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Original Article

Effects of high-intensity interval training on health-fitness, health related quality of life, and psychological measures in college-aged smokers

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Abstract:
Background – The purpose of this study is to analyze the effects of high-intensity interval training on health-fitness, health related quality of life, and psychological measures in college-aged smokers. Methods – 40 college-aged male smokers were randomly assigned to 2 groups: a) HIIT group included high-intensity interval cycling training; b) Control group (CON) included participants without formal physical exercise. Intervention lasted for 8 weeks (3 sessions/week, and 33 minutes/session). HIIT group used 65-75% of maximal heart rate (HR_{max}) with a 20-min maximal work-out at 85%. The health-related quality of life (HRQOL) was assessed using the questionnaire WHOQOL-BREF and assessment of physical health parameters included hemodynamic, anthropometric, lung function and cardiorespiratory assessments. Results – Significant improvements in HIIT were seen in physical health (P=0.000), psychological state (P=0.001), social relationship (P=0.004), environment (P=0.000), resting heart rate (RHR) (P=0.000), systolic blood pressure (SBP) (P=0.007), rate pressure product (RPP) (P=0.000), mean arterial pressure (MAP) (P=0.000), waist (P=0.003), forced vital capacity (FVC) (P=0.001), forced expiratory volume (FEV) (P=0.027), peak expiratory flow (PEF) (P=0.000), (forced expiratory flow) FEF_25 (P=0.023), FEF_50 (P=0.007), FEF_75 (P=0.009), steps/min (P=0.000), VO_{2max} (P=0.000) and heart rate recovery (HRrec) (P=0.000). Interestingly, significant reductions were seen in the CON group in environmental point (P=0.002), Weight (P=0.002), BMI (P=0.001), lean mass (P=0.024), FEV/FCV (P=0.014), PEF_50 (P=0.007) and FEF_75 (P=0.009). Conclusion – The high intensity interval training was effective to improve all dimensions of HRQOL, hemodynamic variables, lung function, and cardiorespiratory endurance indicators in college-aged smokers. Contrarily, this study further supports it is evident that smoking gradually results in unhealthy environmental habits, decreased body weight, BMI, and lean mass as well as significant reductions in lung function as observed in our study. This suggests that HIIT can be a preferred form of training for smokers willing to improve or restore their diminishing health components due to smoking. Additionally, this can be applied in clinical conditions to provide HIIT exercise intervention to smokers to yield healthier benefits over a short period of time during smoking cessation programs and/or rehabilitations.
Keywords: Exercise, Smoking, Physical fitness, Health related quality of life (HRQOL), Pulmonary function

Introduction

Smoking is one of the leading causes of mortalities and morbidities worldwide (Parkes et al., 2008). World Health Organisation (WHO) statistics have been reported to indicate that by 2030 the mortality rate caused by tobacco smoking will exceed eight million, with six million deaths annually (Afanador et al., 2018). The estimated number of cigarette smokers globally has been suggested to be 1.1 billion (Afanador et al., 2018). The use of tobacco products has been widely observed, mainly among low socioeconomic status individuals with low access to healthcare systems (Shandu et al., 2023). This explains the population's contribution to an increase in tobacco-attributable diseases (Mhlanga & Garidzirai, 2020). Moreover, the health status in South Africa remains defined among different groups such as ethnicity, gender, and level of education (Mhlanga & Garidzirai, 2020).). In this regard, various studies report increased use of tobacco products among educated individuals and university students (Mhlanga & Garidzirai, 2020; Saeed & Rashid, 2014; Shandu, et al., 2023).

The increased use of tobacco products by university students is problematic, and it has been found that cigarette smoking has more incidences of death than car accidents, human immunodeficiency virus (HIV), firearms, alcohol, and illegal drugs combined (Efendi et al., 2018). This incidence has been linked to increased cancers and respiratory, cardiovascular, reproductive, and developmental problems commonly observed among college-aged groups (West, 2017). Moreover, smoking has been found to damage nearly all the organs in the human body, including lungs, blood vessels, heart, reproductive organs, mouth, eyes, skin, and bones (Afanador

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et al., 2018). Research indicates that half of the regular smokers will succumb to death due to smoking-related diseases and are likely to suffer a decreased life expectancy of about 13-16 years compared to non-smokers. Smoking can shorten the lives of males by about 12 years and females by about 11 years (West, 2017). However, smokers who relinquish smoking before their mid-30s have an approximately equal life expectancy as non-smokers (West, 2017).

Tobacco products encased with high concentrations of nicotine are commonly known for the negative effects of causing physical and psychological dependency with prolonged tobacco smoking trends (West, 2017). Crucial factors which predict a transition to regular smoking include friends who smoke, weak academic orientation, lack of parental support, drinking alcohol, pro-smoking attitudes, and low socio-economic status (Gellert et al., 2015). However, this transition could be caused by other factors, such as an individual's health-related quality of life (HRQOL), stress, depression, and anxiety (Efendi et al., 2018; Saeed & Rashid, 2014; Wen et al., 2019). The HRQOL of a smoker is different when compared to non-smokers (Efendi et al., 2018; Saeed & Rashid, 2014). HRQOL is a broad multidimensional concept that includes self-reported statements about mental and health status (Saeed & Rashid, 2014; Shandu et al., 2023). The HRQOL consists of four domains; physical health, social relationships, psychological state, and environmental points (Saeed & Rashid, 2014; Shandu et al., 2023; Wen et al., 2019).

