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SPRINT INTERVAL TRAINING VS. HIGH INTENSITY INTERVAL TRAINING IN UNTRAINED UNIVERSITY STUDENTS

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ABSTRACT

Sprint interval training (SIT) involves repeated bouts of high-intensity training ('all-out' activity of 10-30 seconds) with successive periods of low-intensity activity or rest. High-intensity interval training (HIIT) also involves high-intensity training (90% of VO_2 max), usually one to four minutes, interspersed with recovery intervals of low-intensity activity or rest. The study aimed to compare directly various physiological and performance parameters of SIT and HIIT with a non-exercise control group amongst untrained university students. Sixty-three untrained (37 men and 26 women) participants (22±1.7yrs) volunteered for the study and were randomly allocated to SIT, HIIT and control group. Maximal oxygen uptake, the Yo-Yo intermittent recovery test (YYIRT), 20-metre speed, agility T-test, vertical jump and Wingate-test was assessed before and after 7-weeks of training. Both interval groups improved significantly compared to the control group for VO_2 max, peak treadmill speed, YYIRT and 20-metre speed ($p<0.05$) with no significant differences between SIT and HIIT (effect sizes within groups ranging from small to large). Regarding power output associated with the Wingate test, significant improvements compared to the control were realised for SIT only ($p<0.05$). Both methods of IT are feasible to improve exercise capacity in untrained university students.

***Keywords*:** Sprint interval training; High-intensity interval training; Aerobic; Anaerobic; Untrained.

INTRODUCTION

Sprint and high-intensity interval training involve repeated efforts of high-intensity training with successive periods of lower intensity exercise or complete rest. Weston *et al*. (2014b) and Talanian (2015) attempted to provide clearer definitions and terminology for the different types of interval training (IT). They defined two unique types of IT. The first one involves repeated efforts of very high-intensity training ('all-out' or >150% of VO_2 max power) but of shorter duration (10-30 seconds), namely Sprint Interval Training (SIT). The work-rest ratio is usually 1:2 or 1:3. The second type of IT comprises of intervals of longer duration (1-4 minutes) but lower in intensity (80 to 100% of VO_2 max) and labelled this form of IT as High-Intensity Interval Training (HIIT). The work to rest ratio is usually 1:1. In many research studies, SIT is referred to as repeat sprint training (Taylor *et al*., 2015; Boer & Van Aswegen, 2016; Brocherie *et al*., 2017) and HIIT as aerobic interval training (Moholdt *et al*., 2009; Ingul *et al*., 2010; Seiler *et al*., 2013). The study by Weston *et al*. (2014b) and Talanian (2015) assisted researchers in using more uniform terminology.

The improvements were seen in anthropometric, physiological, functional, and performance-based variables for both of these training modalities have been reported extensively in the literature and confirmed by meta-analyses (Hwang *et al*., 2011; Sloth *et al*., 2013; Gist *et al*., 2014; Weston *et al*., 2014a; Weston *et al*., 2014b; Taylor *et al*., 2015). Physiological improvements include enhancements in VO_2 max mediated through the increases in muscle oxidative capacity, stroke volume, contractile capacity, endothelial function, Ca^{2+} transport and capillary density in the skeletal muscle (Helgerud *et al*., 2007; Burgomaster *et al*., 2008; Tjønna *et al*., 2009; Hwang *et al*., 2011). IT has demonstrated significant reductions in body mass, waist circumference, subcutaneous fats and abdominal fat (Boudou *et al*., 2003; Ingul *et al*., 2010; Heydari *et al*., 2012; Boer & Moss, 2016). IT has also been reported to improve performance significantly (Gibala & McGee, 2008; Cicioni-Kolsky *et al*., 2013) and metabolic variables, such as lipid profile, insulin, HOMA-IR and oxidative enzymes (Burgomaster *et al*., 2008; Gibala & McGee, 2008; Heydari *et al*., 2012). The functional ability also improved significantly with the use of IT especially in persons living with chronic diseases and disabilities (Nilsson *et al*., 2008; Boer & Moss, 2016).

