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Brief Report

Impact of Intensive Lifestyle Intervention on Remission of Metabolic Syndrome, Prediabetes, Diabetes, and Hypertension in Adults Living with Obesity

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Abstract: Background: Lifestyle intervention programs have long been shown to be effective in preventing cardiometabolic risk factors (CMRFs) such as metabolic syndrome (MS), impaired fasting glycaemia (IFG), type II diabetes (T2DM), and hypertension (HTA). However, their potential for remission of these CMRFs in overweight/obese adults is less clear. The importance of attaining remission has significantly increased as these CMRFs are more and more prevalent. Objectives: The aim of this study is to determine the impact of an intensive lifestyle intervention program on the remission of MS, IFG, T2DM, and HTA in overweight/obese adults. Methods: Forty participants living with overweight/obesity were enrolled in an 18-month multidisciplinary primary prevention body mass loss intervention program. MS, IFG, T2DM, and HTA statuses were assessed at baseline, 9 months, and the end of the program. Results: At baseline, 25 participants (64.1%) had MS, 7 (17.9%) had IFG, 4 (10.2%) were living with diabetes, and 28 (70.0%) had HTA. At 18 months, six (24%) of the participants living with MS, two (28.6%) of the participants with IFG, two (50%) of the participants with diabetes, and two (7.1%) of the participants with HTA met all criteria for remission. Conclusion: An intensive lifestyle intervention program consisting of monitored exercise training and lifestyle modification counselling has great potential for achieving remission of CMRFs in adults living with overweight/obesity.

Keywords: remission; metabolic syndrome; prediabetes; diabetes; hypertension; intensive lifestyle intervention

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1. Introduction

Metabolic syndrome (MS) is an accumulation of three or more cardiometabolic risk factors (CMRFs), with high prevalence of increased abdominal obesity, type 2 diabetes (T2DM), and hypertension (HTA), leading to an increased incidence of cardiovascular diseases and premature mortality [1,2]. Nowadays, it is estimated that around 10.5% of the world population is living with T2DM and 25% with MS, while the global incidence of HTA was estimated to be 33.1% in 2019 [3–5]. While lifestyle intervention programs have been shown to be efficient in preventing or delaying the onset of MS, T2DM, and HTA, the potential for reversal/remission of these CMRFs has received comparatively less attention in research [6–8]. In fact, the consensus regarding the concepts of remission, especially concerning impaired fasting glycaemia (IFG) and diabetes, is recent, and as of now, there is no universally accepted definition for the remission of HTA or MS, although several studies are beginning to focus on it [9]. Moreover, there is a lack of comprehensive reporting on the enduring impacts of intensive lifestyle interventions on the remission of CMRFs. Many

studies investigating remission of MS, IFG/T2DM, and HTA are focused on the short term, and few have looked at the longer-term remission rates. In a world where cardiometabolic diseases and associated risk factors are highly prevalent and projected to escalate, the significance of prevention and achieving remission has grown considerably [10]. The main objective of this work was to study the impact of an intensive lifestyle intervention program combining aerobic and resistance exercise training and Mediterranean diet counselling on the remission of CMRFs (MS, IFG/T2DM, and HTA) in adults living with obesity. A second objective was to document the changes in CMRFs of the metabolic syndrome and their prevalence during the intensive lifestyle intervention program.

2. Materials and Methods

2.1. Study Overview and Population

This is a retrospective analysis of the multidisciplinary primary prevention body mass loss interventional program (KILO-ACTIF) conducted at the Preventive medicine and physical activity Center (ÉPIC) of the Montreal Heart Institute. At the start of the program, all participants included were living with overweight or obesity with a BMI over 27 [11]. Patients receiving an initial pharmacological therapy for their cardiovascular risk factors (i.e., hypertension, diabetes) were not excluded. Patients with a history of coronary heart disease (documented prior myocardial infarction, prior coronary revascularization, or documented myocardial ischemia on myocardial scintigraphy) were excluded. All participants completed an 18-month intensive lifestyle program consisting of supervised exercise training sessions (high-intensity interval training and resistance training, two to three times a week) alongside Mediterranean diet nutritional and education counselling interventions [11]. Repeated measurements of body composition with bioimpedance analysis (Tanita, model 418 C, Tokyo, Japan), blood parameters (fasting glucose and lipid profile), cardiometabolic risk factors, and a maximal exercise treadmill test were taken at three time points: at baseline, after nine months of the intervention, and at the end of the study, at 18 months. According to the Institutional Review Board policy of the Montreal Heart Institute concerning retrospective studies, the present study was approved by the Medical Director of the Montreal Heart Institute.

