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Effectiveness of High-Intensity Interval Training and Continuous Moderate-Intensity Training on Blood Pressure in Physically Inactive Pre-Hypertensive Young Adults

Short title: Aerobic Training and Blood Pressure

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Abstract: The likelihood of pre-hypertensive young adults developing hypertension has been steadily increasing over the past few years. Despite the fact that aerobic exercise training (AET) has demonstrated positive results in lowering high blood pressure, the efficacy of different types of AET among pre-hypertensive young adults has not been well-established. The objective of this study was to evaluate the effectiveness of high-intensity interval training (HIIT) and continuous moderate-intensity training (CMT) on blood pressure (BP) of physically inactive pre-hypertensive young adults. 32 adults (age 20.0±1.1 years and BMI 21.5±1.8) were randomly assigned into 3 groups: HIIT, CMT and control (CON). HIIT and CMT groups participated in 5 weeks of AET; while the CON group followed a DASH diet plan only. The HIIT protocol consisted of 1:4 minute work to rest ratio of participants 80%-85% heart rate reserve (HR-reserve) and 40%-60% HR-reserve respectively for 20-minutes, CMT group exercised at 40%-60% of HR-reserve continuously for 20-minutes. In both HIIT and CMT groups, systolic blood pressure (SBP) (3.8±2.8 mmHg, P=0.002 VS 1.6±1.5 mmHg, P=0.011) was significantly reduced. While, significant reductions in the diastolic blood pressure (DBP) (2.9±2.2 mmHg, P=0.002) and mean arterial pressure (MAP) (3.1±1.6mmHg, P<0.0005) were noted only in the HIIT group. No significant differences in SBP (-0.4±3.7 mmHg, P=0.718), DBP (0.4±3.4 mmHg, P=0.714), or MAP (0.1±2.5mmHg, P= 0.892) were observed in the CON group. Both HIIT and CMT decreased the BP in physically inactive pre-hypertensive young adults; however, HIIT yielded more beneficial results in terms of reducing the SPB, DBP and MAP.

Keywords: High-intensity interval training; Continuous aerobic training; Systolic blood pressure; Diastolic blood pressure; Pre-hypertension.

1. INTRODUCTION

Hypertension is considered one of the main precursors of cardiovascular diseases (CVD) and has attributed to 7.7 million deaths globally.[1,2] The Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) defined pre-hypertension as systolic blood pressure (SBP) of 120 mmHg to 139 mmHg and diastolic blood pressure (DBP) of 80 mmHg to 89 mmHg.[3] Pre-hypertensive people are at an increased risk of acquiring hypertension, and it has been estimated that those with blood pressure (BP) readings between 130 and 139/80 and 89 mmHg are twice more likely to develop hypertension than those

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with lower readings.[4] Modifiable risk factors of high BP can be controlled by active engagement in physical exercises.[3,5] To prevent the progressive rise in BP and cardiovascular diseases, control of pre-hypertension and lifestyle modifications require special attention.[6]

Studies have suggested that physical exercise is associated with substantial improvement in insulin sensitivity, augmented autonomic nervous system function, and decreased vasoconstriction, which may prevent a pathological rise in BP.[7,8] Physical activity (PA) improves the release of growth factors from skeletal muscles into the bloodstream; stimulates angiogenesis, facilitates neurogenesis, and induces endothelial cell proliferation with endothelial cell membrane permeability. Thus, leading to a substantial reduction in BP and attenuation of hypertension symptoms.[9-11]

Worldwide, 9% of premature mortality contributing to approximately 5.3 million deaths in 2008 occurred due to physical inactivity.[12] Regular PA is a well-established intervention for the prevention and treatment of several chronic diseases,[13] and it has shown a significant effect on BP reduction.[14] Physical exercise has also shown improvement of various factors involved in the pathophysiology of hypertension[15-18] that can extenuate BP in both hypertensive and non-hypertensive adults.[15,19] Continuous moderate-intensity training (CMT) method for at least 30 minutes or more is traditionally recommended for the prevention and treatment of high BP.[13,20]

