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Research Article

Effect of Exercise Intervention Programs on Anthropometric, Physiological and Cardiometabolic Parameters of Persons with and without Metabolic Syndrome

Georgia Torres[1]* Nigel John Crowther[2], and Geoff Rogers[1]

[1]Department of Physiology, University of the Witwatersrand, South Africa
[2]Department of Chemical Pathology, National Health Laboratory Service, University of the Witwatersrand, Faculty of Health Sciences, Johannesburg, South Africa

***Corresponding author**

Georgia Torres, Department of Physiology, University of the Witwatersrand, 1 Allandale Avenue, Parkmore, Sandton, Gauteng, South Africa, Tel: 27117072900; Email: gtorres.fiziq@gmail.com

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Abstract

Background: Metabolic Syndrome (MetS) is a multi-faceted disease and research evidence of the effect of specific exercise protocols on the different components of MetS is contradictory. Therefore, this study compared the effects on the components of the MetS of an exercise program that uses blood lactate transition thresholds (specifically, the anaerobic threshold (AT)) to the same measurements obtained in an exercise program (not using AT) appearing in the literature. The main aim of the study was to design an exercise program that optimized exercise responses and may thus improve metabolic characteristics in individuals with MetS.

Methods: Ten participants with MetS (MetSL) exercised using awaking program which does not use the AT to set training intensities. A second group of ten participants without MetS exercised using velocity at AT to set training intensities (Non-MetSV).The experimental group consisted of ten participants with MetS exercising using velocity at AT to set training intensities (MetSV). Physical, physiological and metabolic responses were measured in all groups before, during and after 20 weeks of exercise.

Results: BMI and waist circumference decreased in all groups. In addition, velocity at AT increased in all training groups. The VO2 peak did not change significantly in the non-MetSV group. The blood pressure response was favourable in the groups with MetS yet absent in the group without MetS. The MetSV group was the only group to show significant, positive changes in any of the metabolic parameters (fasting insulin and HOMA). In addition, the training program used in the MetSV group had a greater effect on reducing the number of MetS components than did the training program not using AT.

Conclusions: An exercise program using AT to set intensity is effective in eliciting beneficial responses in individuals diagnosed with MetS. Moreover, this was achieved at a lower exercise volume and frequency when compared to an effective walking program (not using AT).

INTRODUCTION

The metabolic syndrome (MetS) has been identified as a major health challenge [1,2] and has been shown to be a significant predictor of cardiovascular disease (CVD) and type 2 diabetes mellitus [3,4]. In addition, the syndrome confers additional risk to those accounted for by traditional CVD scoring paradigms [5].

Studies have shown improvements in individual components linked to MetS [6-8] and in reversing MetS [9] after exercise interventions. All these studies have used %VO_2 max to prescribe intensity. Research has however shown measurement of blood lactate transition thresholds (BLTT) as best indices for setting the exercise intensities of training programs [10-14].

The anaerobic threshold (AT), a specific measure of BLTT, has been used in prescribing exercise intensity among healthy, non-athletes [12] and among adults with cardiac disease [15]. Blood lactate measurement, integrated with the objectives above, has not been investigated and applied to exercise programming for MetS.

The present study ascertained how individuals with MetS responded to an exercise program that has been validated in a previous study that assessed obese participants [16]. The responses of this group were compared to the response of individuals with MetS using an exercise program incorporating the AT. The principal aim of this study was therefore to determine the effect of an exercise program that incorporated training at AT on anthropometric, physiological and cardiometabolic parameters in subjects with MetS in comparison to subjects with MetS training using a walking program (not incorporating AT).

METHODS

The Human Ethics Committee of the University of the Witwatersrand, Johannesburg, South Africa, approved the study protocol (MO61104).

Subject groups and definition of MetS

The study investigated three groups of male participants recruited from a medical practice (those being treated for a component of MetS) and from adverts placed in a local newspaper (subjects without MetS): the first group consisted of ten participants with MetS exercising using the walking program of Leon et al. [16], (MetSL group); in the second group, ten participants without MetS exercised using velocity at AT to set training intensities (Non-MetSV group); the final group consisted of ten participants with MetS exercising using velocity at AT to set training intensities (MetSV group).During recruitment subjects were randomized to the 2 MetS groups. Subjects were diagnosed with MetS using the harmonised guidelines [1]. The presence of any three of the five criteria denoted below constituted a diagnosis of MetS: waist circumference (≥ 94 cm); triglycerides (≥ 1.7 $mmol.L^{-1}$) or drug treatment for high triglycerides; HDL-cholesterol (< 1.0 $mmol.L^{-1}$); elevated blood pressure (≥ 130/85) or on anti-hypertensive drug treatment; elevated fasting glucose (≥ 5.6 $mmol.L^{-1}$) or drug treatment for glucose intolerance. Exclusion criteria for the study were: female gender; men younger than 25 and older than 55 years of age; any individuals with known cardiovascular or pulmonary disease; type 1 diabetes. In addition, all participants had not engaged in a formal exercise program for 3 months prior to the start of the study.