2.2. Maximal Exercise Treadmill Test

During the individualized ramp protocol, speed and slope were progressively increased to obtain a linear load and an exercise duration of approximately 10 min [11]. The criteria for the maximal exercise test were: (1) a rate of perceived exertion $\geq$18, and/or (2) an achievement of $\geq$85% of age-predicted maximal HR, or (3) patient's exhaustion with cessation caused by fatigue and/or other clinical symptoms (dyspnea, abnormal BP responses) or ECG abnormalities that required exercise cessation. During maximal exercise testing, ECG and blood pressure were monitored continuously during exercise and 5 min recovery. Maximal exercise tolerance was defined as the highest level of metabolic equivalents (METs) achieved during the exercise test and was estimated with the American College of Sports Medicine equation [11].

2.3. Intensive Lifestyle Intervention Program

Supervised exercise training sessions (HIIT and resistance exercise) consisted of 2 to 3 weekly supervised 60 min sessions. Participants were encouraged to perform 1 or 2 additional unsupervised continuous moderate-intensity sessions per week, such as walking and/or cycling (45 min duration, Borg scale level 12–14) outside or inside the centre [11]. Exercise training program attendance was obtained from medical charts and from an electronic system which automatically records each subject's entry into our centre as previously published by our research group [11]. Weekly supervised exercise training sessions and physical activity performed in and/or out of the center were reported in a diary.

2.4. High-Intensity Interval Training

HIIT prescription was based upon the results of the baseline maximal treadmill exercise test and estimated maximal aerobic power (MAP) as previously described [11]. Maximal aerobic power was estimated from the maximal metabolic equivalent treadmill value according to the following method: (1) the treadmill metabolic equivalent value was converted to oxygen uptake expressed in mL/min; (2) the treadmill VO_2 peak in mL/min was then converted into a cycling VO_2 peak value in mL/min by subtracting 16%; and (3) the cycling VO_2 peak value was then converted to watts using a sex-specific conversion chart [11]. HIIT sessions were performed on an ergocycle (Precor®, model 846i, Woodinville, WA, USA), under the supervision of a kinesiologist and consisted of a 5 min warm-up at 50 watts, followed by two sets of 10 min of repeated bouts of 15 to 30 s at 80% of MAP interspersed with 15 to 30 s periods of passive recovery, and a 5 min cool down at 50 watts. The targeted Borg rating of perceived exertion (RPE) was set at 15 during the exercise sessions. A 4 min passive recovery separated the two 10 min periods. The total exercise time was 34 min for HIIT sessions [11].

2.5. Resistance Training Program

Resistance training was prescribed and performed under the supervision of a kinesiologist and consisted of 20 min of circuit weight training performed with free weights and elastic bands adapted to each patient's capacity. For each muscle group (biceps, triceps, chest, back, and leg muscles), patients performed 1 set of 15 to 20 repetitions, followed by a 30 s rest period, at a target RPE of 15 [11].