High-intensity interval training (HIIT) has been documented as a safe and effective training method for cardiac rehabilitation.[21] HIIT can be defined as a short burst of maximal effort interspersed by a few minutes of rest or active recovery and it has been reported to be more effective than CMT for improving cardiorespiratory fitness in different populations.[16-18, 22-24]HIIT that consists of several bouts of high-intensity exercise (~85% to 95% of HRmax) lasting 1 to 4 minutes interspersed with intervals of rest or active recovery[15,17,18] has been found to improve endothelial function and its markers[16,18] insulin sensitivity,[18] markers of sympathetic activity,[16,17] arterial stiffness,[15,16] blood glucose and lipoproteins.[18] Despite the favorable outcomes, the efficacy of HIIT in reducing BP among pre-hypertensive young adults is not well-established.[25] In addition, there is a scarcity of current literature comparing HIIT and CMT on BP in this particular population. Therefore, the primary purpose of this study was to determine the effects of HIIT and CMT on the BP of physically inactive pre-hypertensive young adults, and secondly to explore which type of exercise training is more efficient in lowering the BP of this population. This is the very first study that targeted pre-hypertensive young adults in Malaysia.

2. MATERIALS & METHODS

2.1. Study setting and subjects

This 5-week randomized-controlled trial was conducted in the Physiotherapy Centre at the Faculty of Medicine and Health Sciences in University Tunku Abdul Rahman, Sungai Long Kajang, Malaysia. G*power (F test) was used to calculate the sample size, based on the power analysis, a total of 42 participants were required for this study. The study subjects were reached through university portal, emails and posters for voluntary participation. Participants were recruited by convenience sampling as the study population required young adults with pre-hypertension. A total of 87 subjects were initially screened, out of which only 32 adults fit the eligibility criteria after they were administered the International Physical Activity Questionnaires (IPAQ), Physical Activity Readiness Questionnaire (PAR-Q+) and measurement of body mass index (BMI). Using the computer generated numbers, study participants (22 males and 10 females) were randomly allocated into 3 groups; HIIT group, CMT group and the control (CON) group.

Inclusion criteria comprised of both genders (unmarried), aged between 18-25 years old, physically inactive with SBP between 120-139 mmHg and/or DBP between 80 -89 mmHg. Participants with known history of respiratory illnesses, cardiovascular diseases, diabetes mellitus, overweight/obesity, psychological disorders, musculoskeletal problems, taking anti-hypertensive medications, and active smokers were excluded from this study.

The protocol was based on the Helsinki Declaration Accord (World Medical Association for Human Subjects). Moreover, prior ethical clearance was obtained from the Universiti Tunku Abdul Rahman's Scientific and Ethical Review Committee (U/SERC/77/20). Written informed consent was taken from each participant after debriefing them about the benefits, potential risks of muscle soreness, strict maintenance of data confidentiality and right to withdraw at any point of time from the study.

2.2. Body Mass Index and Blood Pressure Measurement

In addition to assessing BMI during the screening process, it was also measured at baseline to ensure no abrupt changes in the body weight before study initiation and that participants are within the normal BMI range (18.5-24.9). BMI was recorded by measuring the participants' body weight in kilograms and dividing it by their height squared (kg/m^2). Procedure was carried out early in the morning (8:30am-9:00am) using a calibrated seca 284 EMR (Germany) wireless measuring station for weight and height. Before measuring the BMI, participants were instructed to remove any

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excess clothing, stand straight, and barefooted on the measuring machine. An average of 3 measurements for both weight and height were calculated to assess the BMI score.

Following the standard procedure, participants' BP from the right brachial artery was measured using an automated digital BP monitor (OMRON SEM-1, Japan) in morning between 9:15am-10:15am after 5-minutes of rest in a chair.[26,27] Each participant's right arm was supported on the table at their heart level and both SPB and DBP were measured 3 times with a 5-minute interval between each measurement in order to obtain the most accurate result. If the differences between any of the 3 SBP and/or DBP readings were higher than 5 mmHg, the measurement was taken again after 5-minutes interval and the average reading with the least differences was taken into consideration. BP was measured at the baseline before beginning the intervention and at the end of 5-weeks of intervention. Post-test measurement of BP was carried out in a similar way as recorded at baseline. In addition, mean arterial pressure (MAP) was also estimated at baseline and at the end of intervention with the following formula.