IT has been purported to be more fun and of shorter total duration compared to traditional continuous aerobic training (CAT) (Bartlett *et al*., 2011; Thum *et al*., 2017). Besides, studies have reported more significant improvements for physiological, functional and anthropometric variables with IT compared to CAT (Wisløff *et al*., 2007; Ingul *et al*., 2010; Ciolac *et al*., 2011). However, uncertainty exists regarding physiological and performance improvements if different forms of IT are employed.

Few studies have compared different forms of IT directly, particularly SIT and HIIT (Helgerud *et al*., 2007; Ferrari Bravo *et al*., 2008; Farley *et al*., 2016; Inoue *et al*., 2016; Viano-Santasmarinas *et al*., 2017). In all of these studies, no control group existed and, in some, the random allocation between groups was not followed. Moreover, the sample size per group for most of the studies was small (Stepto *et al*., 1999 [n=5]; Helgerud *et al*., 2007 [n=10]; Ferrari Bravo *et al*., 2008 [n=13]; Farley *et al*., 2016 [n=12]; Inoue *et al*., 2016 [n=7]; Viano-Santasmarinas *et al*., 2017 [n=9]). Only the studies by Helgerud *et al*. (2007) and Ferrari Bravo *et al*. (2008) conducted the gold standard aerobic VO_2 max test.

Lastly, none of these investigations studied untrained individuals. These studies focussed on trained cyclists, soccer players, handball players, mountain bikers and surfers. Different anthropometrical, physiological and performance-based parameters may arise for untrained populations. Although a recent study did consist of a continuous running control group, the participants were physically active, and no laboratory maximal oxygen uptake tests were conducted (Cicioni-Kolsky *et al*., 2013).

PURPOSE OF RESEARCH

The purpose of this study was to compare the effects of SIT and HIIT in untrained individuals using a randomised controlled trial.

METHODOLOGY

Participants

Sixty-three untrained (37 men and 26 women) participants from the North-West University volunteered for the experimental research study. All participants studying towards a degree in the Faculty of Human and Social Sciences were eligible to partake in the study providing they conformed to the inclusion and exclusion criteria. To be included in the study, participants had to sign an informed consent form, needed to be between 18 and 25 years of age, and they had to answer 'no' to all questions listed in the Adapted Physical Activity Readiness Questionnaire (aPAR-Q). Participants were excluded if they were involved in structured exercise or sporting activities. Ethical permission was obtained from the Ethics committee of the North-West University (NWU-00414-17-A9). Only five individuals dropped out of the study leaving n=58.

Study design

A three-group, parallel, longitudinal (pre-test to post-test) experimental design was employed. Participants were randomly allocated to one of three groups (SIT; HIIT and Control). This procedure involved pulling a card from a hat so that the participant had a 33.33% probability of drawing one of the three groups. The random allocation to one of three groups and dropouts throughout the study is demonstrated schematically in Figure 1.

Procedures

Participants visited the Exercise Physiology Laboratory on six occasions. Upon the first visit, the study was explained, and information sheets, consent forms and the aPAR-Q were handed out. After three days, the consent and aPARQ forms were collected and studied for inclusion. Participants were familiarised with the testing equipment, procedures and environment. Upon the third visit, participants visited the laboratory where height and body mass measurements were taken. After a ten-minute warm-up the maximal oxygen consumption test was measured. After another three days, the vertical jump, 20-metre sprint and agility T-tests were done. After two days of rest, the Yo-Yo Intermittent Recovery test was performed.

Finally, after another two days elapsed, the Wingate test was performed. All measurements were conducted in the morning (between 08:00 and 11:00) after an 8-minute warm-up at a low to moderate intensity. Before each testing session, participants were instructed not to eat for at least three hours before testing and not to drink coffee or beverages containing caffeine for eight hours before testing. Before the commencement of the study an informal pilot evaluation was conducted to determine the test-retest reliability of the manually recorded times of the sprint (ICC=0.82) and agility (ICC=0.89) tests.

