Systolic Blood Pressure; DBP= Diastolic Blood Pressure; *Significant (Exp vs Ref) differences at $p \leq 0.05$.

Table 4. Independent *t*-test results for the differences in post-tests between experimental and reference groups in women patients.

Groups		Experimental (n= 10)	Reference (n=10)	*T*- value	*P* ≤
Variables	**Units**	**M±SD**	**M±SD**		
TC	(mg/dl)	169.40±12.59	237.30±15.88	- 10.589	0.001*
HDL	(mg/dl)	42.50±0.84	35.10±3.10	7.264	0.001*
LDL	(mg/dl)	99.52±13.09	166±16.92	- 9.882	0.001*
TG	(mg/dl)	136.90±11.02	181.50±10.33	- 9.333	0.001*
BMI	(kg/m^2)	25.56±1.89	28.78±1.68	- 4.014	0.001*
Fat	(%)	23.63±2.16	28.10±1.26	- 5.646	0.001*
Glucose levels	(mg/dl)	132.90±14.69	185.50±10.84	- 9.108	0.001*
SBP	(mmHg)	143.20±11.73	151.30±3.86	-2.073	0.053
DBP	(mmHg)	87.50±4.32	92.80±4.36	- 2.726	0.014*

Note values are: M±SD= Mean ± Standard Deviation; TC= Total Cholesterol; HDL= High Density of Lipoprotein; LDL= Low Density of Lipoprotein; TG= Triglycerides; SBP=Systolic Blood Pressure; DBP= Diastolic Blood Pressure; *Significant (Exp vs Ref) differences at $p \leq 0.05$.

Discussion

The outcomes of the current study showed that long-term (16 weeks), regular (2 hrs, three times per week) of participation in swimming sessions effect positively on chronic metabolic disorders including T2DM, hyperlipidemia, and HTN in men and women aged 52.4±5.5 yrs. The results revealed that there were statistically significant differences at $p \leq 0.05$ between pre- and post- tests of (TC, HDL, LDL, TG, glycemic parameters, systolic blood pressure, diastolic blood pressure, BMI and fat percent) in the experimental group for both genders. As the Δ % for men were (-22.10%, 21.38%, -30.48%, -23.03%,

-37.46%, -17.21%, -12.04%, -8.15%, -17.99%), respectively. In addition, the Δ % for women were (-24.47%, 21.77%, -35.37%, -22.65%, -25%, -13.15%, -9.92%, -11.55%, -18.99%), respectively.

Whereas, no significant differences were found at $p \leq 0.05$ between pre- and post- tests for all studied variables in the reference group for both genders. Remarkably, these results emphasize that practicing regularly swimming patients have significant and positive effects on hyperlipidemia, T2DM, and HTN in comparison with who never participates in swimming sessions.

Vanhees *et al.* stated that engaging in regular physical exercise and exercise interventions including swimming, cycling, jogging, and walking, which, when carried out at moderate intensity are essential components for reducing the severity of cardiovascular risk factors, such as metabolic risk factors, systemic inflammation, high blood pressure, abdominal fat, and obesity (31). However, an investigation established by Prugger *et al*. showed that the lower frequency of regular exercise and decreased likelihood of exercise intention were observed in coronary heart disease patients with severe depression, while the symptoms of anxiety did not affect the regular exercise intention (32).

In a study conducted by Asa *et al*., 20 patients with both congestive heart failure and T2DM (age 67.4±7.1) were allocated randomly to either aquatic exercise or a control group. The patients exercised for 45 min 3 times per week in 33–34∘C swimming pool temperature for 8 weeks. Hba1c decreased significantly ($p \leq 0.01$) during training, while fasting glucose, insulin, c-peptide, and lipids were unchanged (26). In our opinion, Asa et al. study did not reflect the effect of swimming sessions on metabolic risk factors as in our study, as well as the mean age of the current study is different, also our conducted study was carried out for a 120 min each swimming session, 3 times weekly for 16 weeks. These factors positively affect the lipid and sugar metabolic markers' in our study in which decreased TC, LDL, TG, glucose levels significantly in swimming session men and women groups and increased the HDL levels. This finding is in agreement with the results of a study conducted by Kasprzak *et al.* on 32 obese women aged 41-72 yrs for three months and showed that all mean anthropometric variables were significantly lower ($p \leq 0.01$). The blood lipid profile, total cholesterol, and LDL-cholesterol were significantly lower ($p \leq 0.01$). Furthermore, the levels of fasting TG, glucose, and insulin were decreased significantly ($p \leq 0.05$) after finishing this study (28).

