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A COMPARISON OF REPEATED WINGATE BASED OF HIGH INTENSITY INTERVAL TRAINING AND MODERATE INTENSITY CONTINUOUS TRAINING ON AEROBIC CAPACITY UNDER NORMOBARIC HYPOXIA

PRIMERJAVA PONAVLJAJOČE SE VISOKO INTENZIVNE INTERVALNE VADBE IN ZMERNO INTENZIVNE NEPREKINJENE VADBE NA AEROBNO ZMOGLJIVOST V NORMOBARIČNI HIPOKSIJI

ABSTRACT

Aerobic capacity is very important for all people in terms of health and performance. Therefore, important organizations such as the World Health Organization (WHO) and the American College of Sports Medicine (ACSM) generally recommend that adults should perform physical activity maintain and improve their aerobic capacity. This study aimed to compare the effects of 8-week Repeated Wingate (RW) based of high-intensity interval training (HIIT) vs. moderate-intensity continuous training (MICT) on the aerobic fitness in recreationally active young adults under hypoxic and normoxic conditions. Thirty-two recreationally active young adults (age:22,37±2,30 years) were randomly assigned to Hypoxia RW(n=8), Normoxia RW(n=8), Hypoxia MICT (n=8), Normoxia MICT (n=8) group training protocol. The HIIT groups consisted of 4-7×30-s Wingate "all-out" sprints with 4 min of passive rest. The MICT groups completed 25-40 minutes of continuous running. Before, 4-week and after the 8-week interventions the following tests were completed: maximum oxygen consumption (V̇O2max), anaerobic threshold oxygen consumption (AT VO2), time to exhaustion (TTE) be determined from the Bruce treadmill protocol and submaximal oxygen consumption (Submaximal VO2) be determined from the modified Astrand protocol. Statistical difference was found between the 4th and 8th weeks in the HIIT and MICT groups according to the pre-tests ($p \leq 0.05$). However, no difference was found between the condition (Hypoxia - Normoxia) and training methods (HIIT-MICT) ($p \leq 0.05$).

Keywords: aerobic capacity, continuous training, high intensity interval training, hypoxia

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IZVLEČEK

Aerobna zmogljivost je zelo pomembna za zdravje in zmogljivost vseh ljudi. Zato pomembne organizacije, kot sta Svetovna zdravstvena organizacija (WHO) in Ameriški kolegij za športno medicino (ACSM) na splošno priporočajo, naj odrasli s telesno dejavnostjo ohranjajo in izboljšujejo svojo aerobno zmogljivost. Namen te študije je bil primerjati učinke 8-tedenske ponavljajoče se vadbe Wingate (RW), ki temelji na visokointenzivni intervalni vadbi (HIIT), v primerjavi z zmerno intenzivno neprekinjeno vadbo (MICT) na aerobno zmogljivost pri rekreativno aktivnih mladih odraslih v hipoksičnih in normoksičnih pogojih. Dvaintrideset rekreativno aktivnih mladih odraslih (starost: 22.37±2.30 let) je bilo naključno razporejenih v eno izmed štirih vadbenih skupin (hipoksična vadba RW (n=8), normoksična vadba RW (n=8), hipoksična vadba MICT (n=8), normoksična vadba MICT (n=8)). Skupine HIIT so bile sestavljene iz 4-7×30-s Wingate "all-out" šprintov s 4 min pasivnega počitka med vsako ponovitvijo. Skupine MICT so opravile 25-40 minut neprekinjenega teka. Pred, po štirih in osmih tednih intervencije so bili opravljeni naslednji testi: največja poraba kisika (V̇O2max), poraba kisika na anaerobnem pragu (AT VO2), čas do izčrpanosti (TTE) (Bruceov protokol na tekalni stezi) in submaksimalna poraba kisika (Submaximal VO2) (spremenjen Astrandov protokol). Med 4. in 8. tednom v skupinah HIIT in MICT je bila glede na predhodne teste ugotovljena statistična pomembna razlika ($p \leq 0.05$). Razlike niso bile ugotovljene med pogoji (hipoksija - normoksija) in metodami vadbe (HIIT-MICT) ($p \leq 0.05$).

Ključne besede: aerobna zmogljivost, neprekinjena vadba, visoko intenzivna intervalna vadba, hipkosija

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INTRODUCTION

Regular physical activity and aerobic exercise are crucial for a healthy lifestyle (Milanovic, Sporis, & Weston, 2015). For this reason, authorities recommend that adults do 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity exercise a week to protect their health (Garber et al., 2011). Despite this, a considerable amount of adults cannot reach the recommended physical activity level, which is attributed to a lack of time and motivation (Stuts, 2002). Although there are many methods to improve aerobic performance, the moderate-intensity continuous training (MICT) method is one of the well-received and traditional training programs used in the development of aerobic performance, which increases by approximately 2–7% maximum oxygen consumption (VO_{2max}) in recreationally active adults (Helgerud et al., 2007; Hottenrott, Ludyga, & Schulze, 2012).

