Research Article

Effectiveness of high-intensity interval training and moderate-intensity continuous training on cardiometabolic health in university labourers

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ABSTRACT

Background: The prevalence of obesity continues to drive the growth of chronic, non-communicable diseases in sub-Saharan African countries. Little evidence is available to prevent the spread of chronic diseases in vulnerable African communities and amongst workers living in these settings. This study aimed to compare and evaluate the effectiveness of a 12-week high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on cardiometabolic health in a cohort of African workers.

Methods: Forty-three Black South African university professional workers employed at the University of the Witwatersrand were randomized into 3 groups: HIIT (n = 17), a MICT (n = 15) and a control group (n = 11). The HIIT performed progressive supervised exercise on a cycle ergometer, the MICT performed continuous aerobic activity and the control group maintained their usual routines. Changes in body composition, blood glucose, blood pressure and VO2max outcomes were measured at baseline and at 3-month follow-up.

Results: Compared to controls both HIIT and MICT significantly reduced waist circumference (–5.3 and –4.0 cm), BMI (–2.4 and –1.9), and blood pressure (systolic & diastolic - moderate to large effects) ($p < 0.05$). Similarly, blood glucose levels dropped in both intervention groups (–1.9 and –2.0 mmol/L–1) ($p < 0.05$). Notably, both interventions significantly improved VO2max (+7.5 and +7.0 $mL.kg^{-1}.min^{-1}$) ($p < 0.05$).

Conclusions: These findings suggest both HIIT and MICT effectively improve key health markers. In the context of a growing chronic diseases crisis, our study provides important formative data for developing feasible workplace interventions to improve health outcomes.

Keywords: Body composition, Cardiometabolic outcomes, Exercise, HIIT, MICT

INTRODUCTION

Behavioural risk factors are the main source of the rising prevalence of non-communicable diseases (NCDs), with 80% of all NCD-related deaths occurring in low-and-middle-income countries (LMICs).(1) Physical inactivity is one of the behaviours that requires attention to offset the impact of NCDs in LMICs.(2) There is strong evidence that 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity minutes per week is sufficient to reduce the risk of all-cause mortality, cardiovascular disease and co-morbid conditions associated with NCDs.(3) South Africa is a sub-Saharan African country with one of the high prevalence of obesity especially amongst urban dwelling women. In a 5-year, follow-up study, central obesity increased in urban dwelling women by 6% from a baseline of 64%, while in rural dwelling women central obesity increased by 5% from baseline of 51%. In comparison, urban-dwelling men reported an increase from 6% to 12%, while rural dwelling men did not have a significant increase in obesity.(4) In South Africa, most adults are not meeting the recommended guidelines to lower the increasing obesity trend in the region.(3) To address this concern, it has been suggested that efforts should be focussed on transforming obesogenic settings to create opportunities for physical activity and health eating. The South African workplace has a reportedly high prevalence of risk factors for NCDs and unhealthy behaviours.(5) It is therefore appropriate to develop workplace interventions to promote healthy behaviours. The workplace is an ideal setting to promote health initiatives and could be used to increase compliance with physical activity guidelines.(6,7) This approach is particularly important as evidence suggests that workplace interventions amongst employed populations can help promote physical activity in the community.(8)

In recent years, high-intensity interval training (HIIT) has been gaining recognition in the scientific community as an effective physical activity approach to improve cardiovascular health.(9) The HIIT approach involves alternating periods of high-intensity bouts at near maximum, followed by no activity to low intensity bouts, while MICT training involves continuous aerobic training.(9, 10, 11) A meta-analysis of 22 studies, involving 3–5 training sessions/week of 4 to 12 weeks duration, and utilizing various exercise modalities, found that HIIT and MICT provided similar benefits for improving body mass index (BMI), maximal oxygen uptake (VO2max) and fasting blood glucose. High-intensity interval training at 85–95% of HRmax and MICT at 50-75% of HRpeak resulted in comparable changes in BMI [0.59 (0.14, 1.04); 0.73 (0.27, 1.18)], VO2max [–0.97 (–1.23, –0.67); –0.69 (–1.04, 0.34)], and fasting blood glucose [0.37 (–0.41, 1.14); 0.34 (–0.25, 0.93)].(11) The evidence suggests that MICT is effective in managing obesity-related illnesses, and improving cardiovascular fitness.(12) High-intensity interval training can produce comparable positive outcomes that have real-world application and the added benefit of being time efficient.(13, 14) Participants from recent qualitative studies have reported limited time as the main barrier to physical activity.(15, 16) It would be worth considering HIIT as a feasible alternative to MICT in the workplace. There is data to suggest that individuals may prefer HIIT as the training requires <30 minutes for 3 interspersed days of the week compared with dedicating at least 30 minutes of continuous exercise for most days of the week.(13) To the best of our knowledge, there is no study examining the effectiveness of HIIT and MICT interventions to enhance workplace health in South African workers. We thus sought to investigate the effectiveness of these protocols amongst university workers.

