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Research article

Functional Vs. Running Low-Volume High-Intensity Interval Training: Effects on VO_2max and Muscular Endurance

Verena Menz ✉, Natalie Marterer, Sachin B. Amin, Martin Faulhaber, Alexander B. Hansen and Justin S. Lawley
Department of Sport Science, University of Innsbruck, Innsbruck, Austria

Abstract

The purpose of the study was to assess if high-intensity interval training (HIIT) using functional exercises is as effective as traditional running HIIT in improving maximum oxygen uptake (VO_2max) and muscular endurance. Fifteen healthy, moderately trained female (n = 11) and male (n= 4) participants (age 25.6 ± 2.6 years) were assigned to either running HIIT (HIIT-R; n = 8, 6 females, 2 males) or functional HIIT (HIIT-F; n = 7, 5 females, 2 males). Over a four-week period, both groups performed 14 exercise sessions of either HIIT-R or, HIIT-F consisting of 3-4 sets of low-volume HIIT (8x 20 s, 10 s rest; set rest: 5 min). Training heart rate (HR) data were collected throughout all training sessions. Mean and peak HR during the training sessions were significantly different (p = 0.018 and p = 0.022, respectively) between training groups, with HIIT-F eliciting lower HR responses than the HIIT-R. However, despite these differences in exercise HR, VO_2max improved similarly (~13% for the HIIT-R versus ~11% for the HIIT-F, p=0.300). Muscular endurance (burpees and toes to bar) significantly improved (p =0.004 and p = 0.001, respectively) independent of training modality. These findings suggest that classic running HIIT and functional HIIT both improve VO_2max and affect muscular endurance to the same extent despite a lower cardiovascular strain in the functional protocol.

Key words: Functional training, sprint interval training, body composition, Tabata protocol, calisthenics.

Introduction

Regular physical activity is essential for the prevention of cardiovascular and metabolic diseases (Fealy et al., 2018) and high-intensity interval training (HIIT) is an effective training method to elicit rapid improvements in cardiorespiratory fitness (CRF; expressed as maximal oxygen consumption (VO_2max)) (Astorino et al., 2012; Daussin et al., 2008; Gist et al., 2014b). Recent data suggests that repeated maximal to supramaximal exercise bouts have a similar, or even greater influence on CRF and metabolic adaptions than traditional moderate-intensity continuous training (MICT) (Gist et al., 2014b). Indeed, Tabata et al. (1996) demonstrated that short duration (7-8 sets of 20 s exercise, interspersed with 10 s rest; the "Tabata protocol") high-intensity intermittent exercise caused the same, or even greater improvements in aerobic (VO_2max) and anaerobic power as moderate-intensity endurance training (60 min; intensity 70% of VO_2max). These data indicated that short duration exercise, which is of a sufficiently high intensity, is capable of inducing favorable training adaptions. Considering adherence to classic MICT is typically low, HIIT is a more time-efficient training modality and may therefore be the method of choice for increased encouragement in exercise participation (McRae et al., 2012).

Endurance athletes perform HIIT training to improve sport specific performance (Gist et al., 2015). Typically, this involves using classical exercise modalities such as, running, cycling and rowing (Buckley et al., 2015). For recreationally active individuals, these traditional exercise modalities may be perceived as boring due to little or no variation, which could have a negative impact on training adherence, as "lack of enjoyment" is a commonly cited barrier for engaging in regular exercise (Bartlett et al., 2011).

In recent times, functional training, mostly executed with the individual's own bodyweight, is increasing in popularity. High-intensity functional training (HIFT) comprises a variety of functional movements and exercises executed at a high intensity (Haddock et al., 2016). An important advantage of HIFT is that it can be undertaken with minimal equipment, minimal space, and in various locations (i.e., indoor/outdoor) (Gist et al., 2015). While the "classical" HIIT predominantly targets the aerobic system (central adaptions), HIFT incorporates both endurance and resistance training, providing multiple training benefits within the same training session (Feito et al., 2018).