In the development of aerobic performance, both high-intensity interval training (HIIT) and hypoxia training in the normobaric environment have been frequently practiced recently as an alternative to MICT due to their cardiovascular and metabolic benefits (Ross, Porter, & Durstine, 2016; Vogt et al., 2001). There is also evidence that these methods increase the performance of athletes in a shorter time and more than MICT (Czuba et al., 2019; MacInnis, & Gibala, 2017). In particular, one of the HIIT methods, Repeated Wingate efforts (RW), is a more effective method for improving exercise capacity than traditional training methods (Karabiyik et al., 2021). RW is a form of sprint interval training or HIIT involving the repetition of “all out” 30-s efforts (Gibala, Little, Macdonald, & Hawley, 2012; Akgul, Koz, Gurses, & Kurkcu, 2017). RW is an effective exercise method that increases mitochondrial biogenesis and exercise capacity (MacInnis, & Gibala, 2017). In the literature, there are studies reporting that only 6 sessions of RW training increase exercise capacity (MacInnis, & Gibala, 2017; Akgul, Gurses, Karabıyık, & Koz, 2016).

However, it is known that live low-train high (LL-TH) altitude/hypoxic training methods have been used for aerobic performance improvement for many years (Brocherie, Girard, Faiss, & Millet, 2017). Again, this training method has become more popular with the availability of tools that can provide hypoxic conditions in the normobaric environment. Because these tools also provided the opportunity to perform hypoxic training without changing the athlete's daily routine (Wilbur, 2007; Akgul, & Koz, 2019). Training methods applied with these tools for example in intermittent hypoxic training (IHT), when exposed to insufficient hypoxia, it is thought that the expected hematological adaptations may not occur (Wilbur, 2007). But, hypoxia training can also develop non-hematological adaptations by increasing mitochondrial biogenesis (Schmutz et al., 2010). oxidative glycolytic enzyme (Puype, Van Proeyen, Raymackers, Deldicque, & Hespel, 2013). monocarboxylate transporters (Faiss et al., 2013) and angiogenesis (Wahl et al., 2013). These adaptations develop through the oxygen sensing signal in skeletal muscle tissue and may occur less frequently in the same training performed under normoxic conditions (Hoppeler, & Vogt, 2001). In studies comparing the same training methods in normoxic and hypoxic conditions, it is reported that training in hypoxic conditions can increase physiological adaptations more by creating more exercise stimuli than in normoxic conditions (Westmacott, Sanal-Hayes, McLaughlin, Mair, & Hayes, 2022). According to research, in training performed under hypoxic conditions, decreased fraction of inspired oxygen resulting from lower oxygen availability may negatively affect the exercise stimulus by reducing the intensity or volume of exercise (Vogt, & Hoppeler, 2010).

In the literature, it has been reported that RW training (4-9x30-s Wingate efforts with 4.5- min recovery) (FiO2: 0.144) performed in a hypoxic environment increases glycolytic enzyme activity more, although the performance responses given to both groups are similar when compared to those performed in normoxic conditions (Puype, Van Proeyen, Raymackers, Deldicque, & Hespel, 2013). It has also been reported that long-term exposure to hypoxia may have detrimental effects on mitochondrial adaptations, whereas short-term hypoxic training may improve mitochondrial density (Hoppeler, Vogt, & Weibel, 2003). Again, many studies have compared HIIT and MICT training practices, and in most of these studies, it has been shown that HIIT is a more effective method in improving aerobic performance in both recreationally active adults and athletes (Hottenrott, Ludyga, & Schulze, 2012; Soylu, Arslan, Sogut, Kilit, & Clemente, 2021).

This study aims to compare aerobic performance after 8-week-long MICT and RW exercise protocols performed either in hypoxic or normoxic conditions. We hypothesized that HIIT methods can lead to greater improvements in aerobic capacity than MICT methods, independent of environmental conditions.

METHODS

Participants

In the first interview with the participants, the purpose, procedures and risks of the study were informed and written consent was obtained. The study procedures followed the principles outlined in the Declaration of Helsinki and were approved by Ankara University, Non-interventional Clinical Ethics Committee (09-381-15). Inclusion criteria were the absence of acute or chronic disease, no smoking and subject health was regularly monitored both before and during the study.