Tests

Body mass and height

Body mass and standing height were conducted with a Seca scale and stadiometer (Seca, Hamburg, Germany). Participants wore lightweight trunks and shirt only. The height and mass measurements were used to calculate body mass index (BMI).

Maximal oxygen consumption test

Participants performed a running VO_2 max test on a motorised treadmill (Woodway 4Front, Foster Court, Waukesha, WI, USA) using an incremental protocol in the Exercise Physiology Laboratory of the University. Participants completed an 8-minute warm-up at a velocity of 5- to 8 km/h. For men, the test started at 8 km/h and 1% incline. After two minutes, the speed increased to 9 km/h, and after another two minutes, the speed increased to 10 km/h. After that, the speed increased by 1 km/h every minute until voluntary exhaustion.

For the women, the same protocol was followed, but they started at an initial velocity of 6 km/h. The testing protocols were conducted in such a manner to induce fatigue between 8 and 12 minutes. Achievement of VO_2 max was considered when two of the following three criteria were met: (1) A plateau in VO_2 despite increasing speed (less than 150 ml increase of VO_2 during the last stage of exercise); (2) A respiratory exchange ratio above 1.15; and (3) a heart rate maximum within 10 beats of age-predicted maximal heart rate (220-age) (Howley *et al*., 1995). Gas exchange was continually measured (breath by breath) with the Cosmed Quark CPET metabolic analyser (Cosmed, Rome, Italy).

The system was calibrated with known concentrations of nitrogen, oxygen and carbon dioxide before each test. Participants were fitted with the Cosmed HR monitor. All raw values were filtered and averaged over 10 seconds. Participants were continually encouraged to run to volitional exhaustion. Exercise testing was terminated when the participants signalled to stop or when they grasped the handrails.

Yo-Yo Intermittent Recovery test 1

The YYIRT consists of 20-metre shuttle runs performed at increasing velocities with a ten-second passive recovery between shuttles (Krustrup *et al*., 2006). Audio cues were played with a portable CD player. The test was terminated when the participant failed to reach the front line on two consecutive occasions or when he/she felt unable to perform another shuttle (Krustrup *et al*., 2006). Level scores were converted to shuttle scores.

20-metre sprint test

The 20-metre sprint test was assessed as specified in the Australian Institute of Sport (2013). The participant warmed-up before the test, performing a couple of short accelerations in preparation of the test. Two independent assessors recorded sprint times manually with a stopwatch. If the time between the assessors differed by more than five split seconds, the test was repeated. Three trials were administered with five-minute rest periods between sprints. Participants started from a resting position with the preferred foot behind the front line. The best time of three attempts was recorded. The pilot study indicated good test-retest reliability of manual time measurements (ICC=0.82).

Agility T-test

The Agility T-test was conducted to assess agility (Australian Institute of Sport, 2013). The participant placed the preferred foot behind the starting line (point A). The participant accelerated forward for 10 metres and touched a marker with the hand (point B), then sprinted right (90-degree turn) for 5 metres and touched a cone from where the participant sprinted to the left (180-degree turn) for 10 metres (past point B) and touched a cone. After that, they sprinted back to point B (180-degree turn) for 5 metres where they accelerated back to the starting position (90-degree turn). Two trials were assessed with 10-minute rest between trials. Again, the time was recorded by two independent assessors using the same criteria as outlined before. The best time of two attempts was recorded. The pilot study indicated good test-retest reliability of manual time measurements (ICC=0.89)

Vertical jump

Lower-leg explosive power was analysed with a vertical jump test (Australian Institute of Sport, 2013). Reach height was recorded with the participant extending his/her arm vertically against the wall without stretching. The jump was visually demonstrated on how to execute three jumps of maximal distance. Participants were allowed to use their arms to initiate the movement, but a double-jump was not permissible. Maximum jump height was recorded as the difference between maximum jump height and reach height. The average of the best two trials was recorded.