HIFT has also been shown to induce aerobic improvements to the same extent as traditional endurance exercise, but with the added benefit of improved muscle performance (Buckley et al., 2015; McRae et al., 2012). McRae et al. (2012) demonstrated that four minutes of Tabata style training utilizing whole body aerobic exercises (e.g., burpees, jumping jacks, mountain climbers) conducted four times per week for four weeks, elicited similar improvements in VO_2max (+7% and 8% for MICT and HIFT, respectively) as MICT (30 min treadmill running, 4x/week). Moreover, Myers et al. (2015) demonstrated that circuit-based whole-body aerobic training using only body-weight exercises, elicited greater CRF responses when compared to a traditional training program. Nonetheless, while these data confirm that HIFT matches, or in some instances appears superior in terms of CRF adaptations to MICT, the question remains whether the improvement in CRF from HIFT can match those achieved through high-intensity running.

To the best of our knowledge, only one study (Buckley et al., 2015) has compared the chronic effects of a traditional HIIT (rowing) with a multi-modal HIIT incorporating multiple exercise modalities, with the observation that both training modalities induced similar improvements in aerobic and anaerobic capacity. Albeit, only the multi-

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modal training resulted in greater muscle performance (e.g. squat strength). While these initial data are intriguing, extension to other types of exercise programs incorporated by the general public such as those executed with one's own body weight are important.

Therefore, the purpose of the current study was to compare two different low-volume HIIT modalities including running vs. functional training on VO_2max and muscular endurance in moderately trained female and male participants. Based on the literature discussed, we hypothesized that VO_2max will improve in both groups, but that muscular endurance will only significantly improve after functional HIIT. Our secondary aim was to determine if HIFT (body weight exercises) could generate the same degree of cardiorespiratory strain as high-intensity running.

Methods

Study protocol

The study was designed as a randomized controlled training study including two different training groups (running and functional training) and two measurement times (baseline vs. post-training). Participants were instructed to refrain from intense exercise and alcohol 24 h before the baseline and post-training measurements and to appear fully hydrated on the test days. Baseline measurements included a laboratory treadmill test, muscular endurance tests and the assessment of body composition. Both, baseline and post-training consisted of two testing days, separated by at least 48 hours. On the first visit, body composition measures were completed prior to the graded exercise test (VO_2max test). On the second visit, the muscular endurance test was performed. After baseline measurements, the participants were randomly assigned, stratified by gender and VO_2max (determined in the laboratory treadmill test) to either the running high-intensity interval training group (HIIT-R) or the functional high-intensity interval training group (HIIT-F). After a break of at least four days, both the HIIT-R and HIIT-F started the four week training program. Post-training measurements were the same as for baseline conditions and were conducted three to five days after the last HIIT session.

Participants

Eighteen healthy male (n = 6) and female (n = 12) sport students were recruited for the study. Participants reported to regularly exercise 8.3 ± 4.2 h/week, predominantly running, cycling, fitness training, ball sports as well as alpine sports (alpine skiing, ski mountaineering, hiking and climbing). One participant of the HIIT-F dropped out before the start of the training intervention because of time constraints. During the training intervention, one participant of the HIIT-R and one from the HIIT-F dropped out due to illness, unrelated to the study intervention. Finally, 15 participants completed the study and were incorporated into the current dataset. Age and physical characteristics of the participants are presented in Table 1. All study participants underwent a routine pre-participation screening prior to the baseline testing. Exclusion criteria were pre-existing acute or chronic diseases, pregnancy and lactation period. Before providing their verbal and written informed consent to participate in the study, participants were provided detailed information about the procedure and potential risks of the study. The study was carried out according to the Declaration of Helsinki and was approved by the Board for Ethical Questions in Science of the University (Certificate of good standing, 15/2018).