METHODS

Study population

A randomized controlled trial was conducted at the University of the Witwatersrand in Johannesburg, South Africa and participants were invited by the human resources department via invitation emails and information meetings from January to March 2020 to participate in the study. The inclusion criteria included: (a) employed at the institution, (b) in cleaning, landscaping, or security position, aged ≥18 years. Any participants who were pregnant, terminally ill, or that reported inability to exercise were excluded. The study was approved by the Human Research Ethics Committee, University of the Witwatersrand (ethics certificate number: M190409). Study participants provided written informed consent. Sample size was determined based on BMI change as the outcome variable. To achieve 90% power and 5% significance, a study with 90 participants (30 per group) was needed, assuming a comparable BMI increase rate in males and females in the control group, and a 1% decrease in the intervention group over 6 months. A target sample size of 30 participants per group was chosen due to an anticipated 30% dropout rate. Fifty-four participants were randomly assigned to HIIT (n = 18, 34.6%), MICT (n = 19, 36.6%), or control group (n = 17, 32.7%) in a single-blinded randomized controlled trial. (Figure 1) Eleven (20.4%) participants withdrew from the 12-week intervention. Thus, the study constituted 43 participants, randomly allocated to the HIIT (n = 17, 39.5%), MICT (n = 15, 35%) and control (n = 11, 25.5%) groups.

Interventions

The study was conducted during the COVID-19 alert level 1 and 2 while gyms were operational, therefore standard operating procedure (SOP) was implemented for both the participants and the researcher to adhere to COVID-19 regulations. This ensured the safe delivery of exercise protocols, and no confirmed cases of COVID-19 were reported during the study. The exercise interventions were performed at the Centre for Exercise Science and Sports Medicine cardio gym during the participants' free time. The Recline Excite® stationary recumbent bike (Technogym®, Cesena, Italy) was used for individualised, cycle exercise sessions, conducted 3-days/week for 12-weeks in both protocols and supervised by a trained sports scientist. Heart rate monitors (S810, Polar, Kempele, Finland) were used to determine heart rate and ensure participants exercise at correct intensities. Rating of perceived exertion (RPE) using the Borg CR-10 scale was used for self-reported exercise effort. The MICT sessions commenced and ended with a 5-min warm-up/cool-down (40–45% HRmax) with the main session including a moderate-intensity block (55–70% HRmax). The HIIT included the same cool-down/warm-up, with the main session including interval sprints at near maximum (≥80% HRmax or RPE≥8) intervals of up to 30 sec in duration. Progression volume for the total working duration ranged from 2 min to 8 min 15 sec (week 1–12), total recovery duration from 8 to 12 min 15 sec (week 1–12), and numbers of intervals ranged from 4 to 14 (week 1–12). Thus, the exercise session duration ranged from 20–26 min (including the warm-up and cool-down session) from week 1 to 12. Exercise progression was individualised using HRmax and RPE method.(17)

Participants in the HIIT and MICT groups received health messaging to motivate healthy lifestyle through SMS services, 5-times/week during the intervention.(17) Control group received no intervention to improve physical activity or lifestyle. The researcher only collected data from participants at baseline, 12-weeks, and 3-months post-intervention. The controls were not engaged in any formal exercise program and were advised to maintain their usual routine.