30-second Wingate test

After a 10-minute easy cycle (100 watts for men and 80 watts for women), and two or three sprints of five seconds each, the Wingate test (Bar-Or, 1987) was assessed on the Wattbike (Wattbike Ltd, Nottingham, UK). Before the test, the seat height was adjusted according to the stature of the participant. The knee was slightly bent when the leg was maximally extended. Support around the foot was used to ensure maximal safety during the test. Subjects were verbally and continually encouraged throughout the 30-second test. They were instructed to start the test at the highest possible intensity (out the saddle) and to record maximal watts during the first five seconds of the test. Participants were allowed to assume a seated position nearing the closing seconds of the test. Peak power was assessed as the highest wattage recorded in any five-second segment of the test. Mean power was recorded as the average wattage during the entire 30-seconds of high-intensity cycling.

Intervention programmes

All groups were encouraged to continue with normal daily activities as they had done previously. The control group performed no structured training. Training took place, three days a week for seven weeks. All exercise sessions were supervised by a qualified exercise physiologist. Six possible training sessions were conducted during the week (Monday to Saturday) of which the participant attended three sessions on non-consecutive days.

All participants performed a non-standardised warm-up at a low to moderate intensity for five minutes. For SIT, maximal (all-out) shuttle sprints were conducted between two lines 20 metres apart for 30 seconds using five repetitions. Participants were instructed to sprint maximally from the start of the sprint. A 60-second passive rest period was implemented between repetitions (1 to 2 work-rest ratio). Three sets were performed with five-minute passive rest between sprints. Total session time lasted approximately 32 minutes. Participants were asked to touch the line at every 180-degree turn, with continuous accelerations and decelerations.

The HIIT group performed four-four minute repetitions of high-intensity training at 90% of maximum heart rate (assessed during the VO_2 max test). HIIT consisted of a continuous circular running around a field (400 metres). Each four-minute interval of training was separated by four minutes of passive rest (1:1 work-rest ratio). Total session duration was 32 minutes. Training intensity was monitored using heart rate monitors with short-range telemetry systems (Zephyr Technology Corporation, Annapolis, MD, US). The Bio-harness records HR via cardiac electrical impulses that are relayed to a transmitter.

After four weeks of training, the repetitions in the SIT increased to six per set, and the distance between lines decreased to 10 metres (more 180-degree turns). The sets for the HIIT increased to five and the intensity to 95% of maximum after four weeks of training. Training compliance was monitored and strictly controlled throughout the study. A daily and weekly attendance register was used throughout the study period to record adherence to the intervention. After seven weeks, the same pre-tests were administered in the same order and time of day as before.

Statistical analyses

Statistical analyses were performed with the available statistical software, SPSS (SPSS 24.0, SPSS Chicago, IL, USA). Data were analysed for normality using the Shapiro-Wilk test statistic. Homogeneity of group was assessed with the Levene test statistic. Data are expressed as mean (M) and standard deviation (SD). In order to evaluate pre-post differences between the three groups (time, group and interaction) a repeated analysis of covariance (ANCOVA) with post-hoc Bonferroni was conducted. The covariate variable was the participants' baseline value. Data were screened to determine whether ANCOVA assumptions were violated. Cohen's d effect sizes were calculated and interpreted as trivial $d<0.15$; small with $d\geq0.2$ and $d<0.50$; medium with $d\geq0.50$ and $d<0.80$; and large with $d\geq0.80$ (Cohen, 1988). Significance level was set at $p<0.05$.

RESULTS

Sixty-three (n=63) individuals volunteered for the study. Only five individuals dropped out of the study due to injury in an everyday living activity (n=1); incomplete sessions halfway through the intervention (n=1); no-show after pre-testing in the control group (n=3). The final 58 participants (34 men and 24 women) were 21.9±1.73 years of age with 62.89±16.74kg body mass, 166.8±7.95cm height and BMI of 22.6±6.03kg/m^2. No serious or adverse events occurred during the baseline, intervention or post-testing period demonstrating the feasibility of IT in untrained participants. The information regarding study participation and dropouts are schematically demonstrated in Figure 1.