Procedures

Maximum Oxygen uptake: Participants initially performed a graded exercise test on an electrically driven treadmill (h/p/cosmos pulsar, h/p/cosmos Sports and Medical, Nussdorf-Traunstein, Germany). A treadmill protocol as described in detail by Burtscher et al. (2008), was used to assess VO_2max. Briefly, exercise started at 5 % inclination and 5 km/h, after 2 min inclination was set at 10 % for another 2 min. Subsequently, running speed was increased to 6 km/h and inclination was elevated by 2 % every minute until 20 %. Lastly, inclination was kept at 20 % and the speed was increased by 1 km/h per minute. Ratings of perceived exertion (RPE) were documented at the end of every work load (Borg, 1982). The test was completed when the participant reached volitional exhaustion despite verbal encouragement. Directly after terminating the treadmill test, a capillary blood sample was collected from the hyperaemized earlobe to assess the maximal blood lactate concentration (BLAmax; Biosen C line, EKF Diagnostics, Germany). Gas analysis was performed using an open spirometric system (Oxycon Pro, Care Fusion, Germany) which was calibrated before each measurement, as per the manufacturer's guidelines. Ventilatory parameters (i.e., VE, VO_2, VCO_2) were recorded breath-by-breath during the ergospirometry test. First and second ventilatory thresholds (VT1 and VT2 respectively) were later determined by visual inspection from two experienced researchers. For determining VT1 the (1) V-slope plot (VCO_2 vs. VO_2) as well as (2) the increase in VE/VO_2 with no concomitant increase in VE/VCO_2 were considered for evaluation. For determining VT2 (1) the second disproportional increase in VE vs. CO_2 and (2) the increase in VE/VCO_2 were visually inspected. Heart rate (HR) was determined by chest belt (Wear Link, Polar, Kempele, Finland) and transmitted to the spirometric device. VO_2max was defined as the highest 30 s average in oxygen uptake and maximal heart rate(HRmax) as the highest 10 s average during the treadmill test. A test was considered maximal when three of the following criteria were fulfilled: 1) VO_2 plateau at peak exercise 2) respiratory exchange ratio ≥1.10 3) peak HR ≥90

Table 1. Sex specific baseline anthropometric characteristics of the running and functional training group.

	HIIT-R			HIIT-F			
	Female (n= 6)	Male (n= 2)	Total (n= 8)	Female (n= 5)	Male (n = 2)	Total (n= 7)	p-Values
Age [years]	26 ± 3	29 ± 1	27 ± 3	24 ± 2	26 ± 0	24 ± 2	0.098
Height [m]	1.69 ± 0.05	1.82 ± 0.09	1.72 ± 0.08	1.71 ± 0.09	1.91 ± 0.07	1.77±0.12	0.414
BMI [kg/m²]	22.5 ± 1.9	22.7 ± 3.0	22.5 ± 2.0	22.4 ± 1.9	22.9 ± 0.6	22.6 ± 1.6	0.963

HIIT-R, high-intensity interval training running group; HIIT-F, high-intensity interval training functional group; BMI, body mass index

% of the theoretic maximal HR (220-age), and 4) indication of maximal exhaustion by the athlete (Cunha et al., 2010).

Muscular endurance test: For assessing muscular endurance, participants were asked to perform as many push-ups, toes to bar, and burpees as possible, with at least a five min rest between each test. Finally, they also had to perform three broad jumps from the standing position. All tests were supervised and recorded by the same person. The muscular endurance tests were adopted according to Sperlich et al. (2017) and Buckley et al. (2015). For the push-up test, participants were advised to start the test in proper push-up position with the body lifted from the floor. Upon descent, the upper body had to touch the floor and hands had to be lifted for a second to ensure the body was completely flat on the floor. One repetition was counted when the body moved back to the starting position. The number of completed push-ups was recorded. For the toes to bar test, participants started hanging free from the bar. Participants were then advised to lift both legs simultaneously until their toes touched the bar. The number of completed toes to bar raises was recorded. For assessing muscle power of the lower limbs, the jumping distance of static broad jumps was recorded. The best out of three jumps was used for analysis. For the burpee test, participants started in a standing position and were instructed to squat down, kick out their legs and perform a push up. Participants reversed the order of moves, finishing with a squat jump to complete one full repetition. The number of burpees completed was recorded.

Body composition: Body mass (to the nearest 0.1 kg) was measured with an electronic scale. Body composition was determined by bioelectrical impedance analysis (BIA 101 Anniversary AKERN/RJL Systems; Florence, Italy), including the measurement of fat mass (FM), muscle mass (MM) and fat free mass (FFM). Body composition was determined in the early morning after a light breakfast. Prior to the measurements, participants were instructed to empty their bladder. Fluids and food within the abdominal cavity are reported to be "electrically silent" (Kushner et al., 1996), hence, this procedure should only have minimal influence on the outcome parameters. Moreover, participants were advised to not change their dietary intake/ usual nutrition during the entire study period.