Blood measurements

The following baseline fasting blood lipid measurements were collected from every subject before the training program commenced: triglycerides, high-density lipoprotein cholesterol (HDL-C) and total cholesterol, all measured as described previously [17]. The low-density lipoprotein cholesterol (LDL-C) levels were calculated using the method of Friedewald et al. [18]. An oral glucose tolerance test (OGTT) was performed in a fasting state after administration of a 75 g glucose load. Glucose levels were measured as described previously [17]. Serum insulin levels (measured on the Architect i2000 Abbott instrument using the Chemiluminescent Micro particle Immunoassay) were also measured at each time point. The HOMA-IR [19] was calculated to assess insulin sensitivity.

Anthropometric and blood pressure measurements

Height was measured to the nearest millimeter using a Seca Stadiometer (Hamburg, Germany).Body mass was measured to the nearest gram with a Charder electronic scale (Taiwan, China).Body mass index (BMI) was also calculated and recorded. Waist circumference was measured to the nearest 0.5 cm using a soft measuring tape and was taken as the greatest reading around the girth, midway between the lateral lower ribs and the iliac crests. Blood pressure was measured with a Honsun sphygmomanometer (Shanghai, China) in the sitting position and an average taken of two readings, two minutes apart. The left arm was used and the arm was rested on a table at the level of the heart.

Physiological measurements

Peak VO_2 (oxygen consumption) and heart rate were measured using the Cortex, Biophysik, Metalyzer 3b CPX on-line system (Leipzig, Germany). A BLTT (blood lactate transition threshold) test using the modified ADAPT (Automatic Data Analysis for Progressive Tests) method, was performed at the same time as the peak VO_2 test. The peak VO_2 and BLTT test protocols have been described in a previous publication [17].

Training programs

The MetSL subjects followed the walking program of Leon et al. [16], as outlined in Table (1). The MetSV and Non-MetSV groups followed the 20 week program outlined in Table (2). Heart rate was monitored during training sessions using heart rate monitors (Polar Electro, Kempele, Finland).

Training was performed and controlled at the Techno gym Wellness Centre, Bryanston, on a treadmill, using the Techno gym key system that records all training sessions. These sessions were accessed using the Techno gym Wellness System Software (V7) (Techno gym, Cesena, Italy). Participants who had downloadable Polar heart rate monitors were able to exercise at their own training facility. Their training information was accessed on the Polar web-site.

The Leon et al. [16], training program was chosen for the following reasons: the program increased intensity in a progressive manner during the training period, and our AT-based training program was also based on a periodised model; it measured the same variables that our study investigated and this allowed for effective comparison of the two studies; the subjects were anthropometrically similar across the two studies; the mode of exercise was the same as our training program; the training program was very reproducible and easy to implement in our subject groups i.e. only treadmill velocity and gradient determined intensity; the training program also achieved impressive outcomes with respect to the metabolic syndrome components that our study also measured (Table 1&2).

Measurement frequencies

All baseline measurements were repeated in all groups during weeks 12 and 20, with the BLTT, VO_2 peak and BLTT test, waist circumference and body mass being measured every four weeks for 20 weeks. Participant adherence was monitored via the Techno gym Wellness System (TGS) software. The researcher looked at the training data collected on the TGS software platform daily. The researcher contacted the participants telephonically if adherence was not at the prescribed weekly frequency. Furthermore, participants had a testing appointment with the researcher every 4 weeks (Table 3&4).

Medication and nutrition

All medications taken by the participants were recorded. No participants used any confounding medications (e.g. therapies for lowering blood lipid, blood pressure, and body mass or glucose levels). All participants were given a standardized nutrition

Email: gtorres.fiziq@gmail.com

Table 1: Protocol for the 20-week treadmill walking program.

Week	Day	Speed (Kph)	Duration (minutes)	Elevation (% grade)
1	M	2.4	10 + 5 rest + 5	0
1	T	2.4	10 + 5 rest + 5	2
1	W	2.4	10 + 5 rest + 10	2
1	Th	2.4	10 + 5 rest +10 + 5 rest + 5	4
1	F	2.6	10 + 5 rest +10 + 5 rest + 5	4
2	M	2.6	10 + 5 rest +10	2
2	T	2.8	10 + 5 rest +10 + 5rest + 5	2
2	W	3.0	10 + 5 rest +10 + 5 rest +10	4
2	Th	3.2	15 + 5 rest +10 + 5 rest +10	4
2	F	3.4	15 + 5 rest +15 + 5 rest +15	6
3	M	3.4	15 + 5 rest +10 + 5 rest +10	4
3	T	3.6	15 + 5 rest + 15 + 5rest +15	4
3	W	3.8	20 + 5 rest + 15 + 5 rest +15	6
3	Th	4.0	20 + 5 rest + 20 + 5 rest +15	6
3	F	4.2	20 + 5 rest + 20 + 5 rest +20	6.5
4	M	4.2	20 + 5 rest + 20 + 5 rest +15	6
4	T	4.4	20 + 5 rest + 20 + 5 rest +20	6
4	W	4.6	25 + 5 rest + 20 + 5 rest +20	6.5
4	Th	4.8	25 + 5 rest + 25 + 5 rest +20	6.5
4	F	5.0	25 + 5 rest + 25 + 5 rest +25	7
5	M	5.0	25 + 5 rest + 25 + 5 rest +20	6.5
5	T	5.0	25 + 5 rest + 25 + 5 rest +25	6.5
5	W	5.1	30 + 5 rest + 25 + 5 rest +25	7
5	Th	5.1	30 + 5 rest + 30 + 5 rest +25	7
5	F	5.1	30 + 5 rest + 30 + 5 rest +30	7.5
6	M,T,W,Th,F	5.1	30 + 5 rest + 30 + 5 rest +30	7.5
7	M	5.1	30 + 5 rest + 30 + 5 rest +30	7.5
7	T	5.1	30 + 5 rest + 30 + 5 rest +30	8
7	W	5.1	30 + 5 rest + 30 + 5 rest +30	7.5
7	Th	5.1	30 + 5 rest + 30 + 5 rest +30	7.5
7	F	5.1	30 + 5 rest + 30 + 5 rest +30	8
8 - 20	M,T,W,Th,F	5.1	30 + 5 rest + 30 + 5 rest +30	8

