Accepted Manuscript

Regular Article

Weight-bearing exercise-based high-intensity interval training shows higher exercise adherence than moderate-intensity continuous running: a randomized controlled trial

Running title: Weight-bearing exercise-based HIIT shows high exercise adherence

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Number of tables: 2

Number of figures: 4

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Abstract

For busy individuals seeking to establish an exercise habit, weight-bearing exercise-based high-intensity interval training (HIIT) is a time-efficient option. Although single sessions have been shown to improve postprandial blood glucose, whether unsupervised HIIT supports long-term adherence remains unclear. Therefore, this study compared the effects of eight weeks of supervised HIIT and moderate-intensity continuous training (MICT) on adherence and blood glucose indicators. We recruited 46 healthy young adults with no exercise habits, and low to moderate physical activity. After a two-week pre-measurement period, participants were randomly assigned to a HIIT group that performed weight-bearing exercise-based HIIT three times a week for eight weeks without supervision, an MICT group that performed running three times a week for eight weeks without supervision, or a control group that did not change their lifestyle. The intervention period was followed by a two-week post-measurement period for between-group and pre- and post-intervention comparisons. The primary outcome was exercise adherence, assessed based on a self-report and supplemented with a tri-axial accelerometer and glycemic index. Adherence was significantly higher in the HIIT group (60.6 ± 25.7%) than in the MICT group (27.9 ± 22.3%). No significant differences in glycemic index were observed either pre- to post-intervention or between groups. Overall, unsupervised HIIT produced greater adherence than comparable running but did not alter blood glucose levels in healthy young adults.

Keywords

High-intensity interval training, Exercise adherence, Accelerometer, Unsupervised exercise, Weight-bearing training

「自重運動ベースの高強度インターバルトレーニングは中等度強度持続的運動よりも高い運動アドヒアランスを示す：ランダム化比較試験」

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背景：忙しい人々が運動習慣をつけるため、時間効率のよい運動として自重運動ベースの高強度インターバルトレーニングが挙げられる。単回の自重運動ベースの高強度インターバルトレーニングは、食後血糖値を是正することが明らかになっているが、非監視下で実施する自重運動ベースの高強度インターバルトレーニングが高い運動アドヒアランスを示すかどうかは明らかではない。本研究の目的は、監視下での体重負荷運動ベースの HIIT と中強度継続トレーニング（MICT）における 8 週間の運動アドヒアランスと血糖値指標への影響を比較することであった。

方法：運動習慣がなく、身体活動量が低～中等度の健康な若年成人 46 名が研究

に参加した。2 週間の事前測定期間の後、参加者は、非監視下で自重運動ベースの HIIT を週 3 回 8 週間行う HIIT 群、非監視下でランニングを週 3 回 8 週間行う MICT 群、生活習慣を変えずに過ごす対照群に無作為に割り付けられた。介入期間の後、2 週間の事後測定期間を設け、群間および介入前後の比較を行った。主なアウトカムは、3 軸加速度計を用いて測定された運動アドヒアランスと血糖値指標であった。

結果：運動アドヒアランスは MICT 群（27.9±22.3％）と比較して HIIT 群（60.6±25.7%）において有意に高値を示した。血糖指標は介入前後、または群間で有意差を認めなかった。

結論：非監視下の HIIT は、同様に実施されたランニングと比較して有意に高い運動アドヒアランスを示したが、健常若年者の血糖値指標には影響を及ぼさなかった。

1. Introduction

Despite the obvious benefits of physical activity, one in four individuals do not achieve the recommended 150 or more exercise minutes per week [*1*]. In Japan, this trend is pronounced, with only 33.4% of men and 25.1% of women exercising at least twice a week for 30 minutes or more [*2*]. The most common reason given for not engaging in physical activity is being "busy with work and household chores," at approximately 40% [*2*]. In other words, one of the main reasons for not exercising is the "lack of time." This is not only true for the working-age population but also for young people in early adulthood, whose physical activity tends to decline owing to increased time spent in classes, studying, and operating computers [*3*]. For young adults as well, the lack of time is one of the main reasons for not exercising [*4*]. However, while there has been much discussion about exercise rates among middle-aged and older adults [*5,6*], exercise among young adults has been overlooked; therefore it is necessary to consider exercises that are easy for young adults to perform.

We propose high-intensity interval training (HIIT) as a time-efficient exercise method for young adults. Despite the short duration of HIIT compared to continuous exercise, HIIT has been shown to be superior to continuous exercise for improving body composition, maximal oxygen uptake, glycemic control, concentrations of low-density lipoprotein, and total cholesterol concentrations [*7–10*]. Our research group previously found that brief, weight-bearing exercise-based HIIT suppressed postprandial blood glucose elevation as successfully as running [*11*]. Weight-bearing exercise-based HIIT is not only time-efficient, but also free from spatial constraints as it does not require any equipment.

However, it is debatable whether HIIT, which requires less exercise time, fosters higher exercise adherence than moderate-intensity continuous training (MICT) [*12*]. Existing studies that examined exercise adherence in HIIT have used self-reports [*13–16*] or moderate to vigorous physical activity duration [*17–19*] to assess adherence—methods that may introduce the confounding factor of false reporting and are unsuitable for assessing very short periods of exercise.

This study assessed exercise adherence through self-reports and verified HIIT movement patterns with tri-axis accelerometers (wGT3X-BT ActiGraph; Acti Japan K.K., Chiba, Japan) under unsupervised conditions, confirming consistency between self-reported and actual exercise. Actigraph allows for the measurement of activity counts [*20*], which are cumulative units of acceleration, at intervals of at least one second for each of the three axes. By wearing an Actigraph and exercising, it is possible to check detailed movement patterns based on acceleration after the fact. This approach may enable the accurate measurement of exercise adherence when HIIT is performed in real-world settings and yield results that closely reflect physiological indicators. Considering that single-session weight-bearing exercise-based HIIT has been shown to have a positive effect on postprandial blood glucose levels in healthy young adults [*11*], HIIT may demonstrate higher exercise adherence than running and have a positive impact on blood glucose levels for young adults who find HIIT more enjoyable.