MAP = DBP + 1/3(SBP – DBP)

2.3. Exercise intervention protocol

Before the first exercise session, the subjects' heart rate (HR) was measured using a calibrated pulse oximeter (GIMA: Oxy-5-Plus Oximeter, Italy). To calculate the exercise HR, (HRmax) of the participants in HIIT and CMT groups were calculated using the newest age-based formula, [HRmax = 211-(0.64*age)]**.** The exercise HR was then calculated using the Karvonen formula [Exercise HR = % of target intensity (HRreserve) + HRrest]. To prevent the delayed onset of muscle soreness (DOMS) and to acclimatize all the physically inactive participants in both exercise groups to the exercise regimen, a 1-week familiarization period was provided with a total of 3 exercise sessions on alternate days. Participants in both the experimental groups performed a 5-minute warm-up session followed by 20-minutes of continuous running on treadmill (BH LK-G6700 Pro Action, USA) without inclination at 40% -60% of their HR-reserve. Before ending the exercise session, a 5-minute cool-down was performed by all participants by walking on the same treadmill at their own comfortable pace. A pulse oximeter (GIMA: Oxy-5-Plus Oximeter, Italy) was placed on the participants' index finger during the PA to monitor their exercise HR, in addition of using the treadmills inbuilt heart rate monitor. Differences in the exercise HR in both the monitoring methods were negligible throughout the training protocol. After the familiarization period of 1-week, HIIT group proceeded to 4-weeks of HIIT (3 times per week on alternate days excluding the weekends) consisting of 20-minutes of treadmill (BH LK-G6700 Pro Action, USA) running with a 1:4 minute work to rest ratio with an upper HR target at 80% - 85% of HR-reserve and a lower HR target at 40% - 60% of HR-reserve. The CMT group continued with 4weeks of the same exercise protocol on treadmill that was carried out in the familiarization period at intensity of 40% -60% of their HR-reserve. Exercise HR during these 4-weeks of aerobic exercise training (AET) for both groups were monitored same way as stated above in the familiarization program. The indication for termination of the exercise sessions was followed according to ACSM's guidelines. It was not feasible to blind the participants or therapists, as they both knew the type of intervention being received and delivered respectively, but outcome assessors were blinded to control the detection bias.

The CON group did not participate in any exercise program, they were instructed to follow Dietary Approaches to Stop Hypertension (DASH) diet and restrict the sodium intake (<100mmol/day) according to the JNV VIII guidelines. In addition to the hand-out of the guidelines given, participants in the CON group were reminded via telephone calls once weekly about DASH diet and sodium restriction to strictly follow the guidelines.

All the participants in the 3 groups were instructed not to engage in any other form of PA during these 5-weeks to prevent any extraneous effect on the outcomes. In addition, to avoid the acute post-exercise effects on BP, participants were also instructed not to perform any exercises 24 hours prior to post-test BP measurement. In accordance with the CONSORT statement, detailed description of this clinical trial is shown in figure 1 below.