Table 2: The training program for groups using AT to set training intensity.

Week	Duration (mins/session)	Frequency (sessions/ week)	Intensity (% anaerobic threshold)
1	20	3	90
2	25	3	90
3	25	3	95
4	20	3	95
5	25	3	100
6	30	3	100
7	35	4	100
8	25	3	100
9	35	4	100
10	40	4	100
11	45	4	100
12	35	3	100
13	45	4	100
14	50	4	100
15	55	4	100
16	40	3	100
17	55	4	100
18	60	4	100
Week 19			
Day	Duration (Mins/session)	Frequency (Sessions/ week)	Intensity (% anaerobic threshold)
1	40	1	100
2	35	1	100
3	30	1	100
Week 20			
Day	Duration (Mins/session)	Frequency (Sessions/ week)	Intensity (% anaerobic threshold)
1	25	1	100
2	20	1	100
3	15	1	100

program. The nutrition plan was given in an attempt to maintain a similar energy intake across the three groups. The Willett food frequency questionnaires (20) in combination with a 24 hour eating record for three days were used to monitor the energy intake of all participants. These nutritional records were taken at week 0, 8 and 20 of training. Nutritional records were analyzed for caloric content using data from the following site: www.nal.usda.gov/fnic/foodcomp/search.

Statistical analysis

The n per group for this study was chosen as ten with extra subjects recruited to allow for drop out (see Results). This was based on convenience and was the upper n as determined by infrastructural limitations. A *post hoc* sample size calculation based on the data shown in Table (5) for waist circumference, assuming a power of 0.80 and a α of 0.05 gave an n for each group of 18. If BMI was used, the n per group was eight.

Variables that were found to be significantly skewed were log transformed to normality and presented as median (interquartile range) in the tables and text. Normally distributed data is presented as mean ± SD. Inter-group comparisons were made using an ANOVA (Tables 3 and 5). If the ANOVA analysis found significant differences for possible confounding variables, an ANCOVA analysis was performed adjusting for the confounding variable and a *post hoc* analysis was performed using a Tukey HSD test. An ANOVA followed by Dunnett's *post hoc* test was used for comparing mean values obtained at weeks 4, 8, 12, 16 and 20 with the mean value at week 0 (Table 4). Students paired t test was used when only one time point was being compared with week 0 data (Table 4).

Pearson correlation analyses were used to determine the principal correlates of the percentage changes in VO_2 peak and AT. Variables that gave correlations in the univariate analyses of $p<0.10$ were then used as independent variables in two separate multiple regression models in which percentage change in VO_2 peak and percentage change in AT were the dependent variables. Backward, stepwise regression analysis was then performed until only variables with $p< 0.10$ remained in the model. Unstandardized beta values are given. The statistics package Statistica version 11 (Stat Soft, Tulsa, OK, USA) was used for all statistical analyses.

Table 3: Baseline physical and biochemical characteristics of study participants.