Therefore, this study aimed to determine whether eight weeks of unsupervised, weight-bearing HIIT in healthy young adults without exercise habits was associated with higher adherence than running. In addition, we will verify whether HIIT performed without supervision improves blood glucose levels in healthy young adults. We hypothesized that HIIT would show higher exercise adherence than running and would improve glucose level.

2. Materials and Methods

2.1 Participants

Participants in this study comprised 46 healthy young adults (29 males, age: 22.3 ± 2.1 years, mean ± standard deviation) enrolled in university or graduate school in the health sciences. Inclusion criteria were not having exercise habits as defined by the American College of Sports Medicine (i.e., those who have been engaged in planned, structured physical activity for at least 30 minutes per session at least three days per week within the past three months) [*21*] and average weekly physical activity being low to moderate in the Japanese version of the International Physical Activity Questionnaire [*22*]. Participants were excluded if they had known cardiovascular, respiratory, or metabolic diseases that limited high-intensity exercise, were taking medications known to affect metabolism, or were smokers. This study was approved by the Ethics Committee of the Graduate School of Health Sciences, Kobe University (Approval No. 1159-2), and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki. This trial was registered with the University Hospital Medical Information Network (UMIN). The registered ID is UMIN000050409, and the first registration occurred on February 24, 2023.

2.2 Assignment to experimental groups

Participants were randomly assigned to a group that performed unsupervised HIIT three times per week for eight weeks (HIIT), unsupervised comfortable speed running three times per week for eight weeks (MICT), or did not change their lifestyle for eight weeks (CONTROL). To minimize the effects of season, weather, and class curriculum or school events on exercise adherence, the start date of the experiment was set so that those in the same grade would experience the same factors.

2.3 Experimental protocol

The experimental protocol involved a two-week pre-measurement period, an eight-week intervention period, and a two-week post-measurement period (Figure 1). During the two-week pre- and post-measurement periods, participants visited the laboratory for (a) body composition, (b) glucose, and (c) resting blood pressure and maximal oxygen uptake estimation measurements. Participants wore a tri-axial accelerometer on their non-dominant wrist and a continuous glucose monitor (FreeStyle Libre Pro; Abbott Japan Co., Ltd., Tokyo, Japan) on their upper arm for two weeks of the pre- and post-measurement periods. Finally, participants were asked to record their diet for two weeks, as photographs and an ingredient list. For the intervention period lasting eight weeks, participants in the HIIT group were asked to perform unsupervised HIIT three times a week, participants in the MICT group were asked to perform unsupervised running three times a week, and participants in the control group were asked to maintain their previous lifestyle. The HIIT and MICT groups were asked to perform a total of 24 exercises, with the first exercise performed under supervision. To keep the conditions as close as possible to those of the real world and measure pure exercise adherence, we did not give the participants any encouragement or honorarium during the intervention period; we explained beforehand that they were free to choose the time and place of exercise, and it was entirely up to them whether or not to perform the exercise.

[Insert Figure 1 here]

2.3.1 HIIT group exercise

HIIT was similar to the protocol implemented in a previous study [*12*], with two sets of seven 20-second high-intensity exercise phases (burpee jumps, squats, mountain climbers, high knees, jumping lunge, push-ups, and jumping jacks) for a total of 14 exercises, separated by a 20-second dynamic recovery phase. When performing the exercise, participants were asked to watch a HIIT video and wear the tri-axial accelerometer on the left side of their body at the hip. During the first exercise session, participants performed two sets of the seven exercises at maximum effort under supervision. The remaining 23 sessions were performed unsupervised, and participants were free to choose from four options for each session: (1) two sets of seven exercises at maximum effort, (2) two sets of seven exercises at non-maximum effort, (3) one set of seven exercises at maximum effort, or (4) none.

2.3.2 MICT group exercise

The MICT group was asked to perform running at a comfortable speed. Participants were asked to wear the tri-axial accelerometer on their left wrist while running. During the first exercise session, participants performed supervised running for 30 minutes at a comfortable speed of approximately 11–13 on the rating of perceived exertion. The remaining 23 sessions unsupervised, and participants were free to run for a maximum of

30 minutes per session.

2.4 Outcomes

2.4.1 Exercise adherence

The participants recorded their exercise data in Google Forms each time they exercised, and this is presented in the “Self-reported” column of Table 1. Across 24 sessions, each selected activity was scored from 0 to 3 (Table 1), and adherence was calculated as the percentage of the maximum 72 points. Data from a tri-axial accelerometer (Actigraph) were used to verify the accuracy of the exercise records. When discrepancies occurred, accelerometer data were given priority for scoring. In the HIIT employed in this study, accelerometers attached to the sides of the body captured the movement in two axes—vertical and sagittal. Pearson's correlation coefficient was used to calculate the correlation coefficient between the vertical and sagittal axial activity counts of HIIT performed during the first supervised session and each axis activity counts from the remaining 23 unsupervised sessions. HIIT was determined to have been performed at maximum effort because the activity counts on the vertical and sagittal axes during supervised and unsupervised HIIT showed a higher correlation than the activity counts during sub-maximum effort HIIT estimated in a preliminary experiment (Table S1) (correlation coefficient for the vertical axis > 0.831, correlation coefficient for the sagittal axis > 0.797). In MICT, exercise adherence was assessed by comparing the total number of steps and duration of exercise during the first supervised running with that of the remaining 23 unsupervised sessions. Participants were considered to have performed 30 minutes of running when the duration of exercise was at least 30 minutes and the total number of steps taken was at least 67.6% of the first time. This standard is based on the average

Mean Absolute Percentage Error reported in previous studies when wearing the Actigraph wGT3X-BT on the left wrist at a running speed of 4 km/h to 6 km/h [*23*]. Sections B and C of the Exercise Adherence Rating Scale (EARS) were used to measure subjective exercise adherence. EARS Section B is a 6-item response to prescribed exercise on a 5-point scale, scored on a 24-point scale, with higher scores indicating higher adherence, with acceptable reliability and high test-retest reliability [*24, 25*]. EARS Section C comprises 10 items related to reasons an individual adheres or not to prescribed home exercise and can be used as single items.