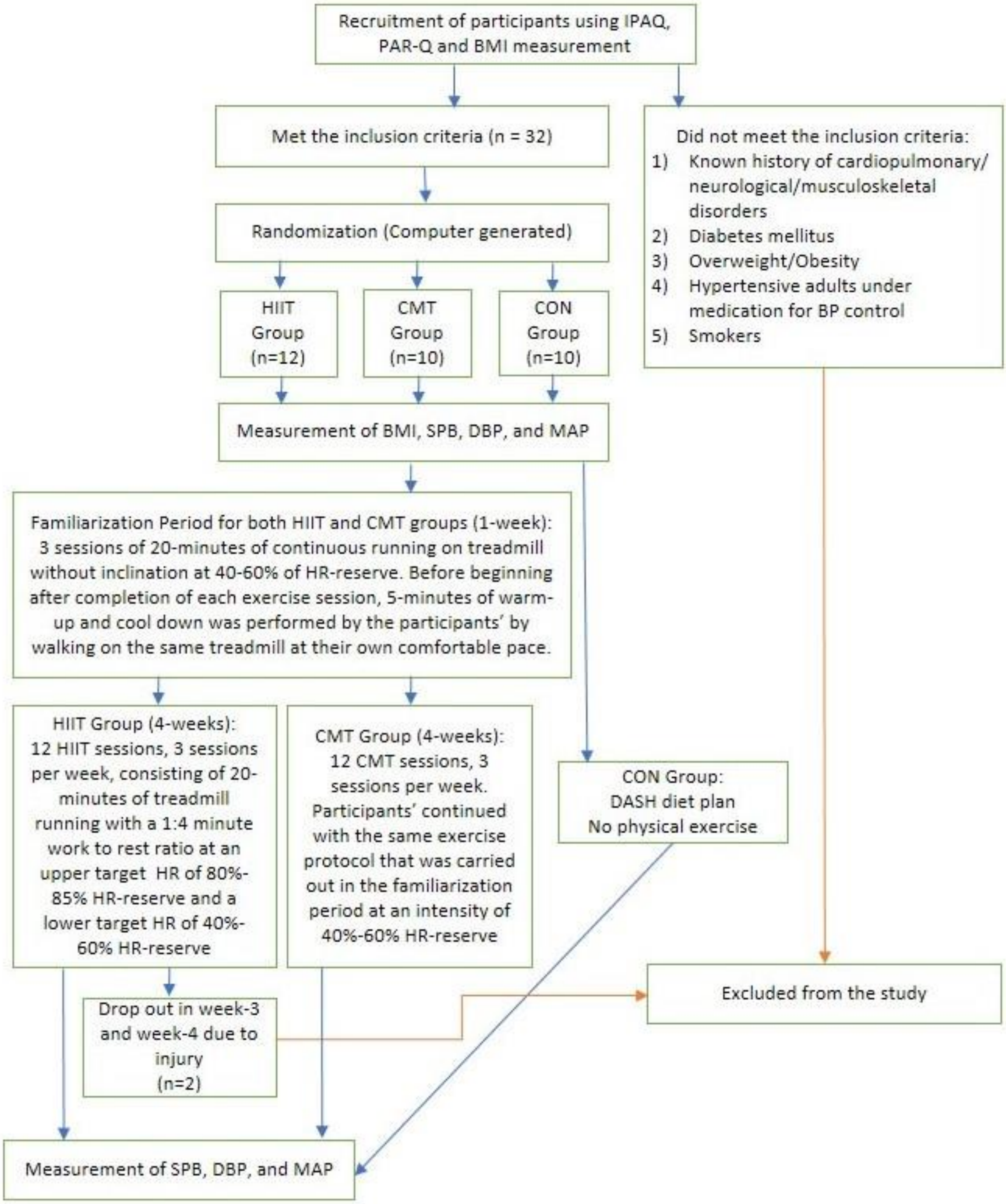

Figure 1 - Flowchart of Trial: IPAQ = International Physical Activity Questionnaire; PAR-Q = Physical Activity Readiness Questionnaire; BMI = Body Mass Index; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MAP = Mean Arterial Pressure; HIIT = High Intensity Interval Training; CMT = Continuous Moderate-intensity Training; CON = Control; HR-reserve = Heart Rate Reserve

Figure 1. CONSORT Diagram.