Table 1. Physical characteristics of the study participants.

n=32	Mean	Standard deviation
Age (year)	23,25	2,30
Height (cm)	175,06	5,67
Body weight (kg)	71,06	6,82
Body fat (%)	18,22	3,36
$\dot{V}O_{2max}$ (ml·min^{-1}·kg^{-1})	50,55	0,88

Experimental Approach to the Problem

A four group, parallel study design was used to compare aerobic performance in recreationally active young adults. Considering the average 75-120 min·wk-1 of moderate intensity and 6-10.5 min·wk-1 of vigorous intensity, the total training time for the MICT group was 63% higher than the RW groups in the present study (Table 2). The present study design lasted 11 weeks, consisting of 1 week of tests (baseline), 4 weeks of RW and MICT interventions and 1 week of test (mid-test), 4 weeks of RW and MICT interventions, and 1 week of tests (post-intervention). Participants also completed a familiarization all protocols in which data was collected but was only used to display any learning effects and not for further analyses. All subjects randomly divided into Normoxia RW and Hypoxia RW or the Normoxia MICT and Hypoxia MICT groups. All participants completed pre, mid and post-testing. All training regimes were performed three times a week and each training session were separated by at least 2 days in order to avoid any possible effects of physical fatigue. All tests with the same order were performed at a similar time of the training day (between 3 p.m. and 6 p.m.) for similar chronobiological characteristics. The participants were familiar with all performance tests and training methods, and they were instructed to maintain normal dietary intake before and during the study.

Exercise tests

All groups completed 24 sessions training over a 8-week period. The Bruce Protocol was carried out on the treadmill, using a Jaeger Masterscreen CPX model ergospirometer system (Germany) gas analyzer to determine the maximal oxygen consumption (VO_{2max}), anaerobic threshold oxygen consumption (AT VO_2) and time to exhaustion (TTE). The test period to find the VO_{2max} was divided into 30-s segments and the mean of the data were taken, while the data of the highest 30-s segment were recorded as VO_{2max}. Also, heart rate was recorded every 30-45 seconds with increasing workload, and work in-tensity was considered AT, where the linear increase in heart rate showed a downward deflection (Kuipers, Keizer, de Vries, van Rijthoven, & Wijts, 1988) and the corresponding oxygen consumption was recorded. Except this, Modified Astrand protocol was carried out all groups 48 hours after Bruce protocol on the treadmill, using a Jaeger Masterscreen CPX model ergospirometer system (Germany) gas analyzer to determine the submaximal oxygen consuption (Submaximal VO_2).

Repeated Wingate Training

The Hypoxia RW (at 2500m, F_iO_2: 15.4%) and Normoxia RW groups performed Repeated Wingate training with a Monark 894E (Monark Exercise AB, Vansbro, Sweden) bicycle ergometer. Sitting and arm positions were adjusted for each participant and exercised in this adjusted position for 8 weeks. The exercises were applied for 8 weeks, 3 days a week, every other day. They did 4 repetitions in the first two weeks, 5 repetitions in the third and fourth weeks, 6 repetitions in the fifth and sixth weeks, and 7 repetitions in the seventh and eighth weeks. Following a 5 min warm-up at 60 watt with 5 s sprints without resistance on the second and third minutes, participants performed 4-7 × 30-s Wingate "all-out" sprints with 4 min of passive rest (Yamagishi, & Babraj, 2016). All training sessions were performed against 7.5% of the body weight of the participants when reaching ≥150 rpm during un-loaded pedaling in the Monark 894E cycle ergometer.

Moderate Intensity Continuous Training (MICT)

The Hypoxia MICT (at 2500m, F_iO_2: 15.4%) and Normoxia MICT groups trained on the treadmill (HP Cosmos Mercury, Germany) for 8 weeks, 3 days a week, every other day. They ran for 25 minutes in the first two weeks, 30 minutes in the third and fourth weeks, 35 minutes in the fifth and sixth weeks, and 40 minutes in the seventh and eighth weeks, at 70-80% of their maximal heart rate calculated by the Karvonen method (Benda et al., 2015; Jones, & Carter, 2000).

Providing hypoxic conditions

In order to provide the specified altitude, the mask connected to the Hypoxico Everest Summit II-Altitude Generator (Hypoxico, NY, USA). was placed on the participants and was kept on during the training. Normoxia altitudes were determined based on the the altitude at which test sessions were performed in Ankara, Turkey (890 m).

Table 2. Description of the 8-weeks of hypoxia-normoxia HIIT and hypoxia-normoxia MICT training interventions.