[Insert Table 1 here]

2.4.2 Glucose concentration

On the first days of the pre- and post-measurement periods, participants were fitted with a continuous glucose monitor on the upper arm, and their mean glucose concentration and predictive HbA1c were recorded for two weeks. On a separate day during the measurement period, after an overnight fast, participants visited the laboratory from 8:00 a.m. to 10:00 a.m. to measure blood glucose changes up to two hours after glucose loading. Participants measured their fasting blood glucose level, then consumed 500 ml of a glucose-containing beverage (200 kcal/50 g carbohydrate/0 g protein/0 g fat; Fanta Grape, The Coca-Cola (Japan) Company, Tokyo, Japan). They self-monitored their blood glucose levels every 15 min for up to 120 min after the start of consumption. The protocol recorded fasting plasma glucose, maximal blood glucose after glucose loading, and the incremental area under postprandial glucose curve (iAUC) using the trapezoidal method.

2.4.3 Body composition measurements

Participants visited the laboratory on the first days of the pre- and post-measurement periods to take body composition measurements and answer questionnaires. Body composition was measured using a body composition analyzer (DF860; YAMATO-SCALE Co., Ltd., Hyogo, Japan) that uses the bioelectrical impedance method; body weight, muscle mass, and body fat percentage were recorded. In addition, participants answered the European Health Literacy Survey Questionnaire Japanese version (J-HLS-EU-Q47) [*26, 27*] as an assessment of health literacy.

2.4.4 Maximal oxygen uptake and resting blood pressure

Participants' resting blood pressure was measured by auscultation in the laboratory. Participants then performed an incremental exercise test on a treadmill (GE Healthcare Japan Corp., Ltd., Tokyo, Japan) according to United States Air Force School of Aerospace Medicine protocol [*28*] to estimate maximal oxygen uptake. Participants stood quietly for one minute, then began walking at 3.2 km/h. After three minutes, participants increased their walking speed to 5.3 km/h. The speed remained at 5.3 km/h, but the treadmill incline increased by 5% every three minutes until the RPE reached 18 or higher. Oxygen consumption and heart rate were measured during walking and maximum oxygen consumption was estimated based on the maximum heart rate predicted from age. Systolic blood pressure, diastolic blood pressure, and estimated maximal oxygen uptake were recorded by this protocol.

2.4.5 Physical activity and nutrition

Participants received a tri-axial accelerometer on the first days of the pre- and post-measurement periods and asked to wear it on their wrist as much as possible during the measurement period, from the time they woke up until they went to bed. Data from participants who did not wear the Actigraph for at least three days during the measurement period were excluded. They were also asked to record their diet for two weeks, both photographically and in writing. This recorded the amount of physical activity during two weeks and average daily food intake during the measurement period.

2.5 Statistical analysis

Sample sizes were calculated using G*Power 3.1.9.7 software (Institut der Universität Bonn, Bonn, Germany), with effect size set at 0.25, alpha at 0.05, and power at 0.8; 14 participants per group were determined to be required. The effect size used for the sample size calculation was based on partial Eta squared values reported in prior studies [*29*]. Considering a dropout rate of 10%, 15–16 patients per group were recruited. A *t*-test was used for exercise adherence, two-way analysis of variance (intervention x group) was used for other physiological outcomes to check for main effects between groups and over time, and Holm's post-test was used when significant differences were found. Cohen's *d* was used to estimate effect sizes. The level of statistical significance was set at $p < 0.05$. All data were analyzed using Jamovi version 2.3.28 [*30*].

3. Results

3.1 Participant characteristics

Of the 46 participants (HIIT group: 15, MICT group: 16, CONTROL group: 15) recruited in this study, 44 were included in the analysis due to one dropout (long-term physical illness or moving) each in the HIIT and MICT groups (Figure 2). The characteristics of the participants included in the analysis are shown in Table 2. Among the reasons for dropout, physical illness was not attributable to the intervention in this study and no adverse events were reported as a result of the intervention.

[Insert Figure 2 here]

[Insert Table 2 here]

3.2 Exercise adherence

Exercise adherence results are illustrated in Figure 3. Both objective, measured by a tri-axial accelerometers, and subjective exercise adherence, assessed by EARS, were significantly higher in the HIIT group compared to the MICT group ($p < 0.01$, $d = 1.32$ and $p < 0.001$, $d = 1.48$, respectively). In addition, “I don't have time to do my exercises” was significantly lower in the HIIT group than in the MICT group for the inhibitory factors of exercise implementation as assessed in EARS Section C. Exercise promotion factors such as “I feel confident about doing my exercises,” “I do my exercises to improve my health,” and “I do my exercises because I enjoy them” were significantly higher in the HIIT group than in the MICT group.

[Insert Figure 3 here]

3.3 Changes in glucose concentration measurements

Glucose concentration measurements were not significantly different either between groups or pre- and post-intervention. Figure 4 shows the results.