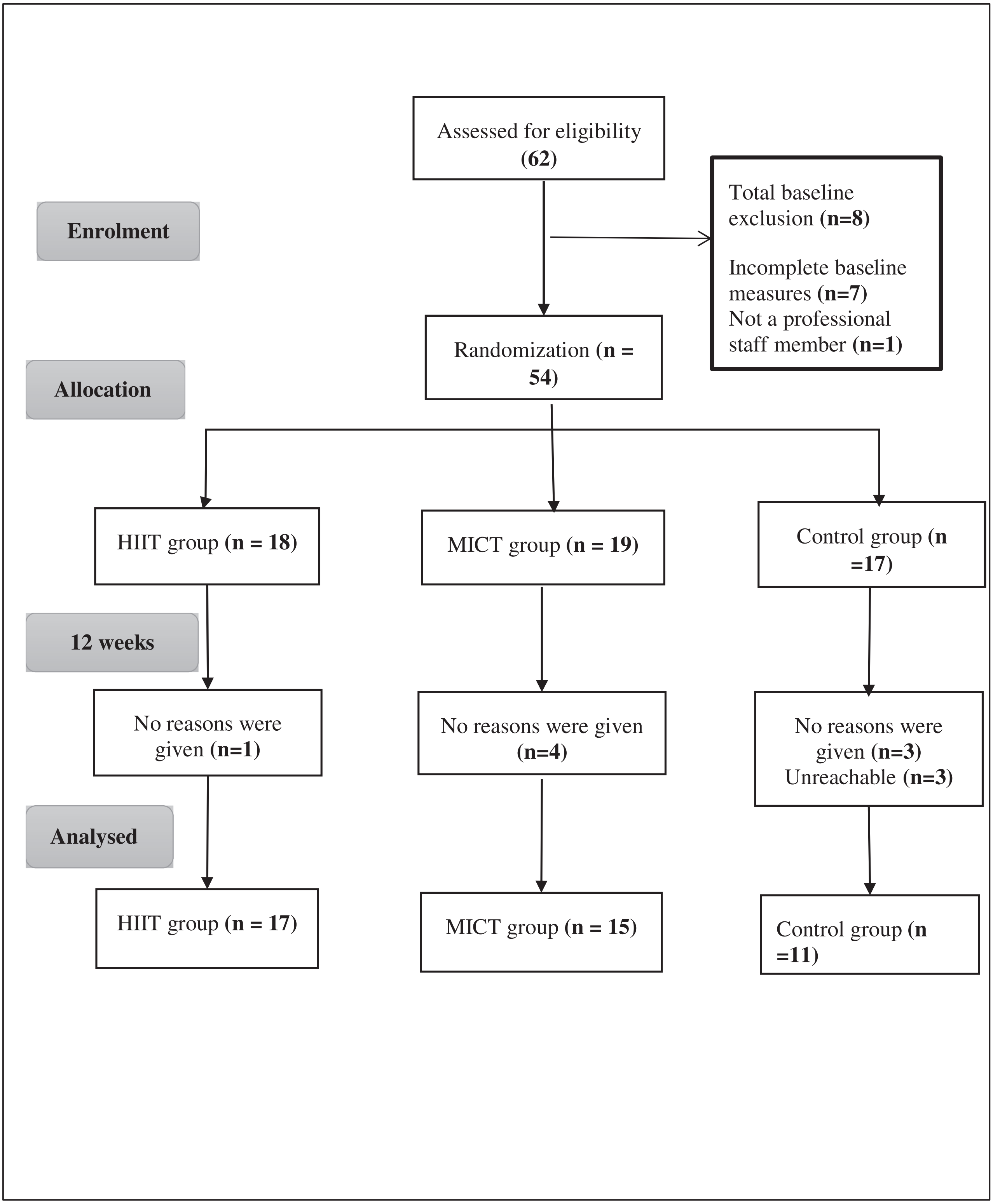

Figure 1: Randomisation process and participant allocation

A questionnaire was used to collect information on age, gender, job role, and education. Height (m), weight (kg), and body mass index (BMI, kg/m^2) were measured using standard protocols (17). Waist circumference (cm), systolic and diastolic blood pressure (using an automated Omron M6 (HEM70001, Omron, Kyoto, Japan), and random blood glucose (using a CardioChek Plus Professional Analyzer) were also measured. Cardiorespiratory fitness (VO_{2max} (mL.kg^{-1}.min^{-1}) was assessed using the 3-minute Queen's College step test (18).