In this regard, smokers with high-stress levels often perceive themselves as less healthy, with low self-esteem, and prone to adopting unhealthy lifestyle habits such as an increase in alcohol consumption/binge drinking, unsafe sex, drug use, and high tobacco use (Wen et al., 2019). Moreover, smoking and stress levels have been associated with various negative outcomes, such as depression and anxiety (Efendi et al., 2018; Shandu et al., 2023). Smokers with depression are often seen with feelings of sadness, emptiness, anhedonia, poor self-care, poor concentration, loss of ability to function, sleep disturbances, feelings of worthlessness, and recurrent suicidal ideation (Koinis-Mitchell et al*.,* 2017). Increasing anxiety levels is commonly associated with smoking initiation since cigarettes are mostly perceived as having a calming effect (Silva et al*.,* 2018). The most common anxiety disorders among smokers include generalised anxiety disorder and anxiety disorder due to substances/drugs (Maina et al., 2016). The generalised anxiety disorder is characterised by constant restlessness, easy fatigue, difficulty concentrating, muscle tension and interrupted sleep (Maina et al., 2016). This is usually recognised in adults younger than 30, but frequent onset can be observed in adolescence or young adulthood. Substances/drugs induced anxiety disorder is seen shortly after intoxication or withdrawal from a substance or during exposure to the drug (Koinis-Mitchell et al*.,* 2017; Maina et al., 2016).

Physical activity (PA) has indicated enhancement in health in many ways (Gellert et al., 2015). Exercise training improves physiologic, psychologic, and metabolic functioning, while risks of exposure to premature mortality and/or morbidity and many chronic diseases decline (American College of Sports Medicine (ACSM), 2013). Furthermore, exercise training reduces the onset of cardiac events, hypertension, incidences of stroke, type 2 diabetes, gallbladder disease, osteoporotic fractures, colon and breast cancer, obesity, depression, anxiety, and delay mortality in smokers (ACSM, 2013). Previous literature has shown that exercise can benefit smokers by mobilising the electrochemical neurological channels, which reduce and reverse any damage caused by smoking which could lead to an increased risk of early mortality (Stubbs et al., 2015). Exercise intensity, duration, and frequency define the magnitude of responses to health fitness, cardiovascular endurance, and HRQOL (Efendi et al., 2018). For instance, training at low intensity (50% of maximal capacity or less) partially stimulates the hypothalamus-pituitary-adrenal (HPA) system, central nervous system (CNS) and the immune system (Hamer & Stamatakis, 2010; Mesquita et al., 2015). Strenuous activity (greater than 70% of maximal capacity) extensively stimulates the activity of HPA, CNS and the immune system (Hamer & Stamatakis, 2010; Mesquita et al., 2015). The broad public health recommendation further addresses the need to acquire a healthy lifestyle for smokers. Healthy adults should at least accumulate 30 minutes of moderate-intensity exercise on most, if not all, the days of the week (ACSM, 2013), and individuals who are interested in enhanced outcomes exercised using larger volumes with high intensity (ACSM, 2013).

In recent years, there has been an increasing amount of literature on the prevalence and popularity of high-intensity interval training (HIIT) among young adults, which has suggested an exciting type of exercise and health promotion intervention with greater health benefits (Cunningham et al., 2020; Lu et al., 2022; Germano et al., 2015; Shandu et al., 2023), however, the experimental data are rather controversial, and there is no general agreement about its efficacy across studies (Batacan et al., 2017; Dias et al., 2018; Sultana et al., 2019). Exercise known as HIIT involves quick, intense bursts of activity followed by intervals of active rest (Shandu et al., 2023). Due to its adaptability to a range of physical fitness levels, HIIT can be used to achieve greater or superior improvements in cardiometabolic fitness (Lu et al., 2022). Interestingly, our recent study indicated improvements in HRQOL, hemodynamic, body composition, lung function, cardiorespiratory fitness and psychological functioning among smokers with both high-intensity and continuous cycling (Shandu et al., 2023). Studies suggest only one in five male students in ages of college meets the weekly PA recommendations while others have an increase levels of sedentary time (Lu et al., 2022; Teixeira et al., 2020). Sedentary time for students includes; studying, attending classes, sitting in front of computers/laptops, and sitting "chilling" alone/with friends (i.e., drinking and/or smoking), which in turn leaves limited time for exercise training (Alessa et al., 2017). As a result, there is a need to identify an efficient and effective type of exercise training to increase

PA participation in this population while indirectly promoting smoking cessation (Lu et al., 2022). Previous research has shown that HIIT can be utilized as a useful alternative to several types of traditional resistance-based training, which yields equal or even greater significant physiological adaptations than conventional training among both healthy and diseased populations (Iyakrus, et al., 2022; Shandu et al., 2023). Therefore, the primary purpose of this paper was to examine changes in health-fitness, health related quality of life (HRQOL), and psychological measures following 8-weeks of HIIT among college-aged smokers.