2.6. Nutritional Counselling Intervention

All participants underwent 5 one-on-one meetings with a dietician in our centre. The first visit was used to obtain data on eating habits and motivation and provide the principles of the Mediterranean diet. The macronutrient composition (% daily calories) of this diet was as follows: protein, 20%; carbohydrate, 45% (with a high intake of fibers); total fat, 35% (saturated fatty acids, 7%; mono-unsaturated, 25%; polyunsaturated, 2.5%, $\omega 6/\omega 3$ ratio = 2/1). The total daily energy consumption was adapted to each patient, without severe restriction. The aim was to meet, as far as possible, the Canadian guidelines (2000–2400 kcal/day). During subsequent visits in the 5th, 12th, 20th, and 36th weeks each year, the principles and adherence to the Mediterranean diet and the reported dietary intake were reviewed, and any questions were answered. Additionally, participants received two group teaching sessions aimed at providing guidance regarding CMRFs control, reading food labels, and tasting Mediterranean-style dishes [11].

2.7. Definitions of Metabolic Syndrome and Remission

Metabolic syndrome was defined according to the NCEP/ATP III criteria as having three or more of the following: waist circumference > 102 cm in men or >88 cm in women, triglycerides $\geq$ 1.7 mmol/L, high-density lipoprotein cholesterol (HDL-C) < 1.03 mmol/L in men or <1.30 mmol/L in women, blood pressure $\geq$ 130/85 mm Hg or fasting plasma glucose (FPG) $\geq$ 6.1 mmol/L [1]. Impaired fasting glycaemia and diabetes were defined according to the Canadian criteria of FPG. Impaired fasting glycaemia was defined as FPG between 6.1 and 6.9 mmol/L and diabetes as FPG > 7.0 mmol/L and/or taking antidiabetic medication [12]. HTA was defined as blood pressure $\geq$ 135/85 mmHg or taking antihypertensive medication. Finally, remission of MS, IFG, T2DM, or HTA was defined by the following three criteria: being under the defined threshold at 9 months (metabolic criterion), which is maintained at 18 months (duration criterion), in the absence of medication [13].

2.8. Statistical Analysis

Out of the 46 participants initially included, 40 were retained for the analysis. We excluded six individuals for whom pharmaceutical therapy information for blood pressure

and diabetes was unavailable. Data were thereafter analyzed with Stata software (Sata version 15.1, StataCorp LLC, College Station, TX, USA). All variables were presented as means ± standard deviation (SD) as appropriate for continuous ones and in numbers and percentages for categorical ones. A one-way ANOVA with repeated measures was used to compare cardiometabolic risk factors of the MS at 0, 9, and 18 months for continuous variables and chi-square was used for categorical variables.

3. Results

The main characteristics of the participants at baseline are described in Table 1. At baseline, the mean age of our participants was 55 ± 8 years and 25 (62.5%) were men. After 18 months, the mean body mass loss was −6.4 ± 6.6 kg. The changes of the CMRFs for the metabolic syndrome in obese adults before and after the intensive lifestyle program are given in Supplementary Materials Table S1. Characteristics of participants for each remission groups are given in Table S2. At the beginning of the program, 25 participants (64.1%) had MS, out of which 6 (24%) met all the remission criteria at 18 months (Figure 1A). At the start of the program, seven participants (17.9%) presented with IFG, while four (10.2%) were diagnosed with T2DM. At the end of the 18-month period, two participants (28.6%) achieved complete remission of IFG, and two participants (50%) accomplished the same for T2DM (Figure 1B). Finally, 28 participants of the study (70.0%) had HTA at baseline, with 2 (7.1%) meeting all three criteria of remission by the end of the study (Figure 1C). At the end of the program, all participants in remission were no longer taking hypoglycemic or hypotensive medications.

Table 1. Participants' characteristics at baseline. Values are expressed as mean ± SD or n, %.

	Total (n = 40)
Age (years)	55 ± 8.0
Male (n, %)	25 (62.5)
Cardiorespiratory fitness (METs)	8.08 ± 1.48
Anthropometrics	
Height (cm)	1.65 ± 0.08
Body mass (kg)	99.6 ± 17.7
BMI (kg/m^2)	36.4 ± 5.2
Waist circumference (cm)	113.6 ± 13.3
Fat mass percentage (%)	42.0 ± 6.8
Overweight (n, %)	5 (12.5)
Obesity (n, %)	35 (87.5)
Abdominal obesity (n, %)	31 (77.5)
Resting blood pressure	
Systolic blood pressure (mm Hg)	131.1 ± 15.2
Diastolic blood pressure (mm Hg)	80.7 ± 7.6
Blood sample	
Total cholesterol (mmol/L)	4.72 ± 1.18
HDL-C (mmol/L)	1.19 ± 0.25
LDL-C (mmol/L)	2.82 ±1.10
Triglycerides (mmol/L)	1.55 ± 0.60
Fasting plasma glucose (mmol/L)	5.64 ± 0.82
Metabolic syndrome and disease prevalence	
Metabolic syndrome (n, %)	25 (62.5)
Impaired fasting glycaemia (n, %)	7 (17.5)