2.4. Statistical analysis

The data were processed using the Statistical Package for Social Science (SPSS) version 26.0. Shapiro-Wilk test was first performed to check the normality assumption of data as it is required to fulfil the conditions of a paired sample t-test. Shapiro-Wilk test (table 1) demonstrated that data was normally distributed (p> 0.05) in all the 3 groups with respect to the SBP, DBP and MAP at baseline; therefore, these outcome measures were compared using the paired sample t-test for within group differences. To evaluate between group differences, one-way ANOVA test was carried out. The conditions to conduct one-way ANOVA test were fulfilled, whereby the factor: Group, was the qualitative variable, and the dependent variables: SBP, DBP and MAP were quantitative variables. A post-hoc test was further employed to assess which group differed significantly from the other two groups after performing one-way ANOVA test. Results were presented as mean±SD for all the outcome measures. All reported probability values were 2-sided and a p-value of <0.05 was considered statistically significant.

Table 1. Test of normality at baseline for SBP, DBP and MAP among 3 groups

	Group	Statistic	p-value
Pre-SBP mean	HIIT Group	.960	.780
	CMT Group	.981	.972
	CON Group	.853	.063
Pre-DBP mean	HIIT Group	.970	.890
	CMT Group	.912	.294
	CON Group	.874	.112
Pre-MAP mean	HIIT Group	.989	.995
	CMT Group	.921	.365
	CON Group	.923	.387

Shapiro-Wilk test, level of significance at *P <0 .05*3.

RESULTS

3.1. Descriptive statistics

At the beginning of this study, 32 participants were randomly assigned into HIIT (6 males and 6 females), CMT (6 males and 4 females) and the CON group (10 males). Two participants dropped out from the HIIT group (both males) during the third and fourth week of training due to musculoskeletal injury. Mean age of the participants in the HIIT, CMT and CON groups were 21±0.8, 19±1.3 and 21±1.0 respectively. Similarly, the mean BMI measured at baseline were 20.8±1.9, 21.7±1.6 and 22.0±1.9 respectively for HIIT, CMT and CON groups. The BMI of CON group was slightly higher than other two groups, most probably due to the fact that all the participants in the CON group were males.

3.2. Comparison within the groups

Table 2 depicts that the CON group has the highest baseline and post intervention SBP mean values of 127.93±5.09mmHg and 128.37±5.32mmHg respectively. The HIIT group has the highest baseline DBP (78.57±5.36mmHg) and CMT group has greater post-test DBP (75.73±4.26). At baseline, MAP was highest in CMT group (93.20±2.89) and greater in CON group (91.86±4.18) at post-test.

Table 2. All groups' SBP, DBP and MAP Mean (X) with standard deviation (SD).

	HIIT Group X±SD		**CMT Group X±SD**		**CON Group X±SD**	
	PRETEST	**POSTTEST**	**PRETEST**	**POSTTEST**	**PRETEST**	**POSTTEST**
SBP (mmHg)	122.76±2.65	119±3.91	125.23±3.76	123.67±3.98	127.93±5.09	128.37±5.32
DBP (mmHg)	78.57±5.36	75.63±4.86	77.23±4.54	75.73±4.26	74.00±6.23	73.60±5.78
MAP (mmHg)	93.14±3.46	90.09±2.57	93.20±2.89	91.71±3.08	91.98±4.62	91.86±4.18

Table 3 illustrates the results of paired sample t-test. In CON group, a mean difference of -0.43 (p-value = 0.718 > 0.05) for the SPB was seen, indicating non-significant difference between the pre-SBP and post-SBP. For the DBP, the mean difference of 0.40 (p-value = 0.714 > 0.05) was found, showing no significant difference between the pre-DBP and post-DBP for CON group. Similarly, MAP did not exhibit any significant difference (mean = 0.11, p-value = 0.892). For CMT group, a mean difference of 1.57 (p-value = 0.011 < 0.05) was observed in terms of SBP which was statistically significant. However, for the DBP, the mean difference between the pre-test and post-test was 1.50 (p-value = 0.161 > 0.05), depicting a non-significant difference between the pre-DBP and post-DBP in the CMT group. MAP in CMT group showed an insignificant reduction of mean (1.49, p-value = 0.054). A mean difference of 3.76 (p-value = 0.002 < 0.05) was found in HIIT group for the SBP and 2.93 (p-value = 0.002 < 0.05) for DBP, inferring a statistically significant difference between the pre-test and post-test of both SPB and DPB respectively in the HIIT group. Similar result was noticed in MAP with a significant mean difference of 3.05 (p-value < 0.0005).