Parameter	Non-MetSV (n=9)	MetSV (n=9)	MetSL (n=7)	MetSV + MetSL (n=16)[a]
Age (years)	40.2 ± 7.90	40.8 ± 8.21	48.3 ± 7.32	44.1 ± 8.50
Body mass (kg)	101 (15.2)	99.8 (29.6)	114 (35.1)	102 (28.7)
BMI (kg.m $^{-2}$)	31.0 (6.10)	31.8 (4.80)	33.9 (11.1)	32.7 (10.1)
Waist circumference (cm)	104 (13.0)	111 (11.9)	116 (27.2)*	116 (20.8)*
Triglycerides (mmol.L $^{-1}$)	1.21 (0.45)	1.70 (1.00)	1.28 (0.69)	1.42 (0.85)
Total cholesterol (mmol.L $^{-1}$)	5.27 ± 1.18	5.48 ± 1.23	5.41 ±1.61	5.45 ±1.36
LDL (mmol.L $^{-1}$)	3.65 ± 1.19	3.76 ± 0.95	3.65 ± 1.48	3.71 ± 1.17
HDL (mmol.L $^{-1}$)	1.06 (0.20)	0.90 (0.01)	1.00 (0.49)	0.90 (0.18)
Systolic BP (mmHg)	120 ± 11.1	134 ± 14.2	144 ± 8.52**	138 ± 12.6**
Diastolic BP (mmHg)	80.0 ± 6.61	88.3 ± 6.61	89.3 ± 9.32	88.8 ± 7.64*
Fasting glucose (mmol.L $^{-1}$)	5.10 (0.40)	4.80 (0.60)	5.90 (0.61)†	5.25 (1.25)
30 min glucose (mmol.L $^{-1}$)	7.42 ± 1.64	6.76 ± 2.38	9.16 ± 1.92	7.72 ± 2.45
2 hour glucose (mmol.L $^{-1}$)	6.20 (2.20)	3.80 (2.00)	7.40 (3.30)†	5.40 (4.00)
Fasting insulin (μU.ml $^{-1}$)	8.51 ± 1.40	11.1 ± 4.78	14.3 ± 2.82*	12.6 ± 4.20*
30 min insulin (μU.ml $^{-1}$)	33.9 (26.4)	73.2 (19.2)	91.3 (38.1)*	74.0 (38.0)*
2 hour insulin (μU.ml $^{-1}$)	31.3 (31.7)	21.9 (24.9)	84.1 (56.1)	36.5 (73.3)
HOMA index	1.97 (0.48)	2.32 (0.97)	3.26 (1.61)*	2.83 (2.13)*
VO_2 Peak (ml.min $^{-1}$ .kg $^{-1}$)	33.8 ± 5.14	29.3 ± 7.07	23.5 ± 2.59*	26.8 ± 6.18*
Velocity at AT (km.h $^{-1}$)	5.37 ± 0.70	5.27 ± 1.53	5.06 ± 0.65	5.18 ± 0.67

Table 4: Changes in physical, physiological and metabolic parameters at weeks 4, 8, 12, 16 and 20 for Non-MetSV, MetSV and MetSL groups.

Variable	Group	Comparison of baseline data with data at weeks 4, 8 and 12[a]				Comparison of baseline data with data at weeks 16 and 20[b]		
		Baseline[c]	Week 4	Week 8	Week 12	Baseline[d]	Week 16	Week 20
BMI	*Non-MetSV*	31.0 (6.10)	-	-	29.3 (4.70)*	31.1 (5.80)	-	29.9 (4.30)*
	MetSV	31.8 (4.80)	-	-	29.8 (5.60)*	29.4 (1.10)	-	28.5 (0.10)*
	MetSL	33.9 (11.1)	-	-	32.0 (11.1)*	35.9 (11.1)	-	33.5 (11.4)*
Waist (cm)	*Non-MetSV*	104 (13.2)	104 (10.0)	103 (10.5)	103 (8.60)	105 (13.3)	101 (12.0)*	102 (12.7)*
	MetSV	111 (11.9)	110 (14.0)*	107 (10.7)	107 (11.5)	110 (18.6)	107 (14.7)	107 (14.1)
	MetSL	116 (27.2)	115 (26.1)*	114 (25.3)*	113 (27.5)*	121 (27.2)	115 (28.1)*	114 (27.0)*
VO2 peak (ml.min $^{-1}$ .kg $^{-1}$)	*Non-MetSV*	33.8 ± 5.10	34.1 ± 4.61	35.6 ± 3.82	36.3 ± 4.21	33.8 ± 5.50	35.9 ± 3.36	37.0 ± 5.32
	MetSV	29.3 ± 7.10	31.9 ± 6.50	33.9 ± 6.20*	36.6 ± 7.70*	33.8 ± 5.62	41.3 ± 6.90*	44.0 ± 7.60*
	MetSL	23.5 ± 2.61	26.8 ± 5.75	27.7 ± 4.62	29.2±5.34	22.8±2.17	29.6 ± 4.25*	30.8 ± 4.90*
Velocity at AT (km.h $^{-1}$)	*Non-MetSV*	5.37 ± 0.74	5.91 ± 0.69*	5.95 ± 0.61*	6.22 ± 0.73*	5.30 ± 0.72	6.22 ± 0 .78*	6.31 ± 0.73*
	MetSV	5.27 ± 1.53	5.60 ± 1.19	6.03 ± 1.33*	6.09 ± 1.34*	5.94 ± 1.43	6.92 ± 2.02	6.90 ± 1.64*
	MetSL	5.06 ± 0.65	5.36 ± 0.79	5.67 ± 0.64	5.93 ± 0.91*	4.91 ± 0.56	5.87 ± 0.53*	5.89 ± 0.75*
Diastolic BP (mmHg)	*Non-MetSV*	80.0 ± 6.61	-	-	79.4 ± 9.50	81.3 ± 5.82	-	78.8 ± 6.41
	MetSV	88.3 ± 6.61	-	-	84.1 ± 4.70*	88.1 ± 7.58	-	78.0 ± 8.37*
	MetSL	89.3 ± 9.32	-	-	80.7 ± 9.76*	89.2 ± 10.2	-	77.5 ± 7.58*
Systolic BP (mmHg)	*Non-MetSV*	120 ± 11.1	-	-	123 ± 10.8	120 ± 11.8	-	120 ± 8.86
	MetSV	134 ± 14.2	-	-	128 ± 9.28	132 ± 16.4	-	120 ± 23.5
	MetSL	143 ± 8.52	-	-	130 ± 10.6*	144 ± 9.17	-	127 ± 13.3*
Fasting insulin (μU. ml $^{-1}$)	*Non-MetSV*	8.51 ± 1.40	-	-	8.01 ± 4.34	8.70 ± 1.37	-	9.26 ± 5.98
	MetSV	11.1 ± 4.78	-	-	9.23 ± 3.56	10.3 ± 1.48	-	7.04 ± 2.56*
	MetSL	14.3 ± 2.82	-	-	10.3 ± 4.12	14.7 ± 2.93	-	11.4 ± 5.29
HOMA	*Non-MetSV*	1.97 (0.48)	-	-	1.65 (0.72)	1.99 (0.57)	-	1.96 (0.84)
	MetSV	2.32 (0.97)	-	-	1.53 (1.36)	2.09 (0.48)	-	1.53 (0.26)*
	MetSL	3.26 (1.61)	-	-	2.29 (0.82)	3.82 (1.61)	-	2.04 (0.89)