Moreover, in the current study, body mass index and body fat percent in the swimming session men group decreased significantly with Δ % of 8.15 and 17.99, respectively. While in women group decreased with the Δ % of 11.55 and 18.99, respectively. However, there were no significant changes in any of these variables in the current study reference group both genders.

However, the study by Gappmaier *et al*. on 38 middle-aged obese women (25-47% body fat) participated in a 13 weeks program aimed to compare the effects of aerobic water exercise *vs* walking on land and their results revealed also a significant reduction in body fat percent (3.7%), body weight (5.9 kg), skinfold and girth measurements, occurred in all groups. There were no significant differences between all the investigated groups as long as similar intensity, duration, and frequency are used (27).

The current study results revealed that the systolic blood pressure of the men patients in the experimental group fell significantly ($p \leq 0.05$) from 151±10.61 to 125±8.36 mmHg, while the diastolic blood pressure changed significantly ($p \leq 0.05$) from 99.60±4.81 to 87.60± 5.64 mmHg. There was a little change in any of these variables in the reference men group (Δ %=0.57) and (Δ %=2.14), respectively. Moreover, in the women experimental group, the results showed that systolic blood pressure fell significantly ($p \leq 0.05$) from 164.90±10.64 to 143.20± 11.73 mmHg (Δ %=13.15), while the diastolic blood pressure changes significantly ($p \leq 0.05$) from 97.70±2.66 to 87.50±4.32 mmHg (Δ %=9.92). There was a little change in any of the systolic and diastolic blood pressure variables in the reference women group (Δ %=4.11) and (Δ %=1.59), respectively.

Hirofumi *et al*. conducted a study on eighteen patients with HTN from both genders [aged 48±2 yrs) for 10 weeks using a swimming training program and the outcomes from this study showed that the systolic blood pressure of patients fell significantly ($p \leq 0.05$) from 150±5 to 144±4 mmHg, while the diastolic blood pressure did not change significantly. There were no significant changes in any of these variables in the control group (33).

Predominantly, recreational swimming exercise is based on aerobic metabolism because both lipids and carbohydrates are involved as the major sources of energy. For that, aerobic exercises have a positive effect on the metabolism of these substances (28). Besides, several published studies demonstrated the positive relationship between aerobic aquatic exercise and good physiological and psychological conditions. These studies showed that regular physical exercises can reduce musculoskeletal disorders, many chronic diseases, anxiety, insomnia, depression, stress, and many others (18, 34-36).

In the post-tests (post-interventions), the findings revealed that the experimental groups for both genders were better than reference groups, and significant differences were found at ($p \leq 0.05$(. These findings indicated the importance of regularly following physical exercises and practicing swimming or any physical activity to positively prevent or treat hyperlipidemia, T2DM, and HTN.

In a previous study conducted on 159 overweight men and women with mild-to-moderate dyslipidemia (aged 40- 65 yrs), Kraus *et al*. demonstrated that there was a beneficial effect of exercise on the variation of lipoprotein and lipid variables and the experimental groups had remarkable and positive improvements in lipids and lipoproteins in comparison with the control group (37).

In another study, Nualnim *et al*. sought to determine the effect of swimming training on decreasing blood pressure and improving vascular function in men and women (60±2) yrs old. The subjects were assigned to swimming exercises (experimental group) and relaxation exercises (attention or control group) for 12 weeks of a swimming training program. The results revealed a significant decrease in systolic blood pressure (SBP) in the swimming group. Swimming produced a 21% increase in carotid artery compliance. No significant changes were observed in the control group (38).