Analysis

Statistica version 13 (StataSoft Inc., Tulsa, OK, USA) was used for analysis. Normality was verified through Shapiro Wilk testing. Descriptive data were presented as mean ± SD. The differences between baseline and 12-week, follow-up analysis of covariance (ANCOVA) is presented as effect sizes (Cohen's d) and the differences between study groups was determined using analysis of variance (ANOVA). The effect sizes were interpreted as large (≥0.8), moderate (0.4 to 0.8), small (0.2 to 0.4), and trivial (<0.2). Data were categorised into weekly blocks for the haemodynamic data in the HIIT and MICT groups. ANOVA was used to determine the differences in absolute changes in outcomes of interest between the control group and intervention groups. Significance was set at $p < 0.05$.

RESULTS

Participant characteristics

The demographic and baseline descriptive statistics of all participants and of each separate group are presented in Table 1. Most of the participants were female; 36 (83.7%). Measurements were similar between the groups at baseline, with notably high BMIs across all groups.

Training data of participants in the HIIT and MICT intervention groups

The HIIT group completed 189 exercise sessions, while the MICT group completed 177 exercise sessions in the 12-week intervention. Supplementary Table 2 displays the progression of training from week 1 to week 12. Overall, the HIIT group had a lower total duration of exercise compared with the MICT group ($t = –7.66$, $p < 0.0001$), however expended more energy ($t = 3.78$, $p < 0.001$) and cycled a higher total distance ($t = 4.73$, $p < 0.001$). The MICT group had lower average heart rates for the exercise session ($t = 15.0$, $p < 0.0001$), lower power output ($t = 6.28$, $p < 0.0001$) and lower self-reported RPE for the session ($t = 5.94$, $p < 0.0001$) compared with the HIIT group.

Effectiveness of the HIIT and MICT interventions

Table 3 presents the values and effect statistics for the between-group comparisons for cardiometabolic health. Compared with the control group, the HIIT and MICT intervention effect on waist circumference was a large effect of –5.3 cm (95%CI: –8.4 to –2.2 cm, d = –1.4) and –4.0 cm (–6.5 to –1.47 cm, d = –1.3), respectively. Similar large effects were observed for BMI in the HIIT (d = –2.4) and MICT (d = –1.9) groups. We observed moderate to large effects for systolic blood pressure (HIIT: –12.4 mmHg (–22.2 to –2.6 mmHg, d = –1.0); MICT: –10.1 mmHg (–18.9 to –1.2 mmHg, d = –0.9), diastolic blood pressure (HIIT: –6.2 mmHg (–13.5 to 1.1 mmHg, d = –0.7; MICT: –7.7 mmHg (–14.5 to –1.0) mmHg, d = –0.9) and glucose (HIIT: –1.9 mmol/L^{-1} (–2.9 to –1.0 mmol/L^{-1}, d = –1.7; MICT: -2.0 mmol/L^{-1} (–3.0 to –1.1 mmol/L^{-1}, d = –1.8). A large effect on VO2max was observed in the HIIT (+7.5 mL.kg–1.min^{-1}; 5.0 to 10.1 mL.kg^{-1}.min^{-1}, d = 2.4) and MICT (+7.0 mL.kg^{-1}.min^{-1}; 4.7 to 9.4 mL.kg^{-1}.min^{-1}, d = 2.4) interventions.

Table 1: Demographic and baseline characteristics (n = 43)