[Insert Figure 4 here]

3.4 Other changes in physiological outcomes

Body composition, maximal oxygen uptake, and blood pressure were not significantly different between the groups or before and after the intervention. The results are shown in supplementary Figure S1.

3.5 Physical activity and nutrition

There were no significant differences in physical activity and average caloric intake between the groups, either before or after the intervention. The results are shown in supplementary Table S2.

4. Discussion

This study compared unsupervised, equipment-free bodyweight HIIT protocols and unsupervised running among inactive young adults using a new objective adherence algorithm. The key findings indicate that among healthy young adults, the 8-week weight-bearing exercise-based HIIT was associated with higher exercise adherence than the most performed exercise, running. However, changes in physiological outcomes, particularly glycemic indicators, were not significant.

In systematic reviews and meta-analyses comparing exercise adherence in HIIT and MICT, no significant difference was found [*31, 32*], in contradiction of the findings of this study. This difference in findings can be explained by the disparity between this study's HIIT and MICT exercise modalities, as well as the participants' youth, health, and low activity levels.

Regarding exercise modality, in most previous studies, HIIT was performed on an ergometer or treadmill [*17, 18, 33, 34*] or involved walking, running, or cycling [*14, 35–39*]; these exercises require a laboratory, gym, outdoor space, or dedicated equipment. Our study employed body weight exercise-based HIIT, which can be performed anywhere, and demonstrated higher exercise adherence than running, which must be performed outdoors. In previous studies that employed weight-bearing exercise-based HIIT [*40–42*], the comparison group was free-selected or home-based MICT, and the differences in the exercise modalities of the comparison group may have led to different findings from those of the present study.

Regarding the participants in this study being healthy young adults with low activity levels, in many previous studies, participants had cardiac disease [*17, 35, 38, 40, 41*], joint disease [*14*], or diabetes/pre-diabetes [*33, 36*], and the mean age was higher than in this study. Although it is debatable whether HIIT or MICT provides more enjoyment, which may affect exercise adherence, the participants in previous studies who found HIIT more enjoyable than MICT were mostly young, in their 20s and 30s [*43–46*]. While high-intensity exercise such as HIIT and sprint interval training have been reported to exacerbate negative emotional responses in inactive individuals [*47, 48*], participants in this study were relatively young and may not have had negative feelings toward HIIT. HIIT has also been shown to elicit positive emotional responses due to time efficiency, exercise confidence, and enjoyment [*49, 50*]. In the present study, HIIT was more time efficient than MICT, and the item scores of exercise confidence and enjoyment as exercise facilitators were higher than those of MICT, consistent with previous studies.

In a similar study, Hesketh et al. reported low adherence rates for both weight-bearing exercise-based HIIT and conventional MICT (39 % vs. 48 %) [*40*]. This contrasts with this study’s higher adherence rates (60 % vs. 28 %, respectively). Notably, Hesketh's participants had a significantly higher mean age (49 years) compared to those in the present study (22 years). Additionally, the duration of home-based HIIT (24–54 minutes) was more than twice that of the current intervention (9 minutes). The patients in the HIIT program cited lack of time as a barrier to exercise participation. These demographic and protocol differences likely contributed to the observed disparities in adherence outcomes.

The HIIT intervention did not result in significant changes in physiological outcomes, including glucose concentrations. This is in line with previous studies reporting no improvements in blood glucose indicators among healthy individuals following HIIT [*51, 52*]. In contrast, HIIT has demonstrated beneficial effects on blood glucose regulation in individuals with diabetes or impaired glucose tolerance [*36, 53*], suggesting its impact may be condition-dependent and limited in metabolically healthy populations. One previous study found contrasting results, with a 10-week HIIT intervention showing improved maximal oxygen uptake and insulin sensitivity in healthy individuals [*54*]. Although these results contradict those of the present study, this discrepancy can be explained by the low HIIT exercise adherence. In this study, HIIT demonstrated higher exercise adherence compared to MICT; however, HIIT adherence under completely unsupervised conditions was not high. Thus, it may not have been sufficient to influence physiological indicators.

Further, it is important to note that differences in exercise modality and total exercise volume between HIIT and MICT may have influenced exercise adherence. This study was conducted among undergraduate and graduate students majoring in health sciences, who are likely to possess knowledge about exercise and health. Therefore, compared to other young adults, they may naturally demonstrate a higher rate of exercise persistence. Another limitation may have been that Actigraph was worn on the waist during HIIT and on the wrist during running, and this difference in wearing location may have affected the results. In the MICT group, exercise adherence was assessed based on step count and exercise duration, so it did not account for the actual exercise intensity or running speed influenced by the slope of the running location. In fact, this study's participants were more likely to rate their health literacy as "Sufficient" and less likely to rate it as "Inadequate." This is in contrast to the self-reported health literacy of Japanese individuals in a previous study [*27*]. In addition, follow-up periods need to be increased in future studies, as a follow-up of 12 months or longer is necessary to accurately assess exercise adherence [*55*]. It should be noted that this study presents a different view than previous studies and that the results are limited to healthy young adults with low levels of physical activity.

4.1 Conclusions

Weight-bearing exercise-based HIIT for healthy young adults was related to higher exercise adherence compared to moderate-intensity running. On the other hand, neither unsupervised body-bearing exercise-based HIIT nor running for 8 weeks improved glucose concentration indicators or other physiological outcomes in healthy young adults. Weight-bearing exercise-based HIIT may be superior to MICT as a first exercise recommendation for healthy young adults who have no exercise habits.

Ethical considerations

This study was approved by the Ethics Committee of the Graduate School of Health Sciences, Kobe University (Approval No. 1159-2), and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

Conflicts of interest

The authors declare that they have no conflict of interest. The funders had no involvement in the design of this study; collection, analysis, and interpretation of the data; writing of the manuscript; or decision to publish the results.