Training intervention: Participants either performed a running HIIT (3-4 sets; 8x 20 s, 10 s rest; set rest: 5 min) or functional HIIT incorporating multiple exercises, all executed with their own body weight (3-4 sets; 8x 20 s, 10 s rest; set rest: 5 min) (Table 2). In the first training week, both groups trained 3x/week and had to complete three sets of 8 x 20 s per session, resulting in an exercise time of 12 min/training session. For the second training week, the training load was gradually adapted by increasing the number of sets to four at 8 x 20 s per session, resulting in an exercise time of 16 min/training session. The training frequency remained the same as in the first week. To guarantee sufficient training load, training frequency was increased to 4x/week during weeks three and four, while the number of sets remained the same (four sets). Participants were advised to perform the training sessions at the highest intensity possible. The training sessions were not supervised, however training intensity was monitored by continuous HR (Polar, Kempele, Finland) and RPE (Borg scale (6–20)) monitoring for both groups. Mean HR ($HRmean_{HIIT}$) and peak HR ($HRpeak_{HIIT}$) as well as RPE were directly recorded after each set (8 x 20 s). For further analysis, $HRmean_{HIIT}$ and $HRpeak_{HIIT}$ of the training sessions are expressed as a % of the HRmax determined by the treadmill test. All training sessions started with a standardized 10-min warm-up at moderate intensity, followed by mobilization exercises and submaximal progressive sprints. All habitual training data (including all endurance and strength training sessions performed outside of the study program during the four week training period) for the HIIT-R and the HIIT-F were recorded in a training log book. The total training loads for the habitual training were determined according to Foster et al. (2001) as perceived exertion × training session time (in min). For the additional training of both groups, we recommended only low-intensity training.

Statistical analyses

Statistical analyses were conducted by PASW Statistics 24 (IBM, Vienna, Austria). Normal distribution of data was tested by the Kolmogorov–Smirnov test. A repeated measures analysis of variance (ANOVA) measurement design was used to determine changes due to the training intervention (main effect: training) and to determine different changes between the HIIT-R and HIIT-F group (interaction: training × group). In addition, paired student's *t* tests were carried out to evaluate within-group effects. Training data (e.g. total training load) were analyzed using unpaired student's *t* tests. *p* values <0.05 (two-tailed) were considered to indicate statistical significance. Values are presented as mean ± SD. Partial eta squared (η^2p) was used as an effect size with the classifications small (0.01), medium (0.06), and large (0.14) (Cohen, 1988). For the analysis of VO_2max, the full data set was available, but for analyzing the HRmax, due to malfunctions of the heart rate monitor, the data set of two participants of the HIIT-F were missing. Additionally, one participant of the HIIT-R was unable to participate in the muscular endurance test for post-measurement due to an elbow injury, which was not related to the training intervention.

Results

No between group differences were found for any variable of interest for baseline condition. Participants of the HIIT-R group completed 96 ± 5 %, participants of the HIIT-F group 96 ± 11 % of all planned training sessions.

Training data: HR responses during the training sessions ($HRmean_{HIIT}$ and $HRpeak_{HIIT}$) and mean RPE for each training session are presented in Figure 1 and Figure 2, respectively. $HRpeak_{HIIT}$ and $HRmean_{HIIT}$ calculated over 14 training sessions were 94 ± 2 % of HRmax and 87 ± 3 % of HRmax for HIIT-R and 87 ± 4% and 78 ± 6 % for the HIIT-F group, respectively and differed significantly between both groups (p= 0.022 and p= 0.018 for $HRpeak_{HIIT}$ and $HRmean_{HIIT}$, respectively).

Table 2. Details of the functional Tabata training intervention.