	Combined (HIIT, MICT & Control) (n = 43)	HIIT (n = 17)	MICT (n = 15)	Control (n = 11)	p-value for model
Female (%)	36 (83.7)	13 (76.5)	12 (80)	11 (100)	0.23
Completed high school (%)	24 (55.8)	10 (23.3)	9 (20.9)	5 (11.6)	0.73
Weight (kg)	82.9 ± 17.9	81.6 ± 16.2	87.4 ± 22.5	78.7 ± 12.8	0.45
BMI (kg/m^2)	31.6 ± 7.1	30.2 ± 6.0	34.2 ± 9.2	30.2 ± 4.9	0.22
WC (cm)	98.0 ± 12.8	95.2 ± 12.6	101.3 ± 13.7	98.0 ± 12.1	0.42
SBP (mmHg)	125.0 ± 15.2	127.0 ± 18.2	124.0 ± 11.1	124.3 ± 16.2	0.81
DBP (mmHg)	81.6 ± 11.0	82.7 ± 12.7	80.7 ± 9.7	81.1 ± 10.5	0.88
RBG (mmol/L^{-1})	6.3 ± 1.5	6.4 ± 1.4	6.7 ± 1.6	5.5 ± 1.3	0.13
VO_{2max} (mL.kg^{-1}.min^{-1})	47.0 ± 9.5	48.0 ± 10.5	47.4 ± 11.3	44.9 ± 2.7	0.71

Body Mass Index (BMI); DBP-diastolic blood pressure; SBP-systolic blood pressure; Waist Circumference (WC); Random blood glucose (RBG)

Supplementary Table 2: Training data of participants in the HIIT and MICT interventions

Week	Exercise modality	Sessions/ week (n)	Duration/ week	Calories/ week	Distance/ week	Average_HR/ session	Average power output (W)/ session	Average RPE/session
1	MICT	2.25	67.5 ± 13.9	329 ± 102	24.0 ± 10.3	136 ± 4.12	52.7 ± 5.52	7.23 ± 0.99
	HIIT	*2*	*42.5 ± 16.7**	*381 ± 186*	*28.2 ± 12.8*	*167 ± 10.1*	*61.5 ± 12.6*	*8.51 ± 1.7*
2	MICT	2.5	75 ± 27.8	368 ± 152	30.6 ± 11.0	133 ± 2.80	56.0 ± 10.5	6.1 ± 0.8
	HIIT	*2.83*	*51 ± 7.35*	*480 ± 53.1*	*35.7 ± 4.43*	*156 ± 9.0**	*58.8 ± 10.8*	*7.1 ± 1.35*
3	MICT	2.5	87.5 ± 26.5	393 ± 138	28.1 ±9.34	131 ± 3.76	53.9 ± 8.6	5.25 ± 0.71
	HIIT	*2.25*	*45 ± 14.1**	*412 ± 172*	*30.0 ± 12.0*	*163 ± 10.2**	*58.0 ± 11.4*	*6.83 ± 1.61**
4	MICT	1.89	65.6 ± 22.4	313 ± 160	23.1 ± 10.3	129 ± 1.57	56.8 ± 6.73	5.12 ± 0.84
	HIIT	*2.13*	*44.5 ± 23.9*	*397 ± 220*	*29.4 ± 16.2*	*161 ± 10.4**	*58.6 ± 9.39*	*6.65 ± 1.36**
5	MICT	1.33	53.3 ± 20.7	234 ± 127	17.2 ± 7.56	129 ± 4.29	60 ± 3.39	5.08 ± 1.02
	HIIT	*1.5*	*33 ± 12.7*	*330 ± 142*	*23.1 ± 9.29*	*156 ± 7.08*	*69 ± 5.58**	*6.25 ± 0.96**
6	MICT	2.13	85 ± 33.4	380 ± 167	27.1 ± 11.6	128 ± 5.3	57.3 ± 6.1	5.1 ± 1.0
	HIIT	*2.33*	*50.7 ± 11.0**	*490 ± 143*	*35.5 ± 8.65*	*154 ± 5.87**	*67.6 ± 11.5*	*5.81 ± 1.33*
7	MICT	1.75	76.9 ± 34.1	350 ± 195	24.8 ± 12.8	128 ± 3.74	58.7 ± 3.31	4.9 ± 1.04
	HIIT	*2.5*	*55.5 ± 19.9*	*537 ± 253*	*40.7 ± 10.2*	*157 ± 6.71**	*71.8 ± 11.5**	*6.14 ± 1.5**
8	MICT	2.13	92.3 ± 38.3	421 ± 184	29.5 ± 11.8	128 ± 4.53	57.8 ± 5.03	4.39 ± 0.70
	HIIT	*2.63*	*63 ± 17.9**	*586 ± 310*	*41.2 ± 16.6*	*155 ± 6.79**	*71.7 ± 20.2*	*5.92 ± 0.85**
9	MICT	1.75	85 ± 0.0	357 ± 147	25.2 ± 9.83	129 ± 7.56	59.1 ± 3.62	5.4 ± 0.88
	HIIT	*2*	*48 ± 0.0**	*389 ± 110*	*31.0 ± 10.1*	*174 ± 53.3**	*73.8 ± 21.5*	*5.75 ± 0.89*
10	MICT	1.5	69.4 ± 25.4	291 ± 119	20.4 ± 7.31	130 ± 5.39	58.1 ± 6.49	5.5 ± 5.39
	HIIT	*2.25*	*56.3 ± 11.6*	*485 ± 162**	*36.0 ± 11.3**	*154 ± 5.46**	*69.4 ± 15.7*	*5.44 ± 0.98*
11	MICT	2.14	117.1 ± 37.0	466 ± 181	31.2 ± 8.28	127 ± 5.61	56.7 ± 6.89	5.09 ± 1.39
	HIIT	*2*	*53 ± 15.3**	*479 ± 150*	*35.1 ± 10.6*	*154 ± 3.47**	*73.3 ± 13.3**	*6.56 ± 0.82**
12	MICT	2.33	128.3 ± 31.8	484 ± 104	34.4 ± 7.55	128 ± 4.8	51.1 ± 6.68	4.83 ± 0.76