Table 3. Paired Sample t-Tests for SBP, DBP and MAP among the 3 groups.

		Paired Differences				
Groups		Mean	Std. Deviation	t	df	p-value
CON Group						
Pair 1	Pre-SBP mean - Post-SBP mean	-0.43	3.68	-0.37	9	0.718
Pair 2	Pre-DBP mean - Post-DBP mean	0.40	3.35	0.38	9	0.714
Pair 3	Pre-MAP mean - Post-MAP mean	0.11	2.50	0.14	9	0.892
CMT Group						
Pair 1	Pre-SBP mean - Post-SBP mean	1.57	1.54	3.22	9	0.011
Pair 2	Pre-DBP mean - Post-DBP mean	1.50	3.10	1.53	9	0.161
Pair 3	Pre-MAP mean - Post-MAP mean	1.49	2.12	2.22	9	0.054
HIIT Group						
Pair 1	Pre-SBP mean - Post-SBP mean	3.76	2.83	4.20	9	0.002
Pair 2	Pre-DBP mean - Post-DBP mean	2.93	2.23	4.16	9	0.002
Pair 3	Pre-MAP mean - Post-MAP mean	3.05	1.64	5.90*	9	<0.0005

Paired sample t test was performed, level of significance at $P < 0.05$.

3.3. Comparison between the groups

For the SBP, the F-test (one-way ANOVA) result was 5.02 (p-value = 0.014 < 0.05) (Table 4). Therefore, it can be concluded that there were significant differences in the mean SBP across the 3 groups. However, for the DBP, the F-test statistics was 1.87 (p-value = 0.173 > 0.05) indicating a non-significant difference among the 3 groups. MAP F-test was 4.76 (p-value = 0.017 < 0.05), showing a significant difference between the 3 groups.

Table 4. Comparison of SBP, DBP and MAP mean difference across the 3 groups.

		ANOVA				
		Sum of Squares	df	Mean Square	F	p-value
SBP	Between Groups	69.72	2	34.86	5.02*	0.014
	Within Groups	187.53	27	6.95		
	Total	257.25	29			
DBP	Between Groups	32.25	2	16.12	1.87	0.173
	Within Groups	232.47	27	8.61		
	Total	264.71	29			
MAP	Between Groups	43.08	2	21.54	4.76*	0.017
	Within Groups	122.13	27	4.52		
	Total	165.21	29			

One-way ANOVA test was performed, level of significance at $P < 0.05$.

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Since one-way ANOVA test showed significant differences in SBP and MAP across the 3 groups, a post-hoc test (Tukey test) was performed to investigate which pairs of the groups were different in terms of the mean SBP and mean MAP. We found that SBP mean difference of HIIT and CMT group was statistically insignificant (p-value = 0.282 > 0.05) (Table 5). However, we noticed a significant SBP mean difference between the HIIT group and the CON group (p-value = 0.010 < 0.05), but, SBP mean difference between CMT and CON group was statistically insignificant (p-value = 0.258 > 0.05). MAP did not show any significant mean difference between the HIIT and CMT groups (p-value = 0.244 > 0.05) and between the CMT and CON groups (p-value = 0.337 > 0.05). However, a significant mean difference in MAP was seen between the HIIT and CON groups (p-value = 0.013 < 0.05). Hence, it can be deduced that HIIT is more effective in reducing the SBP, DBP, and MAP compared to CMT.

Table 5. Post-hoc test (Tukey test).

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	p-value
SBP	HIIT	CMT	-1.83	0.282
		CON	-3.73*	0.010
	CMT	HIIT	1.83	0.282
		CON	-1.90	0.258
	CON	HIIT	3.73*	0.010
		CMT	1.90	0.258
MAP	HIIT	CT	-1.57	0.244
		CON	-2.93*	0.013
	CMT	HIIT	1.56	0.244
		CON	-1.37	0.337
	CON	HIIT	2.93*	0.013
		CMT	1.37	0.337

Post-hoc (Tukey) test was performed, level of significance at $P < 0.05$.