Week	Sessions/week	Number of sets (8 x 20 sec)	Exercises
1	**3**	**1**	Split Squat Jumps
			Squats
			Push-up to plank
			Mountain climber
		2	High knees
			Burpees (without jump)
			Jumping Jacks
			Knee-to elbow
		3	High knees ankle taps
			Push-ups
			Star Jumps
			Both leg jumps (front and back)
2	**3**	**1**	Split Squat Jumps
			Squats
			Plank with rotation
			Mountain climber
		2	High knees
			Burpees
			Jumping Jacks
			Knee-to elbow
		3	High knees ankle taps
			Push-ups
			Star jump
			Stutter steps
		4	Rope Jump
			Crunches
			Kangaroo Jumps
			Squat walk
3 & 4	**4**	**1**	Split Squat Jumps
			Squat Jumps
			Plank with rotation
			Mountain climber
		2	High knees
			Burpees
			Stutter steps
			Knee-to elbow (dynamic)
		3	High knees ankle taps
			Push-ups
			Star jump
			Jumping Jacks
		4	Skydiver (back extension)
			Rope Jump
			Kangaroo Jumps
			Squat walk

Cardiorespiratory fitness: Outcomes of the performance testing are shown in Table 3. All but one participant (for baseline and post-testing) fulfilled at least three criteria for maximal exercise test according to Cunha et al. (2010). VO_2max and HRmax improved to the same extent for both groups, showing no statistical difference between training conditions. VO_2max improved by ~13 ± 4 % and ~11 ± 7 % for HIIT-R and HIIT-F, respectively. HRmax and BLAmax were significantly reduced after both training interventions ($p = 0.011$ and $p = 0.038$, respectively). Both, VT1 and VT2 significantly improved over time, with only VT1 showing a significant interaction effect ($p = 0.040$).

Muscular endurance test: No interaction was found for any muscular endurance test. Push-ups and broad jump performance was unaffected by the training intervention. Burpees performance only significantly improved within the HIIT-F group ($p = 0.004$), whereas toes-to bar performance only improved within the HIIT-R ($p = 0.005$).

Habitual training: Neither total training time, perceived exertion or total training load of the habitual endurance and strength training differed between groups (Table 4). The habitual exercise was allocated to running, cycling, swimming, ball sports (Volleyball, Basketball, Soccer and Tennis), fitness training, hiking and climbing.

Body composition: Body composition and body weight were unaffected by the four week training period for both groups (Table 3).

Discussion

This is the first study comparing the cardiorespiratory and muscular endurance responses between running and functional HIIT regimes. The main findings of the present study are that both interventions caused similar improvements in VO_2max and muscular endurance (toes-to bar, and burpees). Hence, our hypothesis that HIIT-F induces