Abbreviations: Data given as mean ± SD or median (interquartile range); Non-MetSV: Subjects without Metabolic Syndrome Training at AT; MetSV: Subjects with Metabolic Syndrome Training at AT; MetSL: Subjects with Metabolic Syndrome Training with Walking Program; [a]n for Non-MetSV, MetSV and MetSL groups are 9, 9 and 7, respectively; [b]n for Non-MetSV, MetSV and MetSL groups are 8, 5 and 6, respectively; [c]these values used in Dunnett's against weeks 4, 8 and 12;[d]these values used in Dunnett's test against weeks 16 and 20; *p<0.05 vs baseline

Table 5: Comparison of Week 0 to Week 20 percent change data across the three subject groups.

Variables	Non-MetSV (n=8)	MetSV (n=5)	MetSL (n=6)
Body mass (kg)	-3.40 ± 3.61	-4.26 ± 1.36	-8.66 ± 4.99*
BMI (kg.m^{-2})	-3.39 ± 3.42	-4.23 ± 1.36	-8.67 ± 4.97*
Waist circumference (cm)	-3.42 ± 2.45	-3.86 ± 3.05	-6.21 ± 2.94
Triglycerides(mmol.L^{-1})	-11.5 ± 33.7	-35.7 ± 35.1	-8.68 ± 21.1
Total Cholesterol (mmol.L^{-1})	1.51 ± 16.3	-18.3 ± 19.7	-4.02 ± 16.9
LDL (mmol.L^{-1})	3.82 ± 27.3	-20.7 ± 20.4	-5.12 ± 20.9
HDL (mmol.L^{-1})	6.16 ± 14.9	16.4 ± 17.7	3.87 ± 10.5
Systolic bp(mmHg)	-0.12 ± 6.85	-9.36 ± 10.1	-11.9 ± 9.79*
Diastolic bp(mmHg)	-3.03 ± 4.66	-11.2 ± 8.92	-12.6 ± 7.58*
Fasting glucose (mmol.L^{-1})	1.92 (-0.46)	4.35 (1.92)	-11.4 (-17.2)
30 min glucose (mmol.L^{-1})	5.48 ± 27.6	-5.17 ± 25.6	-4.97 ± 15.1
2 hour glucose (mmol.L^{-1})	-7.79 (-22.1)	21.6 (25.3)	-14.9 (-45.9)
Fasting insulin(μU.ml^{-1})	-18.5 (-30.7)	-35.3 (-43.8)	-33.3 (-39.8)
30 min insulin(μU.ml^{-1})	20.4 (-40.8)	-31.4 (-42.5)	2.94 (-2.76)
2 hour insulin(μU.ml^{-1})	-1.79 ± 47.6	16.6 ± 77.9	8.09 ± 84.9
HOMA index	-18.7 (-31.6)	-32.6 (-35.7)	-37.7 (-47.5)
VO_2 Peak (ml.min^{-1}.kg^{-1})	10.7 ± 13.5	30.5 ± 12.8	35.3 ± 18.7*
Velocity at AT (km.h^{-1})	19.6 ± 7.79	16.1 ± 8.05	20.3 ± 11.8

Abbreviations: Data reported as a mean ± SD or median (IQR); Non-MetSV: Subjects without Metabolic Syndrome Training at AT; MetSV: Subjects with Metabolic Syndrome Training at AT; MetSL: Subjects with Metabolic Syndrome Training with Walking Program; *p< 0.05 vs Non-MetSV