Data presented as mean±SD; *p < 0.05 versus the MICT group

Table 3: Changes in anthropometry, blood pressure, glucose and VO_{2max}

	HIIT	MICT	Control	HIIT vs Control		MICT vs Control	
	Mean change (mean (95% CI)	Mean change (mean (95% CI)	Mean change (mean (95% CI)	Mean change (mean (95% CI)	Effect size (*d*)	Mean change (mean (95% CI)	Effect size (*d*)
Waist (cm)	–2.8 (–4.8 to –0.8)*	–1.5 (–2.8 to –0.2)*	2.5 (–0.1 to 5.1)*	–5.3 (–8.4 to –2.2)	–1.4	–4.0 (–6.5 to –1.47)	–1.3
BMI (kg/m^2)	–1.2 (–1.7 to –0.8)*	–0.7 (–1.2 to –0.2)*	1.4 (0.5 to 2.3)*	–2.6 (–3.5 to –1.8)	–2.4	–2.1 (–3.0 to –1.2)	–1.9
SBP (mmHg)	–8.3 (–13.8 to –2.7)*	–6.0 (–10.1 to –2.0)*	4.1 (–5.5 to 13.7)*	–12.4 (–22.2 to –2.6)	–1.0	–10.1 (–18.9 to –1.2)	–0.9
DBP (mmHg)	–0.5 (–4.9 to 3.9)	–2.0 (–5.6 to 1.6)	5.7 (–1.2 to 12.6)	–6.2 (–13.5 to 1.1)	–0.7	–7.7 (–14.5 to –1.0)	–0.9
RBG ($mmol/L^{-1}$)	–0.9 (–1.5 to –0.2)*	–0.96 (–1.7 to –0.2)*	1.1 (0.5 to 1.7)*	–1.9 (–2.9 to –1.0)	–1.7	–2.0 (–3.0 to –1.1)	–1.8
VO_{2max} ($mL.kg^{-1}.min^{-1}$)	4.9 (3.2 to 6.6)*	4.4 (2.9 to 6.0)*	–2.6 (–4.8 to –0.4)*	7.5 (5.0 to 10.1)	2.4	7.0 (4.7 to 9.4)	2.4

Body Mass Index (BMI); DBP diastolic blood pressure; SBP–systolic blood pressure; Waist Circumference (WC); Random blood glucose (RBG)

DISCUSSION

There is an increasing need for interventions in Africa to reverse the rising prevalence of obesity and NCDs.(19) Physical activity has benefits for preventing cardiometabolic diseases, and time efficient modalities such as HIIT protocols are emerging as attractive alternatives to MICT for addressing cardiorespiratory fitness,(20) lowering blood pressure,(21) and improving glycaemic control.(22) This study provides data on the effectiveness of workplace interventions that have potential for application for African populations at risk of disease of lifestyle. Research has confirmed the effectiveness of HIIT in athletic performance,(23) however these studies have little direct application to public health. In recent years, however, emerging studies are investigating the impact of HIIT in the general population.(13, 24, 25) Importantly, no studies of this nature have been conducted in LMIC workplaces,(26) and our findings suggests that either HIIT or MICT exercise protocols provides several health benefits to a cohort of University workers following a 12 week intervention.