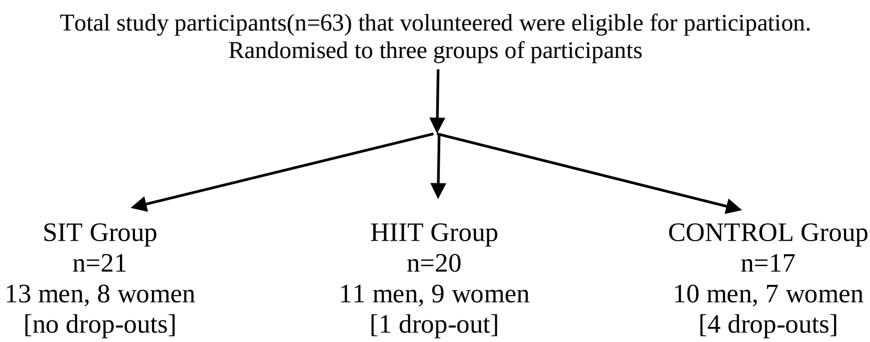

Figure 1**.** **DIAGRAM DEPICTING MATCHING AND RANDOMISATION PROCEDURE DURING THE TRIAL**

Participants attended a minimum of 17 sessions and a maximum of 21 sessions over seven weeks. The mean percentage of compliance in the SIT group was 93% percent and 96% in the HIIT group. Exercise sessions missed were due to personal commitments, sickness or work-related activities.

The results of the general descriptive and anthropometric data are provided in Table 1. No statistically significant differences in baseline values were observed for body mass, height and BMI between groups. No significant differences resulted between groups post-intervention. A significant within-group (time) difference was reported for body mass (p=0.019) and BMI for HIIT (p=0.019) group.

***Table 1*. VARIABLES FOR SPRINT INTERVAL GROUP (SIT), HIGH-INTENSITY INTERVAL GROUP (HIIT)AND CONTROL GROUP (M±SD)**

Variables	SIT (n=21)		HIIT (n=20)		Control (n=17)	
Age (yrs)	21.6±1.6		22.3±1.6		21.7±2.1	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
B-Mass (kg)	62.9±18.4	62.9±18.3	63.8±16.9	62.8±16.2*	61.8±15.2	61.4±14.9
Height (cm)	167.0±6.7	166.8±6.8	165.1±8.8	165.2±8.9	168.6±8.3	168.5±8.2
BMI (kg/m^2)	22.6±6.7	22.6±6.9	23.5±6.7	23.1±6.5*	21.6±4.3	21.4±4.1

* Significant difference within-group (time)

***Table 2*. PHYSICAL PERFORMANCE VARIABLES FOR SIT, HIIT AND CONTROL GROUPS (M±SD)**

Variables	**SIT** (n=21)		**HIIT** (n=20)		**CONTROL** (n=17)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
VO_2 max (ml/min/kg)	36.30±9.7	41.2±10.1#	37.7±9.5	42.2±10.5#	37.8±9.2	38.4±9.9
RER	1.21±0.1	1.19±0.08	1.16±0.07	1.20±0.06	1.15±0.09	1.20±0.09
HR max	195.8±7.4	194.3±7.7	197.4±9.9	193.6±7.2	190.3±7.3	189.3±7.8
PTS (km/h)	13.6±2.8	15.4±3.2#	13.3±3.1	15.1±3.2#	14.0±3.6	14.5±3.7
20-metre sprint (seconds)	3.78±0.5	3.73±0.5#	3.98±0.7	3.89±0.7#	3.73±0.6	3.84±0.5
Agility T-test (seconds)	11.69±1.5	11.21±1.3	12.13±1.6	11.8±1.9	11.41±1.7	11.24±1.3
YYIRT (shuttles)	13.3±8.9	27.0±19.6#	10.3±7.4	23.2±16.3#	16.8±12.0	23.2±17.0
Vertical jump (centimetre)	39.2±10.1	39.3±11.0	36.7±9.2	36.8±10.0	44.1±12.1	42.4±11.6
Wingate-PP (watts)	514.7±230.6	608.5±225.6#	489.1±157.9	538.7±128.9	554.9±253.6	581.6±238.0
Wingate-MP (watts)	344.8±158.4	401.9±147.2#	326.3±100.5	358.8±100.4	374.6±165.9	396.3±154.7