		Hypoxia and Normoxia RW	Hypoxia and Normoxia MICT
Week	**Sessions**	**Pre-intervention testing**	
1 and 2	1-6	4x30s, 4min REST	25 min continuous running
3 and 4	7-12	5x30S, 4min REST	30 min continuous running
		Mid-intervention testing	
5 and 6	13-18	6x30s, 4min REST	35 min continuous running
7 and 8	19-24	7x30s, 4min REST	40 min continuous running
		Post-intervention testing	

Statistical analysis

We analyzed our data with SPSS 22. The Shapiro-Wilk test was used to determine whether the distribution of the data was normal. To determine the differences between the groups for the performance variables obtained as a result of the aerobic performance test, pre-test, 4th week, and 8th week practices, in which the participants participated repeatedly, the Analysis of Variance in Repeated Measurements was used. In cases where a difference was detected as a result of the Analysis of Variance in Repeated Measurements, bonferroni's post hoc test was used to determine from which group the difference originated. All tests for statistical significance were standardized at an alpha level of $p < 0.05$.

RESULTS

Pre, mid and post test values and the effect of training on aerobic capacity of the participants are summarized in Table III. Considering VO_{2max}, a significant difference was found between pretest- 4th week, pretest - 8th week and 4th week - 8th week in HIIT groups. In the Hypoxia

MICT group, a significant difference was found between pre-test - 8th week and 4th week – 8th week. In the Normoxia MICT group, significant differences were detected between pretest - 4th week and pre-test 8th week. Although there was a difference in submaximal VO_2 in the anova test, there was no difference among the groups at any time point in the post hoc test. In the Hypoxia HIIT group, significant differences were detected in AT VO_2 between pretest – 8th week and 4th week – 8th week. In the Hypoxia MICT group, significant differences were detected in AT VO_2 between pretest - 4th week, pre-test - 8th week and 4th week – 8th week. Also in the Normoxia MICT group, significant differences were detected in AT VO_2 between pretest - 4th week and pretest - 8th week. When we look at the TTE parameter, in the Hypoxia HIIT and Normoxia MICT groups, significant difference was found between pretest - 4th week and pretest - 8th week. Furthermore, in the Normoxia HIIT group, while a significant difference was found both at the pretest and 8th week. In the Hypoxia MICT group, significant difference was found between pretest - 4th week, pre-test - 8th week and 4th week – 8th week. As a result of analysis, there is no difference between training methods (HIIT vs MICT) and different conditions (Hipoxia vs Normoxia) on aerobic performance and there is no statistical difference in the group*time interaction either.

Table 3. Effect of all training methods on aerobic performance of the participants.

Group	Time	VO_{2max} (ml.kg-1.min-1)	VO_2submax (ml.kg-1.min-1)	VO_2 at AT (ml.kg-1.min-1)	TTE (min)
RW(H)	Pre	51,20 ± 3,15	20,45 ± 3,33	42,72 ± 3,85	16,90 ± 0,91
	4.Week	56,74 ± 4,10 *	17,05 ± 1,79	47,93 ± 6,68	18,38 ± 1,29 *
	8.Week	62,54 ± 5,15 &#	17,23 ± 1,95	52,25 ± 6,97 &#	18,69 ± 1,33 &
RW(N)	Pre	49,89 ± 6,02	17,60 ± 2,59	40,10 ± 6,44	16,22 ± 2,64
	4.Week	54,08 ± 5,99 *	17,47 ± 1,31	46,62 ± 6,41	17,03 ± 1,84
	8.Week	60,41 ± 8,10 &#	17,01 ± 1,81	44,49 ± 19,25	18,41 ± 0,90 #
MICT(H)	Pre	52,82 ± 5,81	19,28 ± 2,55	46,01 ± 5,25	15,63 ±1,39
	4.Week	58,93 ± 3,80	17,12 ± 1,43	52,35 ± 5,59 *	17,33 ± 1,27 *
	8.Week	61,87 ± 4,33 &#	18,16 ± 1,87	57,08 ± 3,71 &#	17,99 ± 1,21 &#
MICT (N)	Pre	50,58 ± 5,32	18,47 ± 2,27	43,86 ± 6,41	16,12 ± 1,32
	4.Week	55,57 ± 6,27 *	17,97 ± 2,28	49,70 ± 5,05 *	17,39 ± 1,52 *
	8.Week	59,15 ± 5,90 &	18,23 ± 2,04	53,95 ± 4,92 &	17,76 ± 1,45 &
Group	F	0,600	0,731	2,554	0,85
	p	0,620	0,545	0,083	0,482
	ηp2	0,080	0,095	0,267	0,108
Time	F	78,017	12,928	23,574	81,856
	p	0,000	0,001	0,000	0,000
	ηp2	0,918	0,649	0,771	0,921
Group * Time	F	0,715	1,125	0,826	0,623
	p	0,639	0,365	0,557	0,711
	ηp2	0,093	0,138	0,106	0,082