Acknowledgments

Funding

This work was supported by JST SPRING, Grant Number JPMJSP2148.

Author contributions

All authors have contributed sufficiently to the manuscript for publication as the authors. Y.N., conceptualization, methodology, validation, formal analysis, investigation, data curation, writing and preparation of the original draft, and funding acquisition; K.O., conceptualization, methodology, data curation, and review and editing; T.G., R.S., H.E., M.F., and R.M., conceptualization, methodology, data curation, and review and editing; A.I., review and editing and project administration. All authors have read and agreed to the published version of the manuscript.

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Figures and Tables

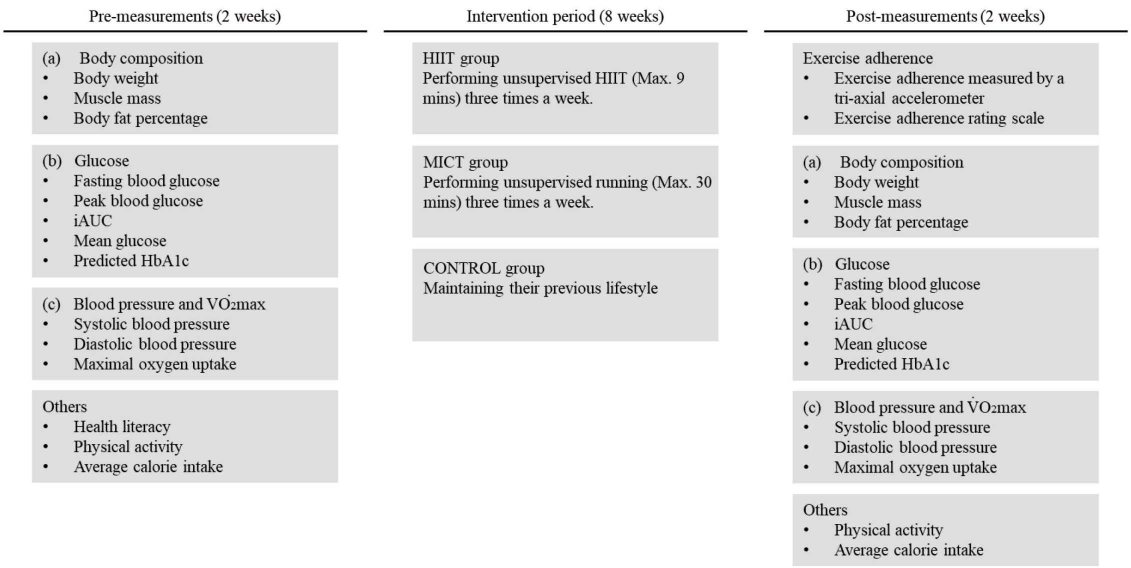

Figure 1. Summary of experimental trials. iAUC: incremental area under postprandial glucose curve; V̇O2max: maximal oxygen uptake; HbA1c: hemoglobin A1c.

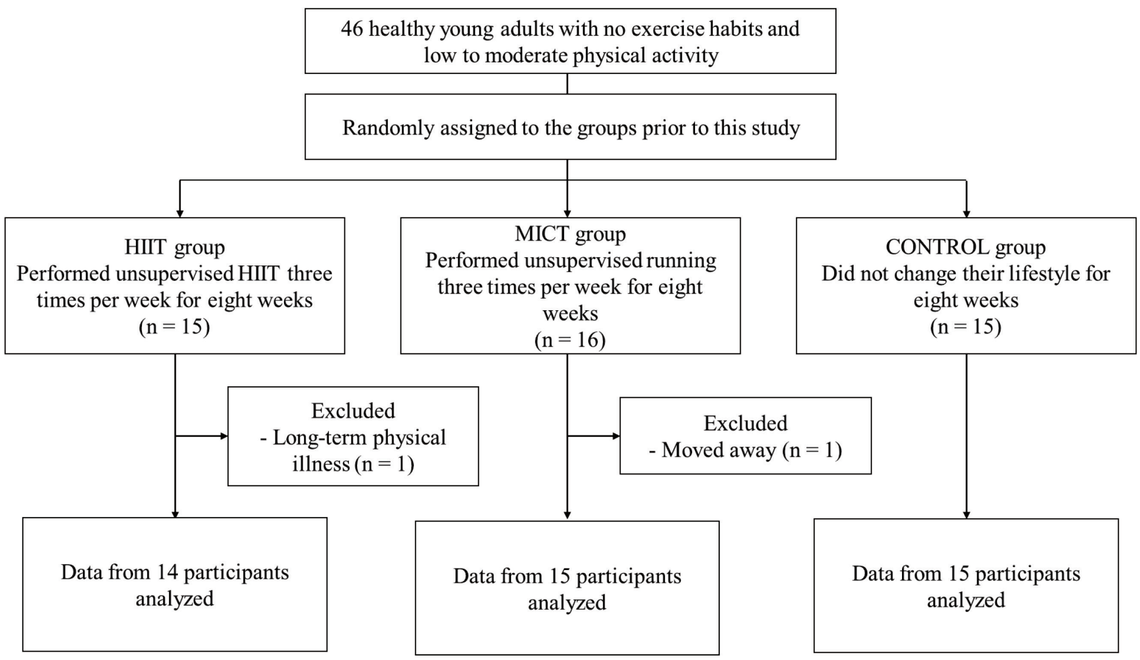

Figure 2. Flow chart depicting sample selection. HIIT: high-intensity interval training.