Material & methods

Participants

Forty males were recruited from students of the University of Zululand, Republic of South Africa (RSA). Male students were selected who met the following criteria 18-30 years, current smokers (≥3 cigarettes/day for last six months and sedentary (no planned exercise sessions per week) registered students, no current use of medications, absence of hypertension and diabetes, and no family history of heart disease. All subjects were free of all relative and absolute contraindications to exercise (Lu et al., 2022). Assignment to the high-intensity interval training (HIIT; n=20) or the control group (Con; n=20) was randomized. None of the smokers in the non-exercising group was participating in our or any regular exercise program, nor were they involved in strenuous duties. The exercise prescription and adherence are described in Table 1. Informed consent was obtained from each subject before the commencement of the study, which the Institutional Review Boards approved of the University of Zululand, RSA.

Data collection

Health-related quality of life Assessment

To assess the HRQOL of the participants, the WHOQOL-BREF questionnaire was used before and after the 8 weeks of intervention (Efendi et al., 2018). The questionnaire targeted mainly four domains: physical health, social relationships, psychological state, and environmental points, and the values of the scores vary across the domains for both raw scores and transformed scores. It has been suggested that the higher the value, the better the perception of functional health and well-being (Silva et al*.,* 2018).

Hemodynamic Assessment

The hemodynamic assessment was assessed according to the standards established by the American College of Sports Medicine (ACSM, 2013). Blood pressure was taken after five minutes of rest with the auscultatory method using a sphygmomanometer and stethoscope (Jiangsu Dengguan Medical Treatment Instrument Co. Ltd.) Resting heart rate (RHR) was assessed with a polar heart rate monitor (Polar F4M BLK, Finland) after a five-minute rest. Standard equations for calculating rate pressure product (RPP) and mean arterial pressure (MAP) (RPP = (SBP × HR) × 10^{-2} and MAP = SBP + 2 (DBP)]/3 respectively were used (Jena, 2017; Shandu et al., 2023).

Table 1: High intensity interval training (HITT) group exercise intervention protocol (Jena, 2017; Shandu et al., 2023)

Component	Mode	Intensity	Duration
Warm-up	Cycling	65-75% HR_{max}	3 min
Main Exercise	Cycling	8 sec sprint: 12 sec passive rest	60 reps/20 min
Cool-down	Cycling	20-40% HR_{max}	5 min
Stretching	Static, whole-body	Pain-free	20 sec each stretch 5 min total

VO_{2max}: maximal consumption of oxygen; min: minutes; rpm: revolutions per minute; sec: seconds; reps: repetitions

Anthropometric Assessment

Standardized procedures were used for all subjects during all anthropometric measurements and were performed by a certified biokineticist according to the proposed methods of the International Society for the Advancement of Kinanthropometry (ISAK). Subjects were in lightweight clothing, and shoes were removed. At baseline, body mass was determined using a calibrated weight scale (Detecto, Mediotronics (PTY) LTD, USA) to the nearest 0.1 kg. Height was measured using a stadiometer (Seca Stadiometer, 216, Seca, DURBAN, SA) to the nearest 0.1 cm. Body mass index (BMI) was calculated using a standard equation of dividing body mass in kilograms by stature squared in meters. Skinfold thickness was measured at the triceps, subscapular, suprailliac, abdominal, thigh, and calf using a Harpenden skinfold calliper (Harpenden, HSB-BI, ATICO Medical Pvt. Ltd, United Kingdom), and values were summed to give the total skinfold thickness (∑7). Percentage body fat (%BF) was calculated using the standard equation of Jackson and Pollock (1978): percentage fat = 100 (4.95/body density (Db) – 4.5), where Db (g/cc) = 1.120 – 0.00043499 (sum of the seven skinfolds in millimeters (∑7)) + 0.00000056 (∑7) – 0.00028826 (age)). Waist and hip circumference was measured using a non-distensible plastic tape measure HOLTAIN® (Crosswell, United Kingdom), with 2 m and a precision of 0.1 cm with WHR calculated with the following standard equation: waist circumference ÷ hip circumference (ACSM, 2013). Fat mass was calculated by multiplying body mass by body fat percentage divided by 100. Lean mass was calculated as total body mass in kilogrammes subtracted by fat mass in kilogrammes.

Lung function/Spirometry Assessment

Lung function assessment was conducted by the same researcher, using a calibrated electronic spirometer (Chest Graph, HI-101, CHEST LTD., Tokyo, Japan) with a precision volume of ± 50ml or ±5%. To ensure reliability and validity participants were notified not to ingest food or smoke one hour before testing. The assessment was conducted with subjects in seated positions with nose clips to prevent breathing through the nostrils. Three trials of the FVC maneuver were given to each subject and the highest value recorded was the included value in the final analyses. Measured values included: FVC, forced expiratory volume in one second (FEV_1), FVC/ FEV_1 ratio, peak expiratory flow (PEF), forced expiratory flow after 25%, 50%, and 75% of vital capacity has been expelled (FEF_{25}, FEF_{50}, and FEF_{75}, respectively) were utilised in the present study.