Data presented as mean ± SD. VO_{2max}: maximal oxygen consumption, AT VO_2: anaerobic threshold oxygen consumption, Submaximal VO_2: submaximal oxygen consumption, TTE: time-to-exhaustion. * $p \leq 0.05$ for within-group changes. # $p \leq 0.05$ for between-group changes. *; 4.Week > pre, #; 8.Week > 4.Week, &; 8.Week > Pre

DISCUSSION

Our study showed that there was an improvement in aerobic fitness parameters in all groups at the end of the 4th and 8th weeks, but there is no difference between training methods (HIIT vs MICT) and different conditions (Hipoxia vs Normoxia) on aerobic performance and there is no statistical difference in the group*time interaction either. These results revealed that all the training protocols applied in the study could be effective in the development of aerobic capacity. So our hypothesis was not confirmed. To the best of our knowledge, the present study is the first to compare the influences of 8-week HIIT vs. 8-week MICT on the aerobic capacity in recreationally active adults under hypoxic and normoxic conditions.

In the literature, studies on similar groups, such as recreationally active men and healthy active women comparing HIIT and MICT training methods, HIIT are frequently shown to cause higher RPE responses, higher PACES scores, and higher performance improvement (Soylu, Arslan, Sogut, Kilit, & Clemente, 2021).

One of the key findings of our study was that both HIIT and MICT significantly increased VO_{2max} values in young adults, although the VO_{2max} improvement was higher in the HIIT groups compared to MICT groups at the end of the 8th week by percentage (Hypoxia HIIT:22.1%, Normoxia HIIT:21% and Hypoxia MICT: 17.1%, Normoxia MICT:16.9%, respectively). In addition, when the total exercise times are compared at the end of the 8th week, it can be said that HIIT is more economical than MICT (HIIT groups :166 minutes, MICT groups: 260 minutes, respectively). In a similar study the $\dot{V}O_{2max}$ responses of female young adults increased from 35.7 ml·min-1·kg-1 to 40.1 ml·min-1·kg-1 with an increase of 10.9% after an 8-week HIIT programme compared with the MICT regime (Mazurek et al., 2016). Nybo et al. demonstrated that a improvement was found following a 12-week HIIT intervention compared with MICT in untrained young adults (14.0% and 7.4%, respectively) (Nybo et al., 2010). Hottenrott et al. found that the $\dot{V}O_{2max}$ response increased from 36.8 ± 4.5 ml·min-1·kg-1 to 43.6 ± 6.5 ml·min-1·kg-1 with an increase of 18.5% after HIIT intervention in recreationally active adults for a period of 12 weeks (Hottenrott, Ludyga, & Schulze, 2012). Contrary to these studies, Connolly et al. reported that MICT training was more effective in VO2max values than HIIT training in a 12-week study on inactive women (19.7% and 15.7%, respectively) (Connolly et al., 2017). The reason for this difference in VO_{2max} values can be the training type, training duration, participants' gender, age, and past training experiences.

A study observed that the improvement in VO_{2max} with training was limited and endurance continued to improve even though VO_{2max} reached an upper limit (Tanaka, & Matsura, 1984) and therefore individual differences in aerobic performance are more closely related to anaerobic threshold (AT) than the VO_{2max} parameter (Allen, Seals, Hurley, Ehsani, & Hagberg, 1985). Also, the AT is more sensitive than VO_{2max} in terms of endurance (Hazır, Hazır, Aşçı, & Açıkada, 2007). Because In this context, the developments between the groups were similar except Normoxia HIIT group at the end of the 8th week in the AT VO_2 value, which we evaluated in the study. (Hypoxia HIIT:22.3%, Normoxia HIIT:10.9% and Hypoxia MICT: 24%, Normoxia MICT:23%, respectively). One of the limited studies similar to our study is the study performed by Czuba et al. on elite cyclists, in which they applied 3-week running-based high-intensity interval training in hypoxic (2500m) and normoxic conditions in the normobaric environment. As a result of this study, they found improvements on AT VO_2 in the hypoxia (7.74%) and normoxia AT VO2 values (4.44%) at the end of 3 weeks (Czuba et al., 2011). Considering the duration of the study, it can be said that the results of the study are similar to our findings. Again, time-to-exhaustion (TTE), in other words, willpower is the soul component of aerobic performance. When athletes perform under exhausting conditions, their strength is mainly dependent on their willpower. High willpower and mental endurance become even more important as the intensity increases during the exercise (Günay & Yüce, 2008). In this context, different developments in percentage were observed at the end of the 8th week in all groups in the TTE parameter that we examined in the study. (Hypoxia HIIT:10.5%, Normoxia HIIT:13.5% and Hypoxia MICT: 15%, Normoxia MICT:10.1%, respectively). Messannier et al. applied MICT on 13 active individuals in hypoxic (3800m) and normoxic conditions for 4 weeks and reported that they could not detect any difference in TTE values between the two groups at the end of 4 weeks, in their study (Messonnier, Geyssant, Hintzy & Lacour, 2004).