4. DISCUSSION

Earlier studies[28,29] roadly supported the improved cardiopulmonary benefits of HIIT over CMT. Nevertheless, no previous study has conspicuously explored HIIT and CMT outcomes in the pre-hypertensive young population incorporating a comparator CON group with the DASH protocol. Thus, the research provided valuable insights to the field of physical therapy and significantly contributed to the current body of scientific literature. This study showed beneficial effects of HIIT and CMT on the resting BP of physically inactive young adults with pre-hypertension. It is evident from the findings of the current study that both HIIT and CMT can reduce SBP significantly among pre-hypertensive young adults. The positive role of exercise training on BP can be perceived through its action on the sympathetic activity, enhanced endothelial function and decreased oxidative stress, that cumulatively contributes to the prevention and progression of hypertension.[30] In addition, PA may be accountable for reducing exercise-induced oxidative stress by producing an increased level of antioxidants, attenuating vascular and cardiac sympathetic activity, dropping serum vasoconstrictor factor levels, and rising endothelial dilating factors that consequently helps in lowering the peripheral vascular resistance and subsuquently leading to improved BP.[16,31] Previous meta-analysis revealed that two most prominent intervention protocols HIIT and CMT were effective in reducing SBP in adults with pre- to established hypertension.[25] Our findings correlate with a study that compared the effects of continuous and interval training in the management of hypertension, whereof researchers found SBP reduction in both experimental groups (-16.4±13.2 mmHg and -13.9±12.6 mmHg respectively).[32] Similar results were also derived from the systematic review by Punia S et al.[33] Our study revealed significant reductions in SBP after conducting 5 weeks of AET (HIIT and CMT) program. Therefore, in addition to lowering SBP among the hypertensive population, HIIT and CMT can be useful tools in reducing the SBP among pre-hypertensive young adults.

Current study demonstrates significant reduction of DBP among the participants undergoing HIIT exercise protocol whereas non-significant reduction of DBP was observed among the CMT and control group. Previous literature[34] suggests that HIIT demonstrated greater improvements in the endothelial function and arterial stiffness compared to CMT. This explains the increased BP reduction in the HIIT group as endothelium plays a pivotal role in homeostasis and maintenance of vascular tonus which can be a contributing factor in BP reduction. A recent randomized clinical trial also revealed similar results where the authors found a significant reduction in SBP but non-significant reduction in DBP.[35] Although the decrease in DBP of the CMT group was statistically non-significant in this study, if given a longer intervention period there would be a more obvious result as most studies have confirmed a significant reduction in DBP following 8 weeks or more of continuous exercise in hypertensive and normotensive adults.[36,37] Interestingly in the current study, within a time frame of 5 weeks, HIIT showed efficacy to reduce DBP significantly. Therefore, HIIT could be a better option in controlling the DBP of pre-hypertensive young adults.

MAP measures the pressure necessary for adequate perfusion of the organs of the whole body. Therefore, it could be a better indicator of perfusion than SBP. High MAP can be detrimental leading towards morbid conditions like ventricular hypertrophy, myocardial infarction and stroke. HIIT intervention in this current study also demonstrated significantly greater reductions in the MAP in comparison to CMT (3.05 vs. 1.49). Similar findings were reported in past studies, whereof, HIIT led to notable reductions in the MAP among pre-hypertensive subjects[38] and sedentary individuals.[39,40] Overall, the HIIT exercise resulted in significant BP reduction and favorable alteration in MAP, thus showing positive cardiovascular response post intervention. However, further studies are required to evaluate the potential mechanisms contributing to these physiological responses and changes in the pre-hypertensive population.