Cardiorespiratory Endurance Assessment

Maximal oxygen uptake (VO_{2max}) was used to measure the cardiorespiratory endurance of participants. A one-minute step test and standardised metronome (30 beeps per minute) have been suggested as reliable measures to estimate oxygen uptake in adults (ACSM, 2013). For each participant, HR response was measured in ml^{-1}. kg^{-1}. min^{-1} was utilised to calculate VO_{2max} with the following standard equation: $3.5 + 0.2 \times steps.min^{-1} + 1.33 \times (1.8 \times step\ height\ (m) \times steps.min^{-1})$.

Intervention

All participants in the CON group remained sedentary (no planned exercise sessions) for the eight-week intervention period. Participants randomized to HIIT performed repeated eight seconds sprints interspersed with 12 seconds bouts of passive recovery on a stationary cycle ergometer (Mornark 874E, Sweden) for a maximum of 60 repetitions thrice weekly for the designated eight-week intervention period under researcher supervision. All exercise sessions included a five-minute moderate warm-up at 50W in an intensity corresponding to 65-75% HR_{max} and a 20-min maximal work-out at 85%. Training ends with a five-minute low-intensity cool-down at 50W, 20-40% HR_{max} and stretching (calf, hamstring, quadriceps, gluteus, back, neck and shoulder muscles) held for 20 seconds, intensity corresponded to the participant's comfort position of no pain experienced (Shaw et al., 2009). The exercise sessions took approximately 33 minutes to complete per day.

Statistical analyses

The pre and post-intervention characteristics of the participants were described using means and standard deviations (SD) for all the measured variables. The clinical characteristics of the participants were analysed per group. The Shapiro-Wilk test verified the normality of the data. Paired-samples t-tests were utilised to examine the differences between pre-test and post-test variables. Analysis of the variance (ANOVA) for repeated measures was used to calculate the differences within groups and between the evaluations. The effect size was calculated using the statistical calculation d Cohen (1988), and the standardized effect sizes were classified as small (<0.20), moderate (0.20 to 0.79), and large (>0.80). Moreover, the relationship between the continuous data was assessed using Pearson's correlation coefficient. Statistical significance was set at $p \leq 0.05$. All statistical analyses used the software Statistical Package for the Social Sciences (SPSS) for Windows (SPSS Inc., Chicago, IL, USA), version 22.0.

Results

Of the 40 randomized participants, 32 participants (56.25% HIIT (n = 18); 43.75% Con (n =14)) were included in the final statistical analysis of this study. Figure 1 describes the flow of participants from recruitment to post-intervention

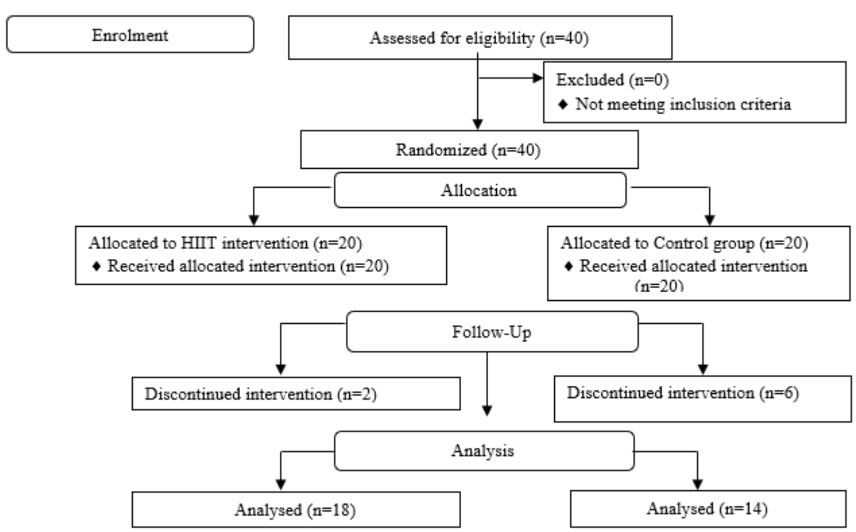

Fig. 1. Cohort flux diagram

Comparisons between evaluations in HRQOL

Table 2 describes the values of the dimensions of the HRQOL at baseline and after an 8-week intervention for each one of the two groups. In the HIIT group, the primary HRQOL domain outcomes of physical health, psychological state, social relationships, and environmental points were statistically significant ($p<0.05$) with a large effect ($d>0.80$) following the intervention. The most striking result to emerge from the data is that there was no evidence that the intervention influenced transformed scores of social relationships in the HIIT group with a medium effect ($0.20 \geq d \leq 0.79$). Interestingly, only the environmental points domain in the Con group was observed to be statistically significant with a large effect ($d>0.80$). In contrast, other domains reported no statistically significant change ($p>0.05$) during the intervention period.

Hemodynamic comparisons between evaluations

After adjusting for baseline values, only RHR and RPP in the HIIT group were statistically significant from 66.61±9.15 to 63.11±5.57 and 73.36±20.78 to 66.64±10.93; mean±SD, ($p<0.05$) respectively, both variables with a medium effect ($0.20 \geq d \leq 0.79$), corresponding to a decrease of 5.5 and 10.1; respectively. In the Con group, none of the variables changed following the intervention period ($p>0.05$) (Table 3).

Table 2: Intra-group comparisons of health-related quality of life variables (raw data and transformed scores): physical, psychological, social relationships and environment in college-aged smokers following 8-week of high-intensity interval training (HIIT), and a control group (Con).