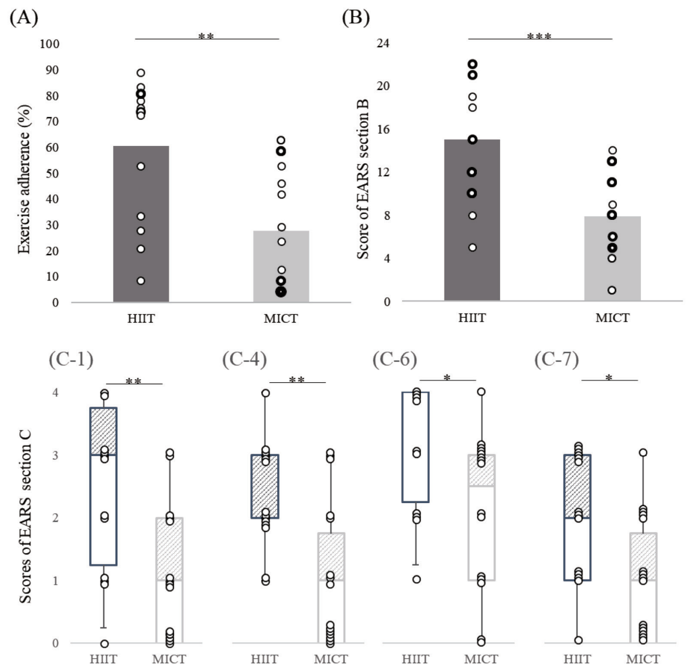

Figure 3. (A) Exercise adherence measured by tri-axial accelerometers. (B) Total scores of Exercise Adherence Rating Scale (EARS) Section B. (C) Scores for each question of EARS Section C; 1: I don't have time to do my exercises; 4: I feel confident about doing my exercises; 6: I do my exercises to improve my health; 7: I do my exercises because I enjoy them. *$p < 0.05$ vs. moderate-intensity continuous training (MICT) group. **$p < 0.01$ vs. MICT group. ***$p < 0.001$ vs. MICT group. This graph only shows significant differences; all results are shown in supplementary Figure 3'.

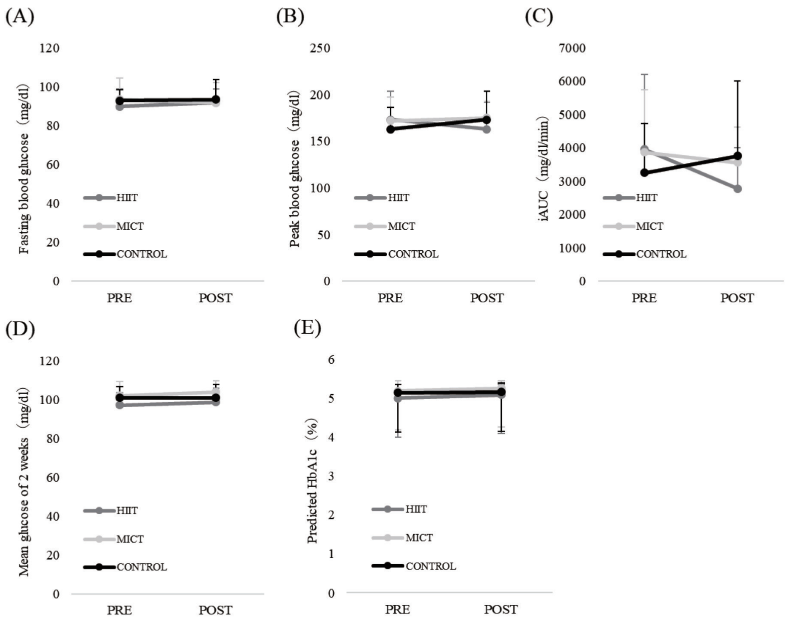

Figure 4. (A): Fasting blood glucose; (B): Peak postprandial blood glucose; (C): Incremental area under postprandial glucose curve (iAUC); (D): Mean glucose concentration at 2 weeks; (E): Predicted HbA1c. No between-group or pre- and post-intervention significant differences were found for any of the measures.

Table 1

Scores for each session

Scores	HIIT		MICT	
	Self-reported	Actigraph	Self-reported	Actigraph
3	Performing 2 sets of 7 HIIT exercises at maximal effort	The correlation coefficients for the vertical and sagittal axes were > 0.831 and > 0.797, respectively	Running for 30 mins	The total steps were greater than or equal to 67.6% of the supervised running steps
2	Performing 2 sets of 7 HIIT exercises at non-maximal effort	The correlation coefficient for the vertical axis is greater than or equal to 0.593 but less than or equal to 0.831, or the correlation coefficient for the sagittal axis is greater than or equal to 0.572 but less than or equal to 0.797	Running for 20 to 29 mins	The total steps were greater than or equal to 45.1% but less than 67.6% of the supervised running steps
1	Performing 1 set of 7 HIIT exercises at maximal effort	The exercise time is halved, the correlation coefficient for the vertical axis > 0.831, and the correlation coefficient for the sagittal axis > 0.797	Running for 10 to 19 mins	The total steps were greater than or equal to 22.5% and less than 45.1% of the supervised running steps
0	Did not exercise	Others	Did not exercise	The total steps were less than 22.5% of the supervised running steps

HIIT: high-intensity interval training group; MICT: moderate-intensity interval training group.

Table2

Participant characteristics

	HIIT (*n* = 14)	MICT (n = 15)	CONTROL (*n* = 15)
Sex (male/female)	8/6	10/5	9/6
Age (years)	22.4 ± 2.2	21.9 ± 2.0	22.3 ± 2.2
Height (cm)	166 ± 10	169 ± 9	166 ± 9
Health literacy (%)	Excellent: 0 Sufficient: 29 Problematic: 50 Inadequate: 21	Excellent: 0 Sufficient: 33 Problematic: 53 Inadequate: 13	Excellent: 0 Sufficient: 33 Problematic: 53 Inadequate: 13

Data presented as mean ± standard deviation. HIIT: high-intensity interval training group; MICT: moderate-intensity continuous training group; CONTROL: control group.