SIT=Sprint Interval Training; HIIT=High Intensity Interval Training; HR max=Maximum Heart Rate; PTS=Peak Treadmill Speed; RER: Respiratory Exchange Ratio; VO_2 max=maximal oxygen consumption, YYIRT: Yo-Yo intermittent recovery test # Significant difference between SIT and control or HIIT and control

The results for all exercise-related variables are depicted in Table 2. No statistically significant differences resulted between groups for any variables at baseline. Maximal oxygen uptake, peak treadmill speed, 20-metre sprint, YYIRT all improved statistically significantly compared to the control group for both training groups (SIT vs. control; HIIT vs. control) ($p<0.05$). This finding was also demonstrated when men and women were analysed separately, keeping in mind that the starting velocities for men and women were different ($p<0.05$). The results from the Wingate test showed that mean power and peak power improved statistically significantly compared to control for SIT only ($p<0.05$). There were no statistically significant improvements between the two exercise groups (SIT and HIIT) for any of the variables assessed.

Cohen's d effect sizes were calculated for all exercise-related variables. The effect was medium for maximal oxygen consumption and peak treadmill speed for both training groups. Small effect sizes were recorded for the agility and mean power of the Wingate anaerobic test for both training groups. Large effect sizes are reported for the YYIRT for both exercise groups (Table 3).

***Table 3*.** **EFFECT SIZES OF EXERCISE-ASSOCIATED VARIABLES FOR SIT, HIIT AND CONTROL GROUPS** (represented as changes within groups)

	Sprint interval training (n=21)		**High intensity interval** (n=20)		**Control** (n=17)	
Variables	**ES**	**Magnitude**	**ES**	**Magnitude**	**ES**	**Magnitude**
VO_2 max (ml/min/kg)	0.50	Medium	0.45	Small	0.06	Trivial
PTS (km/h)	0.61	Medium	0.58	Medium	0.12	Trivial
20-metre sprint (sec)	0.10	Trivial	0.12	Trivial	0.00	Trivial
Agility T-test (sec)	0.33	Small	0.18	Small	0.12	Trivial
YYIRT (shuttles)	0.90	Large	1.03	Large	0.44	Small
Vertical jump (cm)	0.01	Trivial	0.01	Trivial	0.00	Trivial
Wingate-PP (watts)	0.41	Small	0.34	Small	0.11	Trivial
Wingate-MP (watts)	0.37	Small	0.32	Small	0.14	Trivial

ES=Effect Size

DISCUSSION

The primary aim of the study was to compare the effects of two different types of interval training among various anthropometrical, physiological and performance variables in untrained university students. The fitness sessions were well attended as evidenced not only by the excellent compliance and attendance (95%) but also by the low number of drop-outs in the intervention groups (n=1). No injuries occurred during either one of the intervention studies. Participants adhered to the training intensities prescribed.

Previous studies determined the effect of different interval training interventions in trained individuals across different sports, but neglected to include a control group (Helgerud *et al*., 2007; Ferrari Bravo *et al*., 2008; Farley *et al*., 2016; Inoue *et al*., 2016; Viano-Santasmarinas *et al*., 2017). The current study had a large sample size and included a control group utilising a randomised trial.

The results regarding the anthropometric profile revealed no significant improvements for either training group, although the BMI of the HIIT improved significantly pre to post. The population studied were healthy young adults with BMI values ranging within the normative category, and consequently, no significant improvements were expected. Regarding improvements in lean mass or reductions in fat mass, a more thorough investigation of body composition analysis may have provided more specific results.