Variable	Group	Baseline	8-weeks	%Δ	Effect size: Cohen's *d*	*P*-value
Physical domain						
Raw Data (7-35)	HIIT (n=18)	25.89±4.27	29.06±3.81	10.9	-1.791	0.000*
	CON (n=14)	22.86±3.57	21.14±3.55	-8.1	0.425	0.114
Transformed score (4-20)	HIIT (n=18)	14.83±2.46	16.28±2.32	8.9	-1.324	0.000*
	CON (n=14)	13.14±2.11	11.93±2.13	-10.1	0.498	0.069
Transformed score (0-100)	HIIT (n=18)	67.61±15.76	78.72±13.65	14.1	-1.571	0.000*
	CON (n=14)	57.36±13.08	48.29±14.04	-18.7	0.541	0.051
Psychological domain						
Raw Data (6-30)	HIIT (n=18)	20.94±2.84	24.22±3.32	13.5	-1.955	0.000*
	CON (n=14)	19.79±3.29	19.29±4.50	-2.6	0.122	0.636
Transformed score (4-20)	HIIT (n=18)	14.06±1.86	16.28±2.32	13.6	-1.860	0.000*
	CON (n=14)	13.07±2.13	12.86±2.93	-1.6	0.081	0.752
Transformed score (0-100)	HIIT (n=18)	62.83±11.63	75.89±13.43	17.2	-1.894	0.000*
	CON (n=14)	56.64±13.31	55.43±18.16	-2.2	0.074	0.773
Social relationships domain						
Raw Data (3-15)	HIIT (n=18)	10.17±2.18	11.83±1.98	14.0	-0.455	0.001*
	CON (n=14)	10.14±1.75	12.64±2.76	19.7	0.194	0.453
Transformed score (4-20)	HIIT (n=18)	13.22±3.57	15.17±4.18	12.9	-0.462	0.059
	CON (n=14)	13.43±2.44	12.64±2.76	-6.3	0.189	0.465
Transformed score (0-100)	HIIT (n=18)	57.61±22.45	69.89±25.92	16.1	-0.462	0.056
	CON (n=14)	58.86±15.35	53.93±17.28	-9.1	0.189	0.467
Environment domain						
Raw Data (8-40)	HIIT (n=18)	25.17±3.63	29.61±4.35	15.0	-1.840	0.000*
	CON (n=14)	26.07±4.36	45.00±14.45	42.1	0.961	0.003*
Transformed score (4-20)	HIIT (n=18)	12.83±1.82	15.06±2.13	14.8	-1.820	0.000*
	CON (n=14)	13.29±2.16	11.29±2.13	-17.7	0.923	0.000*
Transformed score (0-100)	HIIT (n=18)	55.33±11.33	29.61±4.35	-86.9	-1.852	0.000*
	CON (n=14)	58.14±13.42	45.00±14.45	-29.2	0.926	0.003*

Values are means±SD; HIIT: high-intensity interval training; and CON: control group; *: significance difference of pre-test and post-test.

Table 3: Resting heart rate, systolic BP-resting blood pressure, diastolic BP-resting blood pressure, rate pressure product, and mean arterial pressure in college-aged smokers following 8-week of high-intensity interval training (HIIT) and a control group (Con).

Variable	Group	Baseline	8-weeks	%Δ	Effect size: Cohen's *d*	*P*-value
RHR (BPM)	HIIT (n=18)	66.61±9.15	63.11±5.57	-5.5	0.667	0.009*
	CON (n=14)	74.14±7.51	73.29±4.39	-1.2	0.089	0.728
SBP – RBP (mmHg)	HIIT (n=18)	106.17±12.89	106.22±10.06	0.0	-0.008	0.971
	CON (n=14)	115.21±5.18	115.57±7.37	0.3	-0.048	0.851
DBP – RBP (mmHg)	HIIT (n=18)	67.61±7.95	68.33±5.63	1.1	-0.147	0.523
	CON (n=14)	69.93±5.24	71.00±4.49	0.1	-0.166	0.521
RPP (mmHg*bpm)	HIIT (n=18)	73.36±20.78	66.64±10.93	-10.1	0.495	0.042*
	CON (n=14)	74.14±7.51	83.15±9.46	10.8	0.161	0.534
MAP (mmHg)	HIIT (n=18)	80.80±7.90	80.85±6.56	0.1	-0.015	0.949
	CON (n=14)	79.20±22.64	85.86±4.82	7.8	-0.268	0.306

Values are means±SD; RHR: resting heart rate; BPM: beat per minute; SBP-RBP: systolic blood pressure – resting blood pressure; mmHg: millimeters of mercury; DBP-RBP: diastolic blood pressure – resting blood pressure; HIIT: high-intensity interval training; and CON: control group; BP: Blood pressure; RPP: Rate pressure product; MAP: Mean arterial pressure; *: significance difference of pre-test and post-test.

Comparisons between variables of body composition

For anthropometric variables, all groups significantly improved in weight, BMI, and the sum of skinfolds ($p<0.05$ for all groups) (Table 4). Only the HIIT group experienced positive improvements in %BF

(10.54±3.20) and fat mass (7.19±2.50); mean±SD, both variables p=0.000 with large effect sizes (d>0.80). Interestingly, there were also significant differences in the lean mass of the Con group (p<0.05), with a medium effect (0.20 ≥ d ≤ 0.79), corresponding to a decrease of 2.9.