RESULTS

Subjects

Table (3) describes the baseline characteristics of the study subjects. Significant differences between the Non-MetS and MetS groups were found for waist circumference, systolic and diastolic blood pressure, fasting insulin, OGTT insulin level at 30 minutes, HOMA index and VO_2 peak (Table 3). Data reported as median (IQR) or mean ± SD. Data from ANOVA with Tukeys post hoc test. Non-MetSV=subjects without metabolic syndrome training at AT; MetSV=subjects with metabolic syndrome training at AT; MetSL= subjects with metabolic syndrome training with walking program *p< 0.05, **p< 0.005 vs Non-MetSV; †p< 0.05 vs MetSV; aMetSV and MetSL groups were combined and compared with Non-MetS V group

Study drop-outs

Twelve [12] participants were originally recruited in the MetSL and in the MetSV groups and 15 participants were originally recruited in the Non-MetSV group. These numbers were recruited based on an original sample size of ten per group, to allow for attrition. By week 12, five participants dropped out of the MetSL group (n=7); three from the MetSV group (n=9) and six from the Non-MetSV group (n=9). At week 20, a further one dropped out from the MetSL group (n=6); four from the MetSV group (n=5) and one from the Non-MetSV group (n=8). The reasons for drop-out were that the duration of sessions were long; colds and flu; work commitments and birth of a child.

Intra-group comparisons

Comparisons were made between the baseline values and the value at each follow-up (4,8,12,16 and 20 weeks). The variables shown in Table (4) are those that demonstrated significant differences across the time points in at least one of the three exercise groups. Variables that did not differ significantly across the time points in any of the groups are not shown.

Within the Non-MetSV group (Table 4), BMI decreased significantly at weeks 12 and 20. Waist circumference changed significantly at weeks 16 and 20 (week 4, p=0.09). As opposed to VO_2 peak that did not change significantly at any week, AT increased significantly at all weeks. The only metabolic parameter in this group that came close to a significant change in level was OGTT glucose level at 2 hours at week 12 (p=0.06).

Results for the MetSV group showed significant decreases in BMI at weeks 12 and 20. Waist circumference also decreased significantly only at week 4 (at week 8 and 12, p= 0.06). Except at week 4 (p=0.06), VO_2 peak increased significantly at the remaining measurement points. Except for week 4 and 16 (p=0.06), AT also increased significantly at the other measurement points. Diastolic blood pressure decreased significantly after 12 and 20 weeks of exercise. The only metabolic parameters that showed a significant decrease in this training group were fasting insulin and HOMA at week 20.

The MetSL group also showed significant decreases in BMI at weeks 12and 20. Waist circumference decreased significantly at all weeks. The VO_2 peak increased significantly at weeks16 and 20 only (at week 12, p=0.06). The AT increased significantly at weeks 12, 16 and 20 (at week 4, p=0.06). Systolic and diastolic blood pressures were both decreased significantly after 12 and 20 weeks of exercise. No metabolic parameters changed in this group.

Inter-group comparison

Results for the comparison of the percentage change in variables between week 0 and week 20 by ANCOVA are depicted in Table (5). Both body mass and BMI showed significant trends across the groups and therefore body mass was adjusted for in the ANCOVAs. Adjustment for BMI showed very similar effects.

Body mass decreased in all groups with the highest decrease occurring in the MetSL group and this group was the only group that changed significantly when compared to the Non-MetSV group. Similar results were observed for the percentage change in BMI and the same trend was also shown for systolic and diastolic blood pressures, with a significant difference in percentage change between the Non-MetSV and MetSL groups. The VO_2 peak increased in all groups. The change was only significant between the Non-MetSV and MetSL groups.

The OGTT insulin level at 30 minutes decreased only in the MetSV group and the percentage change was borderline significant between the Non-MetSV and MetSL groups (p=0.07) (Table 5).

Exercise energy expenditure

The MetSL group expended a greater amount of energy via their exercise program when compared to the MetSV and Non-MetSV groups (who were on the same training program). Thus, the MetSL expended 3994 ± 1089 kcal/wk and 358 (292) kcal/kg body mass - loss. The MetSV and Non-MetSV groups expended 1238 ± 173 kcal/wk ($p<0.005$ vs MetSL) (399 (251) kcal/kg body mass – loss) and 1110 ± 280 kcal/wk ($p<0.005$ vs MetSL) (286 (166) kcal/kg body mass – loss) respectively. No significant differences in energy expenditure per kilogram body mass - loss were noted between the groups.

Nutritional intake

No significant changes in total dietary caloric intake or the components of nutritional intake were noted across the three groups at baseline, week 8 or week 20 (data not shown).

Prevalence of metabolic syndrome

The primary outcome of the training programs is that both MetS groups showed a significant reduction in the prevalence of the syndrome after the training period ($p< 0.05$) (Figure 1A, B). A smaller percent of individuals were still diagnosed with MetS after the training period in the MetSV group (one out of nine; 11.1%), as opposed to the MetSL group (three out of seven; 42.9%).