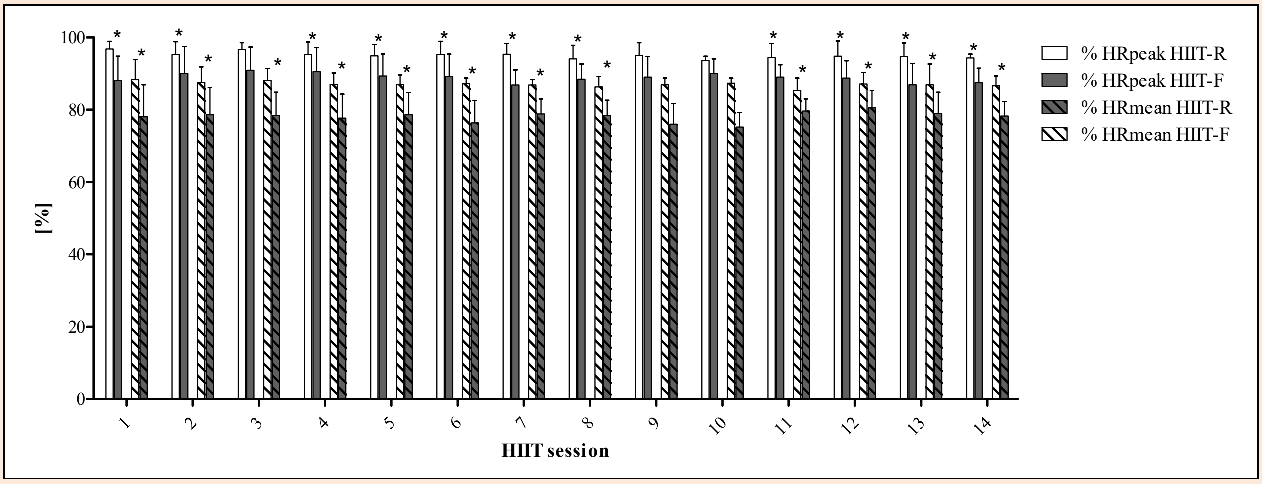

Figure 1. Mean and peak heart rate responses (expressed as %HRmax determined in the VO_2max test) over all training sessions for HIIT-R and HIIT-F. HIIT-R, high-intensity interval training running group; HIIT-F, high-intensity interval training functional group; $\%HRpeak_{HIIT}$, peak heart rate during the training session, expressed as a % of the HRmax determined by the treadmill test; $\%HRmean_{HIIT}$, mean heart rate during the training session, expressed as a % of the HRmax determined by the treadmill test; *indicates statistically significant result (between-groups).

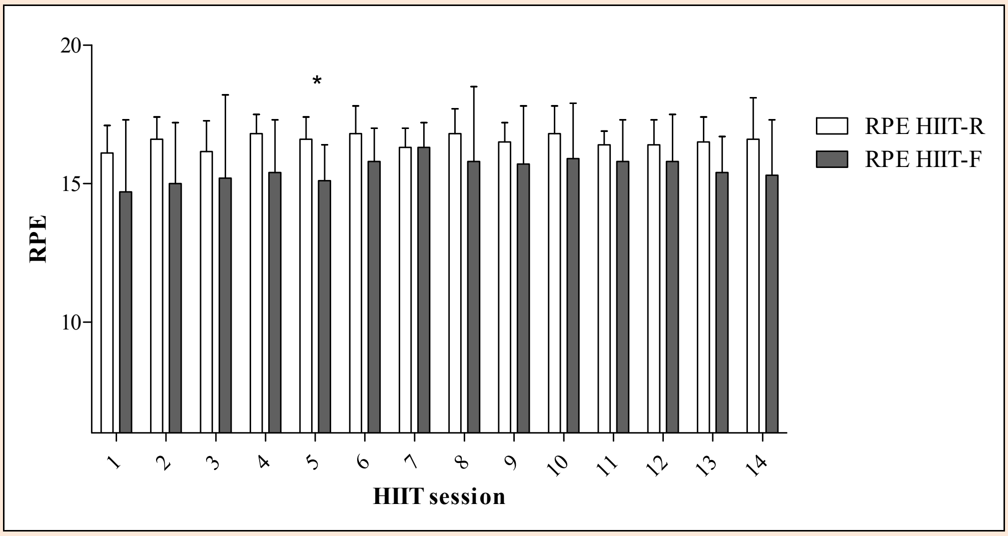

Figure 2. Mean ratings of perceived exertion (BORG) over all training sessions for HIIT-R and HIIT-F. HIIT-R, high-intensity interval training running group; HIIT-F, high-intensity interval training functional group; RPE, ratings of perceived exertion (BORG); *indicates statistically significant result (between-groups)

similar CRF improvements as HIIT-R can be confirmed. However, the hypothesis that HIIT-F is superior in improving muscular endurance has to be rejected. These results suggest that improvements in CRF and muscular endurance are induced by both, running and functional HIIT and that both provide additional benefits regarding certain aspects of muscular endurance.

The observed improvement in VO_2max after HIIT-R was not surprising as classical HIIT modalities such as running, cycling, or rowing frequently evoke significant increases in VO_2max (Gist et al., 2014a). However, the amount of improvement (+13 %) was notable, given the participants were moderately trained. The present study produced an increase in VO_2max per session of 0.93% for the running and 0.79 % for the functional HIIT group, with work out times ranging between 12 to 16 min/training session. This increase in VO_2max per session was noticeably greater than interventions utilizing 47 x 15/15 s (work/rest) running intervals training session, which only increased VO_2max by 0.23 % per session (Helgerud et al., 2007). It is worth noting that VO_2max increased by ~11% after four weeks of functional HIIT. McRae et al. (2012) demonstrated an increase of 8% in VO_2max for the whole-body aerobic-resistance training group (burpees, jumping jacks, mountain climbers or squat thrusts), using only one “Tabata-set” (4 min). To increase VO_2max, it is generally recommended to perform periods of exercise at high levels of VO_2max (above 90 %) (Rønnestad et al., 2015; Thevenet et al., 2007). It should be noted that running at the same relative intensity as cycling, results in greater oxygen consumption (Viana et al., 2019). Consequently, it was unclear whether various aerobic and strength