Table 4: Intra-comparisons of anthropometric variables (weight, height, body mass index, waist, hip, waist-hip ratio, sum of skinfolds, %body fat, fat mass and lean mass) in college-aged smokers following 8-week of high-intensity interval training (HIIT) and a control group (Con).

Variable	Group	Baseline	8-weeks	%Δ	Effect size: Cohen's *d*	*P*-value
Weight (kg)	HIIT (n=18)	66.69±7.50	67.90±7.61	1.8	-0.888	0.001*
	CON (n=14)	73.07±5.06	70.77±6.04	-3.2	0.983	0.002*
Height (m)	HIIT (n=18)	1,72±0.07				
	CON (n=14)	1.73±0.06				
BMI (kg/m2)	HIIT (n=18)	22.56±2.12	22.98±2.10	1.8	-0.913	0.001*
	CON (n=14)	24.56±2.32	23.65±2.61	-3.7	1.008	0.000*
Waist (cm)	HIIT (n=18)	73.81±3.67	74.02±4.96	0.3	-0.077	0.737
	CON (n=14)	82.93±9.41	84.92±10.90	2.3	-0.293	0.265
Hip (cm)	HIIT (n=18)	93.83±5.06	94.34±6.38	0.5	-0.087	0.703
	CON (n=14)	100.93±8.19	101.14±11.44	0.2	-0.029	0.909
WHR	HIIT (n=18)	0.79±0.04	0.79±0.04	0.0	0.141	0.540
	CON (n=14)	0.82±0.07	0.84±0.10	2.3	-0.249	0.341
Sum of skinfolds	HIIT (n=18)	62.06±17.85	73.61±15.95	15.7	-1.233	0.000*
	CON (n=14)	69.07±11.13	61.71±9.36	-11.9	0.840	0.005*
%BF	HIIT (n=18)	8.06±2.88	10.54±3.20	23.5	-1.254	0.000*
	CON (n=14)	8.80±1.86	8.79±2.51	-0.1	0.003	0.991
Fat mass (kg)	HIIT (n=18)	5.39±2.11	7.19±2.50	25.0	-1.237	0.000*
	CON (n=14)	6.43±1.53	6.24±2.03	-3.0	0.087	0.735
Lean mass (kg)	HIIT (n=18)	61.28±6.92	60.71±6.74	-0.9	0.339	0.150
	CON (n=14)	66.42±4.67	64.52±5.50	-2.9	0.642	0.024*

Values are means±SD; kg: kilograms; m: meter; cm: centimeter; %BF: body fat percentage; kg/m2: kilograms per meter squared; BMI: body mass index; WHR: waist-hip ratio; HIIT: high-intensity interval training; and CON: control group; *: significance difference of pre-test and post-test.

Spirometry/lung function comparisons

In the HIIT group, the comparisons of lung function between groups after the 8-week intervention period presented a statistically significant change (p<0.05) in measured FVC, predicted percentage of FEV, and both measured and predicted percentage of FEF_{50} and measured FEF_{75}. In the Con group, there was an impressionable p-value in both the measured and the predicted percentage of FVC / FEV_1 (%) and PEF and the predicted percentage of FEF_{50} and FEF_{75} at the end of the intervention period (p<0.05). Table 5 describes the lung function values at baseline and after 8-weeks of intervention for each of the two groups.

Table 5: Intra-group comparisons of lung function variables (forced vital capacity, forced expiratory volume, forced vital capacity / forced expiratory volume in one second (%), peak expiratory flow and forced expiratory flow) in college-aged smokers following 8-week of high-intensity interval training (HIIT) and a control group (Con).