In the current study, the concentration of glucose in blood decreased significantly ($p < 0.05$) in the experimental groups and better than the control groups. These results emphasize that regular swimming contributes to increase the uptake of glucose into skeletal muscle and could activate some hormones like adiponectin. Punthakee *et al*. confirmed that the higher circulating of adiponectin is beneficial during exercise and favors the oxidation of fat and glucose uptake into muscles. In addition, the weight loss, the decrease in the percentage of fat, and blood pressure could be key elements of decreasing T2DM (39). Colberge *et al*. mentioned that exercise or physical activity plays a central role in the prevention and control of insulin resistance, T2DM, and diabetes-related health complications. Aerobic and resistance training improves the action of insulin and contributes to managing BP, lipids, fat, and body weight. Interestingly, T2DM patients must regularly follow different trainings and exercises to have optimal health benefits (40).

However, to the best of the author's knowledge, no previous data documented the effect of regular long-term swimming program on patients with chronic diseases like T2DM and HTN from the West Bank/Palestine.

Similar to many other aerobic exercise studies on patients, our study was performed in a limited number of participants. A marked difficulty was to recruit patients that were free from other complicating disorders and disabling conditions like the patients who have a history of chronic pulmonary diseases, stroke, peripheral artery diseases, and nephropathy. Moreover, the patients who have severe infections, peripheral ulcers, or have problems with glycemic control, which are more common in patients with the combination of T2DM and HTN, were excluded from the current study. Furthermore, the current study was planned to be carried out for four, eight, and twelve months. Unfortunately, due to the COVID-19 pandemic, which started in our country in May 2020, we stopped the current study to protect the participants and researchers from this lethal infectious disease. A future study required to test all the metabolic risk factor markers, maximal oxygen uptake (VO2), and heart rate monitoring parameters for a longer period with a larger sample size

Conclusions

Sixteen weeks of regular swimming sessions resulted in significant reductions ($p \leq 0.05$) between pre- and post- tests in blood glucose levels, lipids profiles, BMI, body fat percentages, and the arterial blood pressure readings for individuals with T2DM and HTN. Whereas, no significant differences were found at $p \leq 0.05$ between pre- and post- tests for all studied variables in the reference group for both genders. Taken together, our data demonstrated that regular long-term swimming sessions ameliorated glucose, body mass index, body fat percentage, DBP and SBP, and lipid profiles in patients with T2DM and HTN. Therefore, this kind of exercise can be an effective and safe therapeutic tool for patients with T2DM, HTN, hyperlipidemia, obesity, and overweight. This is a clinically crucial finding since a continuous swimming program can be a highly recommended alternative to land-based exercises for individuals with HTN and T2DM. Besides, it can be useful for individuals with obesity, overweight, and hyperlipidemia.

Declarations

Ethics approval and consent to participate

The Ethics Committee of An-Najah National University approved the current study protocol under the archive number (3.7.2019) and consent to participate was taken before starting this study.

Consent for publication

All authors gave constant for publication to Dr. Nidal Jaradat

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 interests

The authors declare no conflict of interest.

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Authors' contributions

Conceptualization, N.J. and J.O.; methodology, N.J., J.O., M.Q. and AQ.; software, M.Q.; validation, N.J., J.O., M.Q. and AQ.; formal analysis, M.Q. and AQ.; investigation, N.J.; resources, J.O.; data curation, M.Q.; writing-original draft preparation, N.J.; writing—review and editing, N.J. and M.Q..; visualization, J.O.; supervision, N.J. and J.O.; project administration, N.J. and J.O.; funding acquisition, J.O. All authors have read and agreed to the published version of the manuscript.