Table 1. *Cont.*

	Total (n = 40)
Diabetes (n, %)	4 (10.0)
Hypertension (n, %)	24 (60.0)
Initial medication	
ACE inhibitors (n, %)	3 (7.5)
Angiotensin II receptor blockers (n, %)	10 (25.0)
Anticoagulants (n, %)	1 (2.5)
Antiplatelet agents (n, %)	1 (2.5)
Aspirin (n, %)	9 (22.5)
β-blockers (n, %)	7 (17.5)
Calcium channel blockers (n, %)	7 (17.5)
Diuretics (n, %)	3 (7.5)
Oral hypoglycemic agents (n, %)	1 (2.5)
Statin (n, %)	16 (40.0)

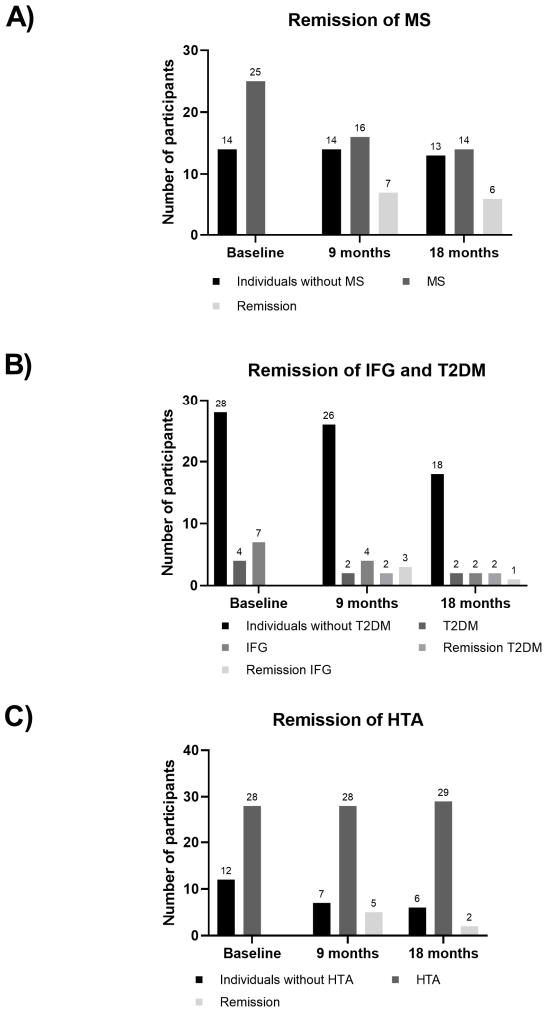

Figure 1. Number of participants in remission of (**A**) MS, (**B**) IFG and T2DM, and (**C**) HTA at baseline, 9 months, and 18 months. Black lines represent participants without CMRFs; dark grey lines represent participants with either MS, T2DM, or HTA; grey lines represent participants with prediabetes and pale grey lines represent participants in remission. MS: metabolic syndrome, IFG: impaired fasting glycaemia, T2DM: type II diabetes, HTA: hypertension.