Variable	Group	Baseline	8-weeks	%Δ	Effect size: Cohen's *d*	*P*-value
FVC(L) – Meas	HIIT (n=18)	3.91±0.49	4.36±0.69	10.3	-0.569	0.022*
	CON (n=14)	3.78±0.21	3.49±0.56	-8.3	0.470	0.084
FVC(L) – Pred%	HIIT (n=18)	84.48±6.40	89.57±13.08	5.7	-0.386	0.105
	CON (n=14)	80.79±6.90	79.41±9.40	-1.4	0.119	0.644
FEV(L) – Meas	HIIT (n=18)	3.46±0.32	3.70±1.02	6.5	-0.243	0.295
	CON (n=14)	3.46±0.10	3.42±0.36	-1.2	0.100	0.698
FEV(L) – Pred%	HIIT (n=18)	87.19±4.80	93.78±9.66	7.0	-0.657	0.010*
	CON (n=14)	86.87±4.92	85.93±9.30	-1.1	0.084	0.743
FVC / FEV_1 (%) – Meas	HIIT (n=18)	87.95±5.06	89.34±4.77	1.6	-0.195	0.397
	CON (n=14)	91.83±3.04	87.24±4.53	-5.3	0.716	0.014*
FVC / FEV_1 (%) – Pred%	HIIT (n=18)	106.36±5.60	108.18±5.87	1.7	-0.222	0.338
	CON (n=14)	110.67±3.51	104.84±6.19	-0.1	0.670	0.020*
PEF (L/s) – Meas	HIIT (n=18)	8.11±1.31	8.90±1.21	8.9	-0.338	0.151
	CON (n=14)	8.62±0.58	7.06±1.34	-22.1	0.966	0.002*
PEF (L/s) – Pred%	HIIT (n=18)	86.92±13.51	92.23±12.21	5.8	-0.228	0.325
	CON (n=14)	91.89±6.51	79.30±12.79	-15.9	0.742	0.011*
FEF_25 (L/s) – Meas	HIIT (n=18)	6.93±0.92	7.40±0.56	0.1	-0.377	0.112
	CON (n=14)	7.18±0.29	6.70±1.05	-7.2	0.371	0.164
FEF_25 (L/s) – Pred%	HIIT (n=18)	87.49±10.50	94.28±9.93	7.2	-0.442	0.066
	CON (n=14)	90.30±4.56	84.82±9.40	-6.5	0.460	0.091
FEF_50 (L/s) – Meas	HIIT (n=18)	4.16±0.61	4.60±0.51	9.6	-0.511	0.037*
	CON (n=14)	4.37±0.33	4.09±0.46	-6.8	0.520	0.059
FEF_50 (L/s) – Pred%	HIIT (n=18)	78.69±10.21	85.22±7.43	7.7	-0.512	0.036*
	CON (n=14)	84.00±6.87	76.49±7.06	-9.8	0.806	0.007*
FEF_75 (L/s) – Meas	HIIT (n=18)	1.63±0.29	2.04±0.50	20.1	-0.628	0.013*
	CON (n=14)	1.79±0.16	1.65±0.26	-8.5	0.453	0.095
FEF_75 (L/s) – Pred%	HIIT (n=18)	68.23±11.61	77.05±12.07	11.4	-0.445	0.064
	CON (n=14)	74.77±7.44	66.74±7.28	-12.0	0.769	0.009*

Values are means±SD; HIIT: high-intensity interval training and CON: control group; FVC: forced vital capacity; FEV: forced expiratory volume; FVC / FEV_1 (%): forced vital capacity / forced expiratory volume in one second (%); PEF: peak expiratory flow; FEF: forced expiratory flow; L/s: liters per second; Meas: measured; Pred%: predicted percentage; *: significance difference of pre-test and post-test.

Comparisons between evaluations in cardiorespiratory endurance

After adjusting for baseline values, the single most striking observation to emerge from the data comparison was no evidence of significant (p>0.05) differences in all groups for change in VO_{2max} (p=0.123) and HR (p=0.717) with a small effect (d<0.20). There were no within-group differences in cardiorespiratory fitness variables between the baseline and post-program. Baseline and change values (mean±SD) of cardiorespiratory endurance variables are presented for each group in Table 6.

Table 6: Intra-group comparisons of cardiorespiratory endurance variables (steps/min, VO_{2max} and heart rate) in college-aged smokers following 8-week of high-intensity interval training (HIIT) and a control group (Con).

Variable	Group	Baseline	8-weeks	%Δ	Effect size: Cohen's *d*	*P*-value
Steps/min	HIIT (n=18)	28.28±3.79	29.67±1.24	4.7	-0.365	0.123
	CON (n=14)	24.64±2.82	25.43±2.90	3.1	-0.202	0.437
VO_{2max} (ml/kg/min)	HIIT (n=18)	26.35±3.06	27.47±1.00	4.1	-0.365	0.123
	CON (n=14)	23.41±2.28	24.05±2.34	2.7	-0.202	0.437
HR (BPM)	HIIT (n=18)	75.22±17.60	70.83±10.67	-6.2	0.322	0.171
	CON (n=14)	97.29±16.06	102.07±13.85	4.7	-0.246	0.346

Values are means±SD; HIIT: high-intensity interval training and CON: control group; VO_{2max}: volume of maximum oxygen consumption; ml/kg/min: milliliter per kilogram per minute; HR: heart rate and BPM: beat per minute; *: significance difference of pre-test and post-test.

Discussion

No acute adverse events were reported during the study, which supports the ideology to continue to utilise HIIT as a safe and feasible intervention for this population. This study explores the relationship between high-intensity interval training and health fitness, health-related quality of life, and psychological measures among college-aged smokers. Engagement in exercise has been shown to provide health benefits (Dias et al., 2018; Lu et al., 2022; Shandu et al., 2023). However, little research has been conducted on the effectiveness of a scientifically structured HIIT program on sedentary college-aged male smokers.

Following previous studies, in the HIIT group, all components of HRQOL were significantly improved with greater differences in raw data and transformed scores of physical health, psychological state, environmental points, and social relationships (not transformed scores) (Efendi et al., 2018; Jurado-Fasoli et al., 2020; Silva et al., 2018). The results of this study support the positive correlation between exercise and HRQOL of middle-aged smokers, which is shown by previous studies that indicated exercise significantly improves HROQL (Kofotolis et al., 2016; Saeed & Rashid, 2014) and is related to well-being, life satisfaction, and other components (i.e., ADLs), which applies to the youth population. One unanticipated finding was the improvement in the environmental points domain of the Con group. Although these results differ from some published studies (Efendi et al., 2018; Balducci et al., 2022), they are consistent with those of (Jurado-Fasoli et al., 2020; Lu et al., 2022). This somewhat contradictory result may be due to the length of the program and differences in sample size at baseline between studies. Another possible explanation for this is that these results corroborate the ideas of previous studies, which suggest that flexibility exercise helps to extensively improve the quality of sleep and rest, which results in positive outcomes of psychological stability and release of stress (Balducci et al., 2022; Jurado-Fasoli et al., 2020).