Determinants of the percent change in VO_2 peak and Velocity at AT

Pearson correlation analysis demonstrated that the percentage change in VO_2 peak correlated with the following variables: age, baseline VO_2 peak, percentage change in waist circumference, percentage change in systolic and diastolic blood pressure and percentage change in fasting insulin and OGTT, 2 - hour glucose level. Percentage change in velocity at AT correlated only with baseline VO_2, baseline velocity at AT and percentage change in fasting glucose. These variables, as well as coding variables for the training groups with metabolic syndrome, were then included as independent variables in two separate backward, stepwise regression models in which percentage change in VO_2 peak and percentage change in velocity at AT were the dependent variables. In the first regression model age (beta= -0.03; p= 0.0004), baseline VO_2 peak (beta= -0.03; p= 0.004), percentage change in waist circumference (beta= -0.04; p= 0.05) and percentage change in fasting insulin levels (beta= -0.15; p= 0.01) were found to correlate with the percentage change in VO_2 peak. In the second regression model, only baseline velocity at AT was found to correlate with the percentage change in velocity at AT (beta= -0.14; p= 0.004).

DISCUSSION

In the current study, we compared the outcomes of an experimental group (MetSV),which used a training program based on AT determination, to the outcomes of a group(MetSL) using a training program taken from the literature that did not use AT to set training intensity [16].

Both training programs used in this study showed favourable anthropometric responses. Both BMI and waist circumference decreased significantly in all training groups (Table 4). There was no significant difference in the percentage changes of BMI and waist circumference across the two different MetS training groups at week 20, although the decreases were greater in the MetSL group. The importance of reducing BMI and waist circumference in persons with metabolic disease has been highlighted [5,17-22,]. There is contradictory evidence regarding the effect of exercise alone on body mass in persons with MetS. Some studies have shown no effect [23-25] while others have shown decreases in body mass [7,26,27]. Differences in the exercise program frequency and intensity used by these studies may contribute to these contradictory results. The STTRIDE studies aimed to address this issue and investigated the effect of different exercise amounts and intensities in sedentary, obese, dyslipidaemic participants [28,29]. These studies showed that body mass and visceral fat responded in a dose-dependent manner, with a greater amount of exercise causing a greater decrease in these parameters. The present study also found a dose-response with respect to body mass - loss. Thus, at 19 $kcal.kg^{-1}.wk^{-1}$ and 36 $kcal.kg^{-1}.wk^{-1}$ energy expenditure for the MetSV and MetSL groups respectively, the body mass - loss was 4.3% and 8.7% respectively at week 20 (Table 5).

The measurements of VO_2 peak and AT were used as indices of cardio-respiratory fitness. Velocity at AT improved significantly in all training groups (Table 4). However, VO_2 peak improved significantly only in the MetS groups and did not change significantly in the group without MetS (Table 4). Studies have demonstrated that it is possible for AT to improve without VO_2 peak changing [12,13]. In addition, the VO_2 peak response in this study indicates a difference in cardiovascular responses to this training program between persons with MetS and those without MetS. The central training adaptations were more evident in the MetS groups than in the Non-MetS groups possibly because of differences in the level of fitness at the beginning of the study between MetS and non-MetS subjects.

There was no significant difference in the percentage changes that occurred in VO_2 peak and AT between the MetSV and MetSL groups (Table 5). This indicates that the training program utilizing AT was as effective in improving the cardio-respiratory fitness of persons with MetS as the training program of Leon et al. [16]. However, the training program using AT achieved this improvement at a third of the exercise energy expenditure of the training program not using AT. To our knowledge there are no other studies that have shown the response of velocity at AT to a training program in persons with MetS. These data show a favourable response indicative of an increase in cardio-respiratory fitness. There was no significant difference in the improvement in velocity at AT across the three groups (Table 5). This suggests that persons with MetS and persons without MetS have a similar blood lactate response to endurance exercise.

The regression analyses suggest that the improvement in VO_2 peak was associated with age, baseline VO_2 peak, the decrease in waist circumference and the decrease in fasting insulin levels. The improvement in velocity at AT with training was associated with baseline BLTT levels only. These analyses support data from our earlier cross sectional study demonstrating the influence of waist circumference on VO_2 peak [17] and extend these findings to show that improved insulin sensitivity is associated with a higher VO_2 peak. A previous longitudinal study has also demonstrated a negative relationship of VO_2 peak with waist circumference [30] but the negative relationship between change in VO_2 peak and change in insulin sensitivity has not been previously reported. It is unknown why a fall in waist circumference would lead to an improved VO_2 peak. We previously hypothesised that this may be due to improved insulin sensitivity, which in turn would lead to more efficient glucose metabolism in skeletal muscle [17]. However, the current data suggests that the relationship between VO_2 peak and waist circumference is independent of the change in insulin sensitivity. Other factors must therefore mediate this relationship, and it is interesting to note that markers of systemic inflammation do correlate negatively with VO_2 peak [31] and positively with abdominal obesity [32]. Therefore future studies must be conducted to determine whether waist circumference influences cardio respiratory fitness through effects on the inflammatory system.