Another important result of our study is the percentage difference in submaximal VO_2 parameter in favor of Hypoxia HIIT group at the end of the 8th week. Submaximal VO_2, which enables the effective use of energy in training and competitions, is shown as a reason for the differences in the performance level of the athletes with the equivalent VO_{2max} level (Jones & Carter 2000; Midgley, McNaughton & Jones, 2007). In studies conducted on athletes with the same VO2max level, it is stated that there are individual differences in O2 use (Jones & Carter 2000). Our finding supports the initial work of Levine and Gundersen in 1997. In this study, it was reported that the moderate natural altitude significantly increased the submaximal VO_2, which is one of the most crucial elements of endurance performance (Levine & Stray-

Gundersen, 1985). It reports that natural and simulated altitude training can have a similar effect. However, it is reported that a 2% improvement in submaximal VO2 provides a 2.5-minute advantage in marathon performance (Morgan, Martin, Krahenbuhl, & Baldini, 1991). This finding reveals the importance of the result in our study. Similarly, Czuba et al., found, as a result of running-based high-intensity interval training in hypoxic (2500m) and normoxic conditions, with 20 well-trained basketball players for 3 weeks, 3 days a week, an improvement in submaximal VO2 value (10%) in hypoxia group and improvement in normoxia group (4%) (Czuba et al., 2013).

The present study has some limitations that need to be acknowledged. The main limitation of this study is that there was a lack of dietary intake control. Because the diet of the participants may affect their aerobic capacity. Additionally, a second limitation to this investigation is that HIIT groups performed the exercise on a bicycle ergometer, while the tests were performed on a treadmill. It should be noted that these results were observed in recreationally active young adults. Therefore, our study results may not generalize to participants of different performance levels, sex, and age groups.

CONCLUSION

This study showed the effect of HIIT and MICT performed in hypoxic and normoxic conditions on the aerobic performance of young adults. The HIIT and MICT performed 3 days a week for 8 weeks revealed similar improvements in VO_{2max}, AT VO_2, and TTE parameters. Considering that HIIT is also economical in terms of time compared to MICT, HIIT can be an alternative method to improve the desired physical condition. In the light of this information, HIIT methods applied in different forms can be preferred as a more economical training strategy to improve aerobic capacity for trainers and recreational exercisers.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Akgul, M.S., Koz, M,, Gürses, V.V., & Kurkcu, R. (2017). High intensity interval training. *Spormetre*, *15*(2),39-46. https://doi.org/10.1501/Sporm_0000000306

Akgul, M.S., & Koz, M. (2019). Effect of high intensity interval training under hypoxic conditions in a normobaric environment on moderately trained university students' antioxidant status. *Physical education of students*, *23*(5), 217-222. https://doi.org/10.15561/20755279.2019.0501

Akgul, M.S., Gürses, V.V., Karabıyık, H., & Koz, M. (2016). The influence of 2 weeks of low-volume high intensity interval training on aerobic indices in women. *International Journal of Science Culture and Sport*, *4*(17), 298-305.

Allen, W. K., Seals, D. R., Hurley, B. F., Ehsani, A. A., & Hagberg, J. M. (1985). Lactate threshold and distance-running performance in young and older endurance athletes. *Journal of applied physiology*, *58*(4), 1281–1284. https://doi.org/10.1152/jappl.1985.58.4.1281

Benda, N. M., Seeger, J. P., Stevens, G. G., Hijmans-Kersten, B. T., van Dijk, A. P., Bellersen, L., Lamfers, E. J., Hopman, M. T., & Thijssen, D. H. (2015). Effects of High-Intensity Interval Training versus Continuous Training on Physical Fitness, Cardiovascular Function and Quality of Life in Heart Failure Patients. *PloS one*, *10*(10), e0141256. https://doi.org/10.1371/journal.pone.0141256

Brocherie, F., Girard, O., Faiss, R., & Millet, G. P. (2017). Effects of Repeated-Sprint Training in Hypoxia on Sea-Level Performance: A Meta-Analysis. *Sports medicine*, *47*(8), 1651–1660. https://doi.org/10.1007/s40279-017-0685-3

Connolly, L. J., Bailey, S. J., Krustrup, P., Fulford, J., Smietanka, C., & Jones, A. M. (2017). Effects of self-paced interval and continuous training on health markers in women. *European journal of applied physiology*, *117*(11), 2281–2293. https://doi.org/10.1007/s00421-017-3715-9

Czuba, M., Bril, G., Płoszczyca, K., Piotrowicz, Z., Chalimoniuk, M., Roczniok, R., Zembroń-Łacny, A., Gerasimuk, D., & Langfort, J. (2019). Intermittent hypoxic training at lactate threshold intensity improves aiming performance in well-trained biathletes with little change of cardiovascular variables. *BioMed research international*, 2019, 1287506. https://doi.org/10.1155/2019/1287506

Czuba, M., Waskiewicz, Z., Zajac, A., Poprzecki, S., Cholewa, J., & Roczniok, R. (2011). The effects of intermittent hypoxic training on aerobic capacity and endurance performance in cyclists. *Journal of sports science & medicine*, *10*(1), 175–183.