In the current study, significant haemodynamic changes were observed only in the HIIT group in RHR and RPP after an 8-week HIIT intervention. These results align with previous studies (Alessa et al., 2017; Teixeira et al., 2020). These relationships may partly be explained by the physiological mechanism induced following intense training sessions, which is an intrinsic adaptation for the sinoatrial node rather than autonomic activity changes (Teixeira et al., 2020). Moreover, the benefits of high-intensity aerobic exercise for improving the health and function of blood vessels are linked to endothelial cells within the vasculature, which release nitric oxide and have potent vasodilating effects to protect cardiovascular function and health in smokers. Thus the proper function of these endothelial cells ensures efficient blood flow distribution. Therefore, similar physiological adaptions might have occurred in participants in the HIIT group. In contrast to earlier findings, however, no evidence of changes in MAP, SBP, and DBP was detected (Efendi et al., 2018). This discrepancy could be attributed to the training program duration and type of participants utilised.

A strong relationship between exercise and changes in body composition among smokers has been reported in the literature (Efendi et al., 2018, Sultana et al., 2020). Consistent with the literature, this research found that participants who engaged in HIIT indicated significant improvements in weight, BMI, sum of skinfolds, %BF, and fat mass following 8 weeks of intervention (Sultana et al., 2020). It is difficult to explain this result, but it might be related to the changes in the musculoskeletal system. HIIT exercise causes an increase in body and skeletal muscle fatty acid oxidation and inhibition of appetite by facilitating the release of corticotrophin hormone (Batacan et al., 2017). However, no evidence of changes in WHR was detected in the same experimental group. The reason for this is unclear; thus, the impact of strenuous interval training on body composition may depend on factors such as the training frequency, duration, and intensity, the method of body composition measurement, and the type of participants (Shokri et al., 2022).

Progressive declines in cardiorespiratory fitness and physical inactivity are recognized as important risk factors for premature morbidity and mortality (Lu et al., 2022). In a previous longitudinal study of Norwegian men, the authors concluded that the decline in physical fitness and lung function among healthy middle-aged men was considerably greater among smokers than non-smokers (Dias et al., 2018). In the current study, most pulmonary function parameters were improved and reduced to a greater extent in both participants of the HIIT groups and the non-exercising group, respectively. The most significant improvements occurred in measured FVC, predicted percentage of FEV, and both measured and predicted percentage of FEF_{50} and measured FEF_{75} in HIIT Group. In the Con group, reductions were shown in the measured and predicted percentage of FVC / FEV_1 (%) and PEF and the predicted percentage of FEF_{50} and FEF_{75} at the end of the intervention period ($p<0.05$). These findings contradict previous studies, which have suggested that FEV1 and PEF are associated with training groups (Gellert et al., 2015). In light of these results, we believe that training programs of this duration have only minor effects on the spirometric variables of smokers.

In the current study, no evidence indicated that the intervention significantly improved cardiorespiratory fitness variables in both groups. Although these results differ from some published studies (Batacan et al., 2017; Jena, 2017), they are consistent with those of Shokri et al. (2022) who found no improvements in VO_{2max} following short-term training compared to CON (Shokri et al. (2022). This result may be explained by the fact that in the cardiovascular system, HIIT exercise increases cardiorespiratory endurance by increasing plasma volume and blood flow mechanisms as well as better central adaptation, to an increase in maximal heart rate stroke volume. This increase in stroke volume causes an increase in cardiac output. This then increases the value of VO_{2max}, which is one of the critical parameters in assessing cardiorespiratory function. An increase in oxygen capacity makes the heart work more effectively, and blood flow to muscles increases when exercising. In general, therefore, these findings indicate that some minimum volume or duration of training may be a key feature in the benefits related to HIIT.

Conclusions

The eight-week HIIT program significantly improved health-related quality of life, hemodynamic variables, body composition, and lung function in middle-aged smokers, although no correlation with cardiorespiratory fitness was found. In accordance with recent research, the study's findings suggest that HIIT as an exercise training may momentously affect and improve the cardio-metabolic profile, and physiological, and psychological functioning associated with smokers (Shandu et al., 2023; Shokri et al., 2022), however, more studies are warranted to better understand the inconsistency of evidence from studies on high-intensity exercise and smoking among college-aged populations. Interestingly, no acute adverse events were reported during the study, which further supports the ideology of considering utilising HIIT as a safe and feasible intervention for this population from both the public health and clinical points of view.

Limitations

This study has several limitations. The first is its small number of participants. Secondly, the was a potential limitation in that we only included males. Another limitation is the lack of other relevant covariates, such as lifestyle elements (e.g., nutrition, smoking habits, physical activity). Findings cannot be extended to the entire population of South African youth as the sample was only university students.

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