The percentage changes that occurred in blood pressure were not significantly different between the two MetS groups (Tables 5). There was no change in blood pressures within the non-MetS group (Table 4). This may once more allude to differences in adaptations to endurance training in persons with MetS as opposed to those without MetS. Other studies have also reported the beneficial effect of exercise on blood pressure [5,26]. In contrast, some studies have shown no changes in blood pressure after exercise intervention [22,33], the MetSV group showed significant intra-group changes in insulin-related parameters, with fasting insulin and the HOMA index falling by week 20 (Table 4). Thus, insulin sensitivity may have been positively influenced by the training program using AT. No such improvements were noted in the non-MetSV group. It is speculated that exercise training at the AT may improve skeletal muscle insulin sensitivity by increasing muscle GLUT-4levels due to an increase in the demand for glucose when training at the AT. This speculation is based on the finding that exercise increases the level of GLUT-4, which in turn results in a more rapid glucose uptake [34,35]. However, research in this area has been contradictory with some studies showing improved glucose tolerance and reduced insulin responses to oral glucose with exercise training [7,33,36] and other studies finding no changes [23,37].

Systematic reviews of the effects of lifestyle modification interventions (LMI) on individuals with MetS have shown that LMI decrease the prevalence of MetS and associated abnormalities [5,38]. It was however suggested that dietary modifications might be more effective than exercise interventions [38].The training programs used in this study had a significant influence on the incidence of MetS. There was a marked reduction in the number of individuals that were still diagnosed with MetS after the training program (Figure 1). The research of Katzmarzyk et al. [9], also investigated the effect of 20 weeks of supervised aerobic cycle exercise training on the presence of MetS. The exercise training program involved three sessions per week, starting at 55% of baseline VO_2 max for 30 minutes and progressing to 75% VO_2 max for 50 minutes for the final six weeks. In support of our finding, this research found that 32.7% of men with the MetS were no longer classified as having the syndrome after training. Within our study the exercise volume was over three-fold greater

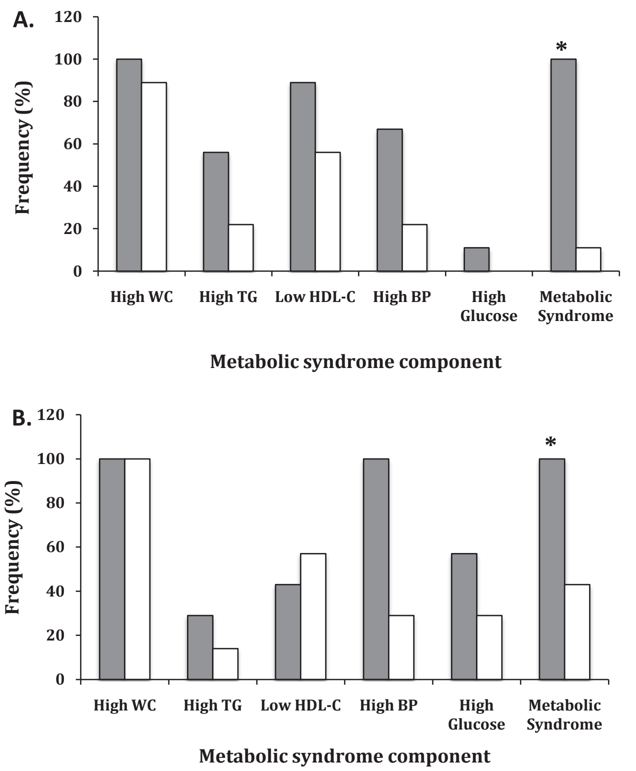

Figure 1 Change in frequency of the components of the metabolic syndrome and of the metabolic syndrome in the MetSV (A) and MetSL (B) groups. Data in filled bars is frequency levels before start of training program and data in open bars is frequency after 12 weeks of training

Abbreviations: WC: Waist Circumference; TG: Triglycerides; HDL-C: High-Density Lipoproteins; BP: Blood Pressure; MetSV: Subjects with Metabolic Syndrome Training at AT; MetS: Subjects with Metabolic Syndrome Training with Walking Program; *$p< 0.05$ vs frequency after 12 weeks

for the MetSL group than for the MetSV group. In spite of the much lower work volume, the MetSV group displayed a greater lowering in the prevalence of MetS when compared to the MetSL group, although this difference was not statistically significant.

It should be noted that a *post hoc* sample size calculation showed that in order to observe significant differences across groups for a percentage change in waist circumference, an n of 18 participants per group would be required. Thus, our study was under-powered to observe changes in waist across the groups. A sample size calculation based on percentage change in BMI gave an n of eight per group, which is close to the actual number used in this study. Therefore, one of the drawbacks of the current study is that the small sample size used was not large enough to observe significant changes in all the variables analyzed. The high study drop-out rate highlights the need to assess psychological profiles and offer support in this area during an exercise intervention. This is a further limitation of this study.

CONCLUSION

The most important finding of this research is that an exercise intervention program can reverse the presence of MetS. A smaller percent of individuals were still diagnosed with MetS after a 12 week training period in the MetS group using AT to set intensity, as opposed to the MetS group not using AT to set intensity. An advantage of the training program using AT is that its effects occurred at a reduced exercise frequency and lower exercise energy expenditure than that of the Leon et al. program.

In summary, the program using AT had similar effects on anthropometric and physiological parameters of individuals with MetS when compared to the program not using AT. In addition, the program using AT significantly reduced insulin resistance but the fall in this parameter in the MetSL group was not significant.

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