Table 3. Changes of performance and metabolic parameters from baseline to post-training of the running and functional training group.

	HIIT-R		HIIT-F		ANOVA		η²p
	Baseline	Post	Baseline	Post	Main effect (Time)	Interaction (Time x Group)	Interaction (Time x Group)
VO_2max [ml/min/kg]	47.8 ± 5.6	54.1 ± 5.6*	49.5 ± 6.6	54.4 ± 5.3*	0.000	0.300	0.082
VO_2max [ml/min]	3208 ± 620	3619±690*	3552 ± 973	3884 ± 915*	0.000	0.349	0.080
HRmax [bpm]	187 ± 10	184 ± 10*	191 ± 11	187 ± 7*	0.011	0.843	0.004
BLAmax [mmol/l]	10.0 ± 2.0	9.3 ± 1.5	9.7 ± 3.0	8.2 ± 2.3	0.038	0.358	0.065
RPEmax	18.8 ± 1.0	19.5 ± 0.5	19.5 ± 1.0	19.4 ± 0.8	0.268	0.185	0.131
VO_2 VT1 [ml/min]	1635 ± 168	2188 ± 493*	1894 ± 400	2072 ± 459	0.001	0.040	0.285
HR VT1 [bpm]	119 ± 4	133 ± 12*	127 ±11	131 ± 16*	0.132	0.187	0.167
VT1 % of VO_2max	51.8 ± 5.4	60.4 ± 7.7*	54.3 ± 5.0	53.9 ± 6.7	0.068	0.051	0.262
VO_2 VT2 [ml/min]	2765 ± 508	3222 ± 631*	2943 ± 720	3411 ± 740*	0.000	0.929	0.001
HR VT2 [bpm]	172 ± 9	168 ± 10	168 ± 10	171 ± 9*	0.281	0.004	0.630
VT2 % of VO_2max	86.4 ± 3.9	89.0 ± 5.5	83.7 ± 6.9	88.2 ± 4.2	0.025	0.534	0.030
Push-ups [n]	30 ± 8	34 ± 8	29 ± 9	30 ± 9	0.077	0.575	0.077
Toes to bar [n]	7 ± 6	9 ± 6*	6 ± 5	7 ± 6	0.001	0.223	0.121
Broad Jump [m]	2.12 ±.39	2.10 ±.41	2.10 ±.20	2.11 ± 0.18	0.816	0.467	0.045
Burpees [n]	25 ± 15	31 ± 13	28 ± 6	37 ± 8*	0.004	0.458	0.047
Weight [kg]	66.9 ± 8.6	66.7 ± 8.4	70.9 ±10.9	70.6 ± 11.4	0.493	0.933	0.001
FFM [%]	77.4 ± 6.5	77.5 ± 5.9	77.4 ± 3.0	77.6 ± 4.2	0.729	0.982	0.000
FM [%]	22.6 ± 6.5	22.4 ± 5.7	22.6 ± 3.0	22.4 ± 4.2	0.912	0.582	0.002
MM [%]	55.0 ± 6.8	54.6 ± 6.9	55.0 ± 3.4	54.7 ± 3.3	0.606	0.266	0.094

HIIT-R, high-intensity interval training running group; HIIT-F, high-intensity interval training functional group; η²p, effect size partial η squared; VO_2max, maximal oxygen uptake; HRmax, maximal heart rate (VO_2max test); BLAmax, maximal blood lactate concentration; RPEmax, maximal ratings of perceived exertion (BORG); VO_2 VT1, oxygen uptake at the first ventilatory threshold; HR VT1, heart rate at the first ventilatory threshold; VT1 % of VO_2max, percentage of the first ventilatory threshold on the maximal oxygen uptake; VO_2 VT2, oxygen uptake at the second ventilatory threshold; HR VT2, heart rate at the second ventilatory threshold; VT2 % of VO_2max, percentage of the second ventilator threshold on the maximal oxygen uptake; FFM, fat free mass; FM, fat mass; MM, muscle mass; *significant within-group change from pre-to post-training ($p \leq 0.05$).