Table S1. Correlation coefficient of vertical and sagittal activity counts during sub-maximal effort HIIT (n=8)

	Vertical		Sagittal	
Preliminary experiment participants	RPE	Correlation coefficient	RPE	Correlation coefficient
A	14	0.975	14	0.895
B	13	0.919	13	0.901
C	12	0.891	12	0.762
D	11	0.593	11	0.572
E	12	0.815	12	0.871
F	13	0.855	13	0.761
G	13	0.852	13	0.827
H	12	0.831	12	0.789
Mean	12.5	0.841375	12.5	0.79725

RPE: rate of perceived exertion. The average correlation coefficient of vertical and sagittal axis activity counts was set as the baseline for unsupervised maximum-effort HIIT, and the minimum coefficient as the baseline for sub-maximal effort HIIT.

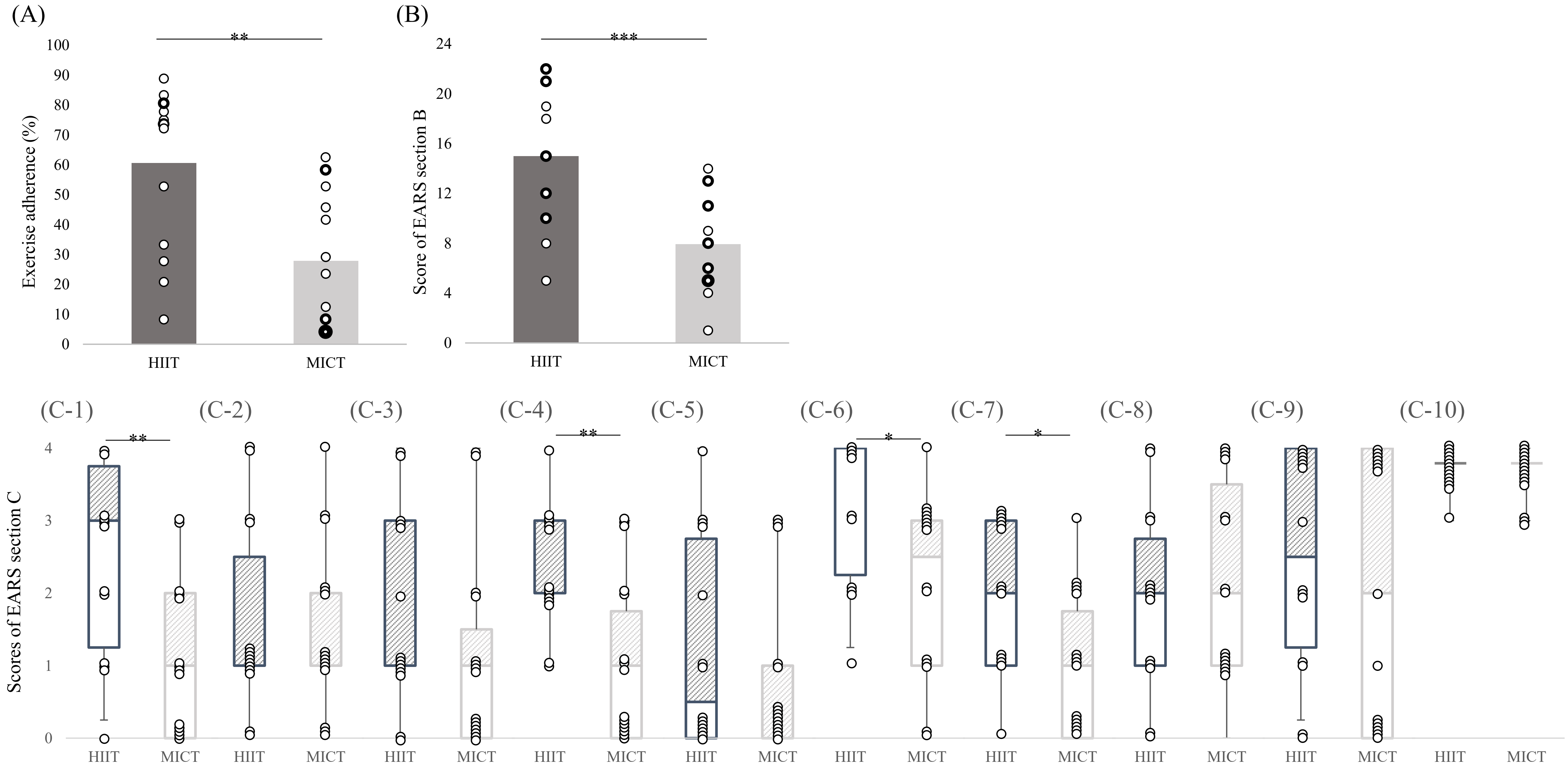

Fig. 3'

(A) Exercise adherence measured by tri-axial accelerometers. (B) The total scores of EARS section B. (C) The scores for each question of EARS section C; 1: I don't have time to do my exercises; 2: Other commitments prevent me from doing my exercises; 3: I don't do my exercises when I am tired; 4: I feel confident about doing my exercises; 5: My family and friends encourage me to do my exercises; 6: I do my exercises to improve my health; 7: I do my exercises because I enjoy them; 8: I adjust the way I do my exercises to suit myself; 9: I stop exercising when my pain is worse; 10: I'm not sure how to do my exercises. *$p < 0.05$ vs. MICT group. **$p < 0.01$ vs. MICT group. ***$p < 0.001$ vs. MICT group.