HIIT interventions are considered to be more effective and time-efficient interventions for BP and aerobic capacity level improvements as compared to other exercises.[41] Wahl P et al found that HIIT stimulated a transient increase in the circulating levels of vascular endothelial growth factor and hepatocyte growth factor.[42] Thus, it can be postulated that HIIT intervention reduces BP by actively promoting and stimulating the angiogenic factors. Study by Ciolac et al showed that HIIT is far more superior in lowering the BP compared to CMT due to 3 factors; improving cardiorespiratory fitness, hormonal response and nitric oxide response which is a mediator of vasodilation in blood vessels that plays a major role in BP control.[43] It has been stated that HIIT interventions that lasts for 4-12 weeks duration are able to produce a larger decrease in SPB (-3.63mmHg) than other forms of exercise.[41] Previous studies also support that HIIT is superior to CMT in improving cardiorespiratory fitness and reducing BP among normotensive and hypertensive individuals,[16-18] but its efficacy in reducing BP among pre-hypertensive population needed further investigation. In the current study, there was a significant difference in the mean SBP across the three groups; HIIT, CMT and CON as revealed by ANOVA test. Further analysis by post-hoc test demonstrated a significant mean difference in the SBP between the HIIT group and CON group (p-value = 0. 010 < 0.05). However, there was an insignificant mean difference in the SBP between the CMT and CON group participants (p-value = 0.282 > 0.05). Additionally, HIIT was found to be effective in reducing the DBP significantly (p-value = 0.002 < 0.05). Although PA has been associated with reduced BP but there can be some variations due to different training modality, exercise prescription, intensity, frequency and the duration of intervention.[34] Nevertheless, the current study clearly demonstrates that HIIT is superior to CMT in controlling the progression of pre-hypertension towards hypertension in Malaysian young adults.

Studies by Stephen PJ et al and Paula TP et al revealed that the DASH diet and sodium restriction have significant effect on the reduction of SBP, DBP, and HR among hypertensive patients.[44,45] A recent meta-analysis also revealed similar observations.[46] Therefore, a possible reason why there was no reduction in SPB and DBP in the CON group could be due to non-adherence to the diet protocol, even after weekly reminders via phone calls to the participants for strict follow of the regimen. Although HIIT and CMT groups were not instructed to follow DASH diet and sodium restriction as the researchers aimed to determine the effectiveness of HIIT and CMT solely, however, a significant SBP reduction and non-significant DBP reduction was observed among the participants of CMT group. Whereas in the HIIT group, both SBP and DBP were significantly reduced after 5 weeks. Conclusively, the study results indicate a higher efficacy of HIIT over CMT even in the absence of the DASH diet to control the resting BP in the pre-hypertensive young adults.

5. STRENGTHS, LIMITATIONS & RECOMMENDATIONS

Due to the time constraint and limited resources; the researchers were able to recruit only 32 participants for this research. However, this was a hypothesis-generating study and differed methodologically; so even with the limited sample size, this research provided a deeper insight into the cardioprotective role of exercise training on BP. Secondly, the HIIT and CMT groups, each consisted of only 4 and 6 females in the respective groups; whereas the CON group consisted of all males. This is due to the fact that during screening process, many females were under hypotensive or normotensive categories and after screening, eligible participants were allocated randomly into 3 groups. Dietary intake of the participants in CON group may have also played a significant role when it comes to controlling the BP, since it was not possible to directly observe and monitor their adherence to the DASH diet and sodium restriction. Therefore, future studies with bigger sample size, longer intervention duration, and stringent control of the DASH diet plan is highly recommended. Furthermore, HIIT collectively with the DASH diet plan could be a better approach towards controlling pre-hypertension in a short frame of time.

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6. CONCLUSION

HIIT can effectively reduce both SBP and DBP of healthy, physically inactive pre-hypertensive young adults, but CMT reduced only the SBP in this study. Therefore, HIIT could be a promising alternative intervention in BP reduction and thus could be functional to prevent the progression of pre-hypertension towards hypertension among physically inactive young adults.

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ETHICS STATEMENT: This study was conducted according to the Helsinki Declaration Accord. In addition, prior ethical clearance was obtained from the Universiti Tunku Abdul Rahman's Scientific and Ethical Review Committee (U/SERC/77/20), and written informed consent was taken from each participant.

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