Czuba, M., Zając, A., Maszczyk, A., Roczniok, R., Poprzęcki, S., Garbaciak, W., & Zając, T. (2013). The effects of high intensity interval training in normobaric hypoxia on aerobic capacity in basketball players. *Journal of human kinetics*, *39*, 103–114. https://doi.org/10.2478/hukin-2013-0073

Faiss, R., Léger, B., Vesin, J. M., Fournier, P. E., Eggel, Y., Dériaz, O., & Millet, G. P. (2013). Significant molecular and systemic adaptations after repeated sprint training in hypoxia. *PloS one*, *8*(2), e56522. https://doi.org/10.1371/journal.pone.0056522

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., Swain, D. P., & American College of Sports Medicine (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine and science in sports and exercise*, *43*(7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefbGibala,

M. J., Little, J. P., Macdonald, M. J., & Hawley, J. A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *The Journal of physiology*, *590*(5), 1077–1084. https://doi.org/10.1113/jphysiol.2011.224725

Gunay, M., & Yüce, I. (2008). *A Scientific foundations of football training*, Gazi Bookstore.

Hazır, S., Hazır, T., Aşçı, A., & Açıkada, C. (2017). Metabolıc responses to varıous exercıse ıntensıtıes. *Hacettepe journal of Sport Sciences*, *18*,1-13.

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Simonsen, T., Helgesen, C., Hjorth, N., Bach, R., & Hoff, J. (2007). Aerobic high- intensity intervals improve VO2max more than moderate training. *Medicine and science in sports and exercise*, *39*(4), 665–671. https://doi: 10.1249/mss.0b013e3180304570

Hoppeler, H., Vogt, M., Weibel, E.R., Flück, M. (2003). Response of skeletal muscle mitochondria to hypoxia. *Experimental physiology*, *88*(1), 109–119. https://doi.org/10.1113/eph8802513

Hoppeler, H., & Vogt, M. (2001). Muscle tissue adaptations to hypoxia. *The Journal of experimental biology*, *204*(Pt18), 3133–3139. https://doi.org/10.1242/jeb.204.18.3133

Hottenrott, K., Ludyga, S., & Schulze, S. (2012). Effects of high intensity training and continuous endurance training on aerobic capacity and body composition in recreationally active runners. *Journal of sports science & medicine*, *11*(3), 483–488.

Jones, A.M., & Carter, H. (2000). The effect of endurance training on parameters of aerobic fitness. *Sports medicine*, *29*(6), 373–386. https://doi.org/10.2165/00007256-200029060-00001

Karabiyik, H., Eser, M.C., Guler, O., Yasli, B.G, Ertetik, G., Sisman, A., Koz. M., Gabrys, T., Pilis, K., & Karayigit, R. (2021). *International journal of environmental research and public health*, *18*(8), 3976. https://doi.org/10.3390/ijerph18083976

Kuipers, H., Keizer, H. A., de Vries, T., van Rijthoven, P., & Wijts, M. (1988). Comparison of heart rate as a non-invasive determinant of anaerobic threshold with the lactate threshold when cycling. *European journal of applied physiology and occupational physiology, 58*(3), 303–306. https://doi.org/10.1007/BF00417267

Levine, B.D., & Stray-Gundersen, J. (1985). "Living high-training low": effect of moderate-altitude acclimatization with low-altitude training on performance. *Journal of applied physiology*, *83*(1), 102–112. https://doi.org/10.1152/jappl.1997.83.1.102

MacInnis, M.J, & Gibala, M.J. (2017). Physiological adaptations to interval training and the role of exercise intensity. *The Journal of physiology*, *595*(9), 2915–2930. https://doi.org/10.1113/JP273196

Mazurek, K., Zmijewski, P., Krawczyk, K., Czajkowska, A., Kęska, A., Kapuściński, P., & Mazurek, T. (2016). High intensity interval and moderate continuous cycle training in a physical education programme improves health-related fitness in young females. *Biology of sport*, *33*(2), 139–144. https://doi.org/10.5604/20831862.1198626