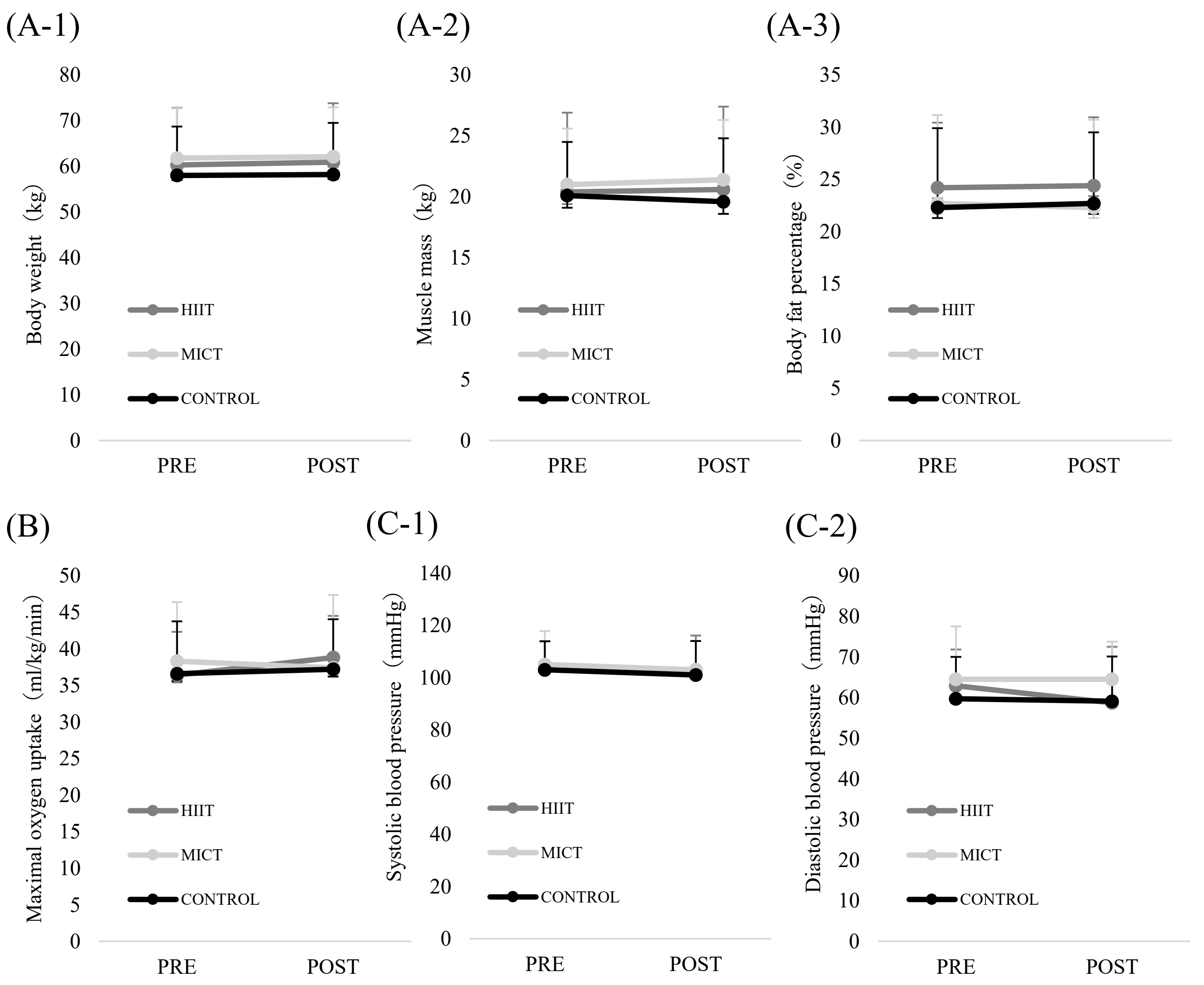

Figure S1

(A) Body composition; 1: body weight; 2: muscle mass; 3: body fat percentage. (B) Maximal oxygen uptake. (C)Blood pressure; 1: systolic blood pressure; 2: diastolic blood pressure. No significant differences were found between groups or before and after the intervention in all measures.

Table S2
Physical activity and nutrition

	HIIT			MICT			CONTROL		
	Pre	Post	p	Pre	Post	p	Pre	Post	p
Actigraph wearing time (min)	804 ± 130	808 ± 133	n.s.	773 ± 79	750 ± 94	n.s.	776 ± 189	723 ± 69	n.s.
Physical activity(%)									
%Sedentary	45.6 ± 12.6	44.3 ± 12.1	n.s.	47.8 ± 11.6	44.2 ± 11.3	n.s.	52.0 ± 15.2	49.8 ± 10.7	n.s.
%Light	39.7 ± 10.9	42.0 ± 9.6	n.s.	37.2 ± 7.9	41.4 ± 10.3	n.s.	30.5 ± 9.8	33.2 ± 8.7	n.s.
%Moderate	16.3 ± 5.6	14.7 ± 5.6	n.s.	14.8 ± 6.5	14.0 ± 6.7	n.s.	17.8 ± 7.0	16.6 ± 5.0	n.s.
%Vigorous	0.1 ± 0.3	0.7 ± 1.2	n.s.	0.2 ± 0.4	0.2 ± 0.6	n.s.	0.1 ± 0.4	0.4 ± 0.7	n.s.
%Very vigorous	0	0.2 ± 0.4	n.s.	0	0	n.s.	0	0	n.s.
Nutrition(kcal)									
Average caloric intake	1670 ± 377	1742 ± 448	n.s.	1803 ± 250	1845 ± 402	n.s.	1911 ± 417	1772 ± 268	n.s.

Data are presented as mean ± SD. n.s.: no significant.