4. Discussion

Results from this study involving adults living with overweight/obesity suggest that an intensive lifestyle intervention, comprising exercise training and Mediterranean diet nutritional counselling, holds promise for achieving remission of major CMRFs. This effect was evidenced by notable remission rates: 24% for MS, 28.6% for impaired fasting glycaemia, 50% for diabetes, and 7.1% for HTA. Available literature supports our findings and underscores the possibility of remission with lifestyle interventions, although there exists a vast disparity in the success rate of such interventions. The success rates for partial diabetes remission in the review by Kelly, J. et al. ranged from 13 to 100% and complete remission from 0 to 100% after 8 to 64 weeks [14]. Powell et al. found that lifestyle intervention resulted in 53.6% of remission for MS after 2.5 years [15]. Saboya et al. also found that the benefits of a lifestyle intervention on MS were not maintained 6 months after the end of the intervention program, highlighting the importance of maintaining the new lifestyle over time [16]. The literature on remission of HTA through lifestyle intervention is sparse but shows similar or even superior results to our data, indicating that an intensive program could yield interesting results [17–20]. Weight loss seems to be the factor driving remission of HTA and diabetes, which is consistent with its observed effects on the reduction of blood pressure.

One of the downsides of lifestyle intervention is maintaining the gains in the long term, and participants seem to relapse if the intervention is not maintained as previously shown [16]. Most of the studies in the literature only involve short interventions with no long-term follow-up. However, in our study, we had data available at 18 months of follow-up, allowing us to assess the maintenance of the gains. Our intensive lifestyle intervention showed great potential in maintaining the remission status from 9 months to 18 months with only one participant (14.3%) with MS who relapsed. Additionally, we found similar results in diabetes remission, with all participants maintaining their remission. On the other hand, two (66.7%) participants with impaired fasting glycaemia and three participants (60.0%) with HTA relapsed. Futures studies evaluating remission of CMRFs with or without lifestyle intervention should be careful to include sufficiently long follow-up to correctly ascertain the possibility and success of CMRFs remission.

Strengths and Limitations

There are some strengths and limitations that need to be taken into consideration. Firstly, this was not a randomized control trial and therefore did not allow us to compare the effectiveness of exercise and diet alone and combined on CMRFs remission vs a control group. Secondly, due to the combined nature of the intervention, we cannot isolate the specific contributions of high-intensity interval training, resistance training and diet modifications on CMRFs remission, and adherence to nutritional counselling were not monitored. Thirdly, the relatively small participant numbers for each CMRF (i.e., MS, T2DM, IFG, and HTA) reduce the scope of our results. Finally, the research protocol was not designed for medication deprescription. By implementing a specialized protocol targeting the absence of medication to achieve the remission criterion, it might have been possible to achieve higher remission rates. Randomized controlled trials assessing the effectiveness of intensive lifestyle intervention programs on the remission of CMRFs are therefore necessary to confirm these results. The main strength of our study was the long-term follow-up. This extension allowed us to not only assess the sustainability of remission status, but also to fulfill the requisite duration criterion for remission. Moreover, our 18-month follow-up considerably exceeded the 1-year timeframe typically recommended for the duration criterion for remission [13]. However, there is no universally accepted definition for the remission of MS or HTA and more research on this topic is necessary.

5. Conclusions

In conclusion, our results suggest that an intensive lifestyle intervention program, consisting of supervised high-intensity interval exercise, resistance training, and lifestyle

modification counselling, holds considerable potential for achieving remission of CMRFs in adults living with overweight/obesity. This comprehensive approach has demonstrated the ability to lead to remission of MS, diabetes, IFG, and HTA. Another interesting finding is the program's efficacy in sustaining remission status at the 18-month follow-up.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/obesities4010001/s1, Table S1: Changes of cardiometabolic risk factors of the metabolic syndrome in obese adults before and after the intensive lifestyle program; Table S2: Characteristics of participants for each remission groups.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Medical Director of the Montreal Heart Institute for the retrospective study.

Informed Consent Statement: Patient consent was waived due to retrospective clinical routine nature of this work.

Data Availability Statement: Not available due to ethical restriction.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

CMRFs	Cardiometabolic risk factors
MS	Metabolic syndrome
T2DM	Diabetes
HTA	Hypertension
BMI	Body mass index
HDL-C	High-density lipoprotein
FPG	Fasting plasma glucose

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