Both training groups improved significantly on most exercise parameters compared to the control group. However, there was no statistical indication that the one training modality outperformed the other on all measured variables. However, the anaerobic Wingate test's mean and peak power improved significantly in the SIT group only when compared to the control group. Although the intervention period included running based intervals, the anaerobic nature of the short sprints (30-second all-out intensity) may have contributed to this finding. Besides, the continuous acceleration and deceleration nature of SIT could have provided the necessary leg power for 30-second all-out peak and mean cycling intensity.

Maximal oxygen uptake and peak treadmill speed improved significantly in both training groups compared to the control group with no significant differences between training modalities. The improvement is most likely due to the many central and peripheral adaptations that accrue with both training modalities as evidenced in other SIT and HIIT studies (Helgerud *et al*., 2007; Burgomaster *et al*., 2008; Tjønna *et al*., 2009; Hwang *et al*., 2011; Gibala *et al*., 2012). The studies that compared SIT with HIIT (without a control group), demonstrated significant improvements within groups for maximal aerobic capacity with no difference between groups (Helgerud *et al*., 2007; Ferrari Bravo *et al*., 2008). Regarding performance-based aerobic measures, both SIT and HIIT improved significantly within and not between groups in adolescent surfers with a 400-metre paddling time trial (Farley *et al*., 2016). This finding was also reflected in trained cyclists with SIT and HIIT training groups improving in a simulated 40-km time trial (Stepto *et al*., 1999). Lastly, a similar improvement in 3000-metre running time-trial performance was also studied between SIT and HIIT (with no significant difference between training groups) in physically active individuals (Cicioni-Kolsky *et al*., 2013).

The mechanisms responsible for an improvement in aerobic capacity could be explained by an enhancement in skeletal muscles oxidative capacity, stroke volume, oxidative enzymes and PGC-1α as demonstrated by studies using SIT (Helgerud *et al*., 2007; Burgomaster *et al*., 2008; Gibala *et al*., 2012). Studies using HIIT, demonstrated improvements in peak oxygen pulse, cardiac output, contractile capacity, capillary density, left ventricular ejection fraction, oxidative enzymes, endothelial function and calcium reuptake. In the current study, no central or peripheral adaptations were assessed, but similar aerobic improvements for both training groups were reported in previous studies (Helgerud *et al*., 2007; Ferrari Bravo *et al*., 2008).

Significant improvements with large effects sizes were reported for both training groups in the YYIRT. This finding was also reported by Ferrari Bravo *et al*. (2008) with SIT and HIIT in professional football players. However, in their study, the SIT improved more significantly compared to the HIIT group. SIT more closely mirrors the YYIRT test with repeated shuttles and continuous 180-degree turns. Perhaps the lower baseline fitness levels of the untrained participants in the current study contributed to both the SIT and HIIT groups improving significantly but not so between the two groups. It has been shown that the YYIRT is moderately correlated to VO_2 max and both training groups improved similarly on this measure (Castagna *et al*., 2006; Krustrup *et al*., 2006). It is possible that both training groups improved performance on the YYIRT, but with different physiological adaptations. Lastly, the SIT group may have improved more than the HIIT group if the number of the 180-degree turns during the SIT training increased at an earlier stage.

Significant improvements were reported for 20-metre speed for both training groups compared to the control group although trivial effect sizes were reported. Ferrari Bravo *et al*. (2008) and Viano-Santasmarinas *et al*. (2017) reported no differences in 10-metre sprint times between SIT and HIIT after 6 weeks and 7 weeks of training, respectively. The study by Ferrari Bravo *et al*. (2008) demonstrated no improvements in sprinting ability. Their study hypothesised that the work-to-rest ratio was not specific to improve sprinting ability and that additional strength or power training was needed to elicit improvements in straight line sprinting. To obtain larger effect sizes, extra strength and power training may also be needed for this study. In another study, Cicioni-Kolsky *et al*. (2013) demonstrated that SIT training improved 40-metre sprinting more than HIIT with approximately 1:2 work-to-rest ratios.