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Figures

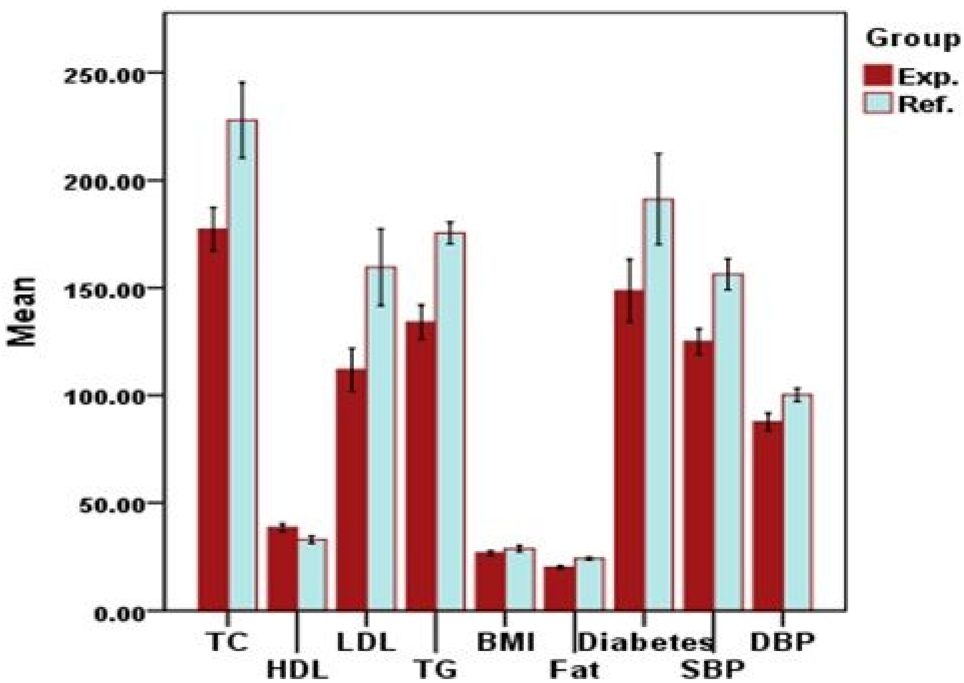

Figure 1

Means of post-tests according to group variable in men patients.

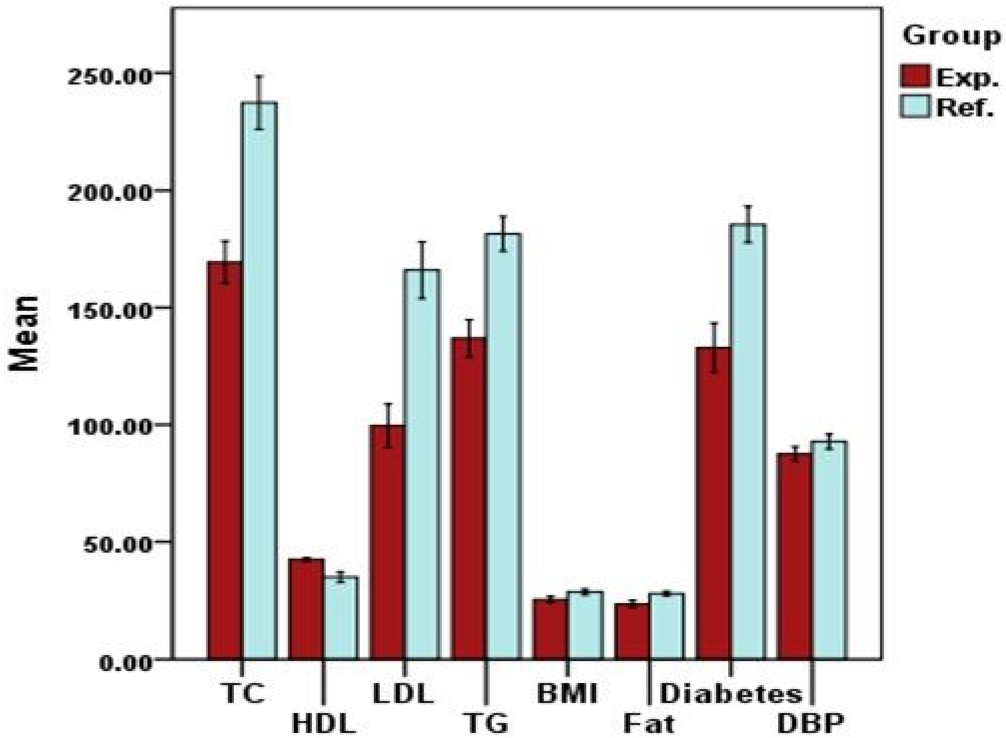

Figure 2

Means of post-tests according to group variable in women patients.