Messonnier, L., Geyssant, A., Hintzy, F., & Lacour, J. R. (2004). Effects of training in normoxia and normobaric hypoxia on time to exhaustion at the maximum rate of oxygen uptake. European journal of applied physiology, *92*(4-5), 470–476. https://doi.org/10.1007/s00421-004-1117-2

Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge?. *Sports medicine*, *37*(10), 857–880. https://doi.org/10.2165/00007256-200737100-00003

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of High-Intensity Interval Training (HIT) and Continuous Endurance Training for VO2max Improvements: A Systematic Review and Meta-Analysis of Controlled Trials. *Sports medicine*, *45*(10), 1469–1481. https://doi.org/10.1007/s40279-015-0365-0

Morgan, D. W., Martin, P. E., Krahenbuhl, G. S., & Baldini, F. D. (1991). Variability in running economy and mechanics among trained male runners. *Medicine and science in sports and exercise*, *23*(3), 378–383.

Nybo, L., Sundstrup, E., Jakobsen, M. D., Mohr, M., Hornstrup, T., Simonsen, L., Bülow, J., Randers, M. B., Nielsen, J. J., Aagaard, P., & Krustrup, P. (2010). High-intensity training versus traditional exercise interventions for promoting health. *Medicine and science in sports and exercise*, *42*(10), 1951–1958. https://doi.org/10.1249/MSS.0b013e3181d99203

Puype, J., Van Proeyen, K., Raymackers, J. M., Deldicque, L., & Hespel, P. (2013). Sprint interval training in hypoxia stimulates glycolytic enzyme activity. *Medicine and science in sports and exercise*, *45*(11), 2166–2174. https://doi.org/10.1249/MSS.0b013e31829734ae

Ross, L. M., Porter, R. R., & Durstine, J. L. (2016). High-intensity interval training (HIIT) for patients with chronic diseases. *Journal of sport and health science*, *5*(2), 139–144. https://doi.org/10.1016/j.jshs.2016.04.005

Schmutz, S., Däpp, C., Wittwer, M., Durieux, A. C., Mueller, M., Weinstein, F., Vogt, M., Hoppeler, H., & Flück, M. (2010). A hypoxia complement differentiates the muscle response to endurance exercise. *Experimental physiology*, *95*(6), 723–735. https://doi.org/10.1113/expphysiol.2009.051029

Soylu, Y., Arslan, E., Sogut, M., Kilit, B., & Clemente, F. M. (2021). Effects of self-paced high-intensity interval training and moderate-intensity continuous training on the physical performance and psychophysiological responses in recreationally active young adults. *Biology of sport*, *38*(4), 555–562. https://doi.org/10.5114/biolsport.2021.100359

Stutts W. C. (2002). Physical activity determinants in adults. Perceived benefits, barriers, and self efficacy. *AAOHN journal : official journal of the American Association of Occupational Health Nurses*, *50*(11), 499–507.

Tanaka, K., & Matsuura, Y. (1984). Marathon performance, anaerobic threshold, and onset of blood lactate accumulation. *Journal of applied physiology: respiratory, environmental and exercise physiology*, *57*(3), 640–643. https://doi.org/10.1152/jappl.1984.57.3.640

Vogt, M., & Hoppeler, H. (2010). Is hypoxia training good for muscles and exercise performance?. *Progress in cardiovascular diseases*, *52*(6), 525–533. https://doi.org/10.1016/j.pcad.2010.02.013

Vogt, M., Puntschart, A., Geiser, J., Zuleger, C., Billeter, R., & Hoppeler, H. (2001). Molecular adaptations in human skeletal muscle to endurance training under simulated hypoxic conditions. *Journal of applied physiology*, *91*(1), 173–182. https://doi.org/10.1152/jappl.2001.91.1.173

Wahl, P., Schmidt, A., Demarees, M., Achtzehn, S., Bloch, W., & Mester, J. (2013). Responses of angiogenic growth factors to exercise, to hypoxia and to exercise under hypoxic conditions. *International journal of sports medicine*, *34*(2), 95–100. https://doi.org/10.1055/s-0032-1314815

Westmacott, A., Sanal-Hayes, N. E. M., McLaughlin, M., Mair, J. L., & Hayes, L. D. (2022). High-intensity interval training (HIIT) in hypoxia improves maximal aerobic capacity more than HIIT in normoxia: A Systematic Review, Meta-Analysis, and Meta-Regression. *International journal of environmental research and public health*, *19*(21), 14261. https://doi.org/10.3390/ijerph192114261

Wilbur R. L. (2007). Live high + train low: thinking in terms of an optimal hypoxic dose. *International journal of sports physiology and performance*, *2*(3), 223–238.

Yamagishi, T., & Babraj, J. (2016). Influence of recovery intensity on oxygen demand and repeated sprint performance. The Journal of sports medicine and physical fitness, *56*(10), 1103–1112.