The reductions in anthropometric variables (BMI and waist) in the HIIT and MICT groups using cycle ergometers in a gym setting demonstrates that these approaches to physical activity significantly enhanced weight loss. While these protocols were both effective on weight loss, the magnitude of weight was greater than for waist circumference, an indicator of central fat, following the HIIT training (–2.8, 95%CIs: –4.8, –0.8, $p < 0.05$). These findings are consistent with evidence from a meta-analysis (11) and a recent RCT investigation,(27) showing that HIIT can result in better improvements in body composition and anthropometric factors associated with NCDs, than MICT. Our findings are important for developing workplace interventions that support the emerging body of literature showing a reduction in body weight with shorter duration, dose-dependent exercise.(14) The HIIT group exercised less than the MICT group (51.3 ± 16.8 mins/week vs 81.7 ± 32.6 mins/week, respectively), however, expended a larger amount of energy (460 ± 194 calories/week versus 361 ± 156 calories/week, respectively). Our data, therefore, indicates that HIIT can provide additional benefits to weight loss in approximately 60% of the time required for MICT to achieve comparable results, which is similar to data demonstrated by previous studies.(28, 29) In the context of the increasing obesity crisis in SSAs, further investigation is therefore needed on the long-term effects of HIIT and MICT on weight management in the study participants.

Blood pressure is an important marker of cardiovascular health and the main driver of multi-morbidity amongst South Africans.(30) Physical activity that is performed regularly at a moderate-to-high intensity is known to reduce blood pressure in hypertensive patients (31) and improve glycaemic control in people living with type 2 diabetes.(32) However, most individuals in sub-Saharan African countries, including South Africa, are insufficiently active.(33) In our study, significant and comparable reductions in systolic blood pressure were observed with HIIT training ($d = -1.0$) and MICT training ($d = -0.9$), supporting previous research.(31, 34) These findings indicate that HIIT and MICT protocols could be considered as effective modalities to help address elevated blood pressure in the workplace. In addition, and in agreement with several studies, our results observed large reductions in blood glucose concentrations (22, 35) and improvements in cardiorespiratory fitness.(9, 20). Cardiorespiratory fitness has an inverse independent association with cardiovascular disease and all-cause mortality,(36, 37) and prevents obesity-related complications.(11) Thus, our study findings support current evidence for continuous training and the growing evidence for exercise benefits from short, interspersed exercise efforts that are time-efficient and not disruptive on work responsibilities.

LIMITATIONS

In considering the limitations of the study, a significant portion of participants did not complete the 12-week trial. We suspect that COVID-19 lockdown measures at the time presented restrictions including limited public transport access, hindering adherence to the exercise programmes. The study involved a relatively small number of participants, potentially affecting the generalizability of the findings. Research with larger sample sizes and longer follow-up periods is necessary to confirm the applicability of these results.

CONCLUSIONS

This study demonstrates the effectiveness of workplace interventions, with reduced BMI, waist circumference and blood pressure, and improved cardiorespiratory fitness. The improvements in cardiometabolic health were higher in the HIIT group compared with the MICT group, suggesting the potential for integration into vocational working hours as the HIIT protocols are relatively shorter in duration and therefore less demanding than MICT protocols. Further studies will be needed to test the generalizability of our findings in varying LMIC workforce environments and the adherence and acceptability of adopting HIIT and MICT workplace interventions in the long-term.

DECLARATIONS

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

PJG and MP conceived the study design, analysed and interpreted the data and drafted the manuscript. All authors read, edited and approved the last version of the article.

Funding

Research reported in this publication was supported by the South African Medical Research Council [SAMRC] with funds received from the Self-Initiated Research Grant [SIR]. MP is supported by the South African NRF Thuthuka grant.

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