The fact that the results of this study differed with the other studies (Ferrari Bravo *et al*., 2008; Viano-Santasmarinas *et al*., 2017) could possibly be attributed to the more substantial length of the sprint, different baseline fitness levels or different work-to-rest ratios. Also, the lack of a peak speed generation with 30-second sprint intervals (compared to shorter sprints [<15 seconds]) could explain the lack of improvement between SIT and HIIT (McKie *et al*., 2018).

Both groups demonstrated no significant improvements in agility performance compared to the control group. Recent studies employing SIT also showed no significant improvements compared to the control group in the agility T-test (Shalfawi *et al*., 2013; Boer & Van Aswegen, 2016). No studies that we are aware of that have compared different IT strategies have assessed agility performance. The reason for no improvement could be that the agility T-test involves 90- and 180-degree turns whereas SIT only included 180-degree turns. Furthermore, as explained in the previous paragraph, additional strength and power training or additional specific agility training may be necessary to elicit significant improvements in agility performance and larger effect sizes.

The last performance measure, explosive power in the lower limbs, resulted in no significant improvements with trivial effects sizes for both groups in the vertical jump test. It was not expected that the HIIT group would improve on lower body explosive strength (Helgerud *et al*., 2007; Ferrari Bravo *et al*., 2008), but that the SIT group with the numerous 180-degree turns associated with constant accelerations and decelerations could improve. Perhaps a standing long jump in a horizontal plane would have revealed different results as in a study of sub-elite football players (Boer & Van Aswegen, 2016). The SIT and HIIT group in the study by Ferrari Bravo *et al*. (2008) also revealed no significant improvements in jump height after 7-weeks of training, yet a study that included a greater amount of maximal sprints (shorter in duration) did report a significant improvement in jumping ability (Markovic *et al*., 2007).

The improvements shown in this study, are not only limited to various aerobic and anaerobic performance advantages but may also hold multiple functional and health benefits in an untrained population. Although not assessed in the study, other researchers have demonstrated improvements in quality of life, functional capacity, activities of daily living, skeletal muscle fat oxidation and variables associated with health, such as blood pressure, lipid profile and glucose tolerance as a result of SIT and/or HIIT training (Wisløff *et al*., 2007; Nilsson *et al*., 2008; Tjønna *et al*., 2008; Boutcher, 2010; Smart *et al*., 2011).

The limitations of the study are that speed and agility sessions could not be conducted with a photocells system, as the researchers did not have access to this kind of equipment. However, two independent exercise physiologists recorded the time, and if disagreement of more than four split seconds occurred, the test was repeated. Measurement and procedures were followed precisely as outlined in the Australian Institute of Sport (Australian Institute of Sport, 2013:202 & 236). A second limitation of the current study was that the training programmes were matched for time and were not necessarily isocaloric.

Future research should be conducted to determine the differences between SIT and HIIT when training programs are isocaloric. A prospective study should also compare the effect of shorter sprint intervals (<15 seconds) to a HIIT regimen, as recent studies demonstrated the positive effects and time-saving advantages thereof (Yamagishi & Babraj, 2017; Benitez-Flores *et al*., 2018; McKie *et al*., 2018). Future studies could also determine the combined effect of strength and SIT compared to strength and HIIT training. Lastly, a further study could determine the effect of SIT training protocols of the same work interval (30 seconds), but different rest intervals.

CONCLUSION

IT is an effective method to improve fitness and performance on various aerobic and anaerobic tests in untrained university students. Both training groups improved significantly on various aerobic (maximal oxygen uptake and peak treadmill speed) and anaerobic (YYIRT, 20-metre sprint) performance measures, but only the SIT group improved on 30-second all-out Wingate performance. The participants attended the vast majority of fitness sessions and no injuries resulted due to the very intense training regimens. Additional plyometric, strength training or combined training may be needed to elicit agility and lower limb explosive movement performance.

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