Table 4. Habitual physical activity (additional endurance and strength training to the HIIT sessions).

		Training time (min)	*p*-Value	RPE	*p*-Value	TTL	*p*-Value
Week 1	HIIT-R	281 ± 256	0.951	12.8 ± 0.7	0.055	3,339 ± 3,538	0.785
	HIIT-F	273 ± 139		14.4 ± 1.5		3,793 ± 1,939	
Week 2	HIIT-R	286 ± 336	0.731	13.0 ± 0.4	0.356	3,869 ± 4,259	0.857
	HIIT-F	225 ± 285		13.6 ± 1.3		3,446 ± 3,917	
Week 3	HIIT-R	284 ± 255	0.850	13.0 ± 1.1	0.540	3,697 ± 3,326	0.967
	HIIT-F	256 ± 274		13.5 ± 1.4		3,610 ± 4,203	
Week 4	HIIT-R	272 ± 142	0.753	14.4 ± 1.3	0.988	3,227 ± 2,252	0.557
	HIIT-F	324 ± 364		14.4 ± 1.3		5,459 ± 5,340	
Total	HIIT-R	1,084 ± 908	0.991	13.3 ± 0.6	0.189	14,131 ± 11,828	0.866
	HIIT-F	1,078 ± 1,019		14.3 ± 1.5		15,398 ± 14,591	

HIIT-R, high-intensity interval training running group; HIIT-F, high-intensity interval training functional group; RPE, ratings of perceived exertion (BORG); TTL, total training load (perceived exertion × training session time (in min))

exercises, executed using bodyweight could elicit similar increases in HR as running and stimulate endurance adaptations in moderately trained individuals. Indeed, Gist et al. (2014b) documented no statistical difference in %HRpeak and %VO_2peak between sprint interval cycling and HIFT using modified burpees. However, it is worth noting that the exercises for the HIIT-F incorporated aerobic whole-body exercise (e.g. burpees), interspersed with classical strength exercises such as squats, plank, crunches and push-ups, (see Table 2) which do not evoke a high percentage of VO_2max. This aspect may be reflected in the average (over all 14 training session) mean HR response. HIIT-F induced a mean HR response of 78 % of HRmax, whereas the HIIT-R showed a significant higher mean HR response of 87 % of HRmax. The same applies to the highest HR reached during the training sessions (87 % vs 94 % of HRmax for the HIIT-F and HIIT-R, respectively). Average RPE according to the BORG-scale was slightly higher for the HIIT-R, however, not significant. Despite a lower relative cardiopulmonary demand, HIIT-F achieved the same CRF improvements as HIIT-R, which could be advantageous regarding exercise compliance, as training may be perceived as less strenuous compared to running.

Surprisingly, the effect of HIIT-R and HIIT-F on muscular endurance (push-ups, toes-to bar, broad jump, and burpees) showed no significant interaction. Only the HIIT-F improved the maximal numbers of burpees achieved. However, toes-to bar exercise was improved for HIIT-R only. Other HIFT studies demonstrated enhanced muscle performance after the functional training intervention (Buckley et al., 2015; McRae et al., 2012). We speculated that training adaptions are specific to the modality of exercise. Therefore, HIIT-F training was expected to improve muscular endurance tests to a greater extent, compared with HIIT-R. However, somewhat surprisingly HIIT-R also demonstrated significant improvements in certain muscular endurance tests, including toes to bar, which actually did not improve in the HIIT-F group. We speculate that running increased the strength of the hip flexors, thus aiding performance of movements involving hip flexion (Andersson et al., 1997). Alternatively, this isolated effect in a single test may be a type I error or could be a learning effect due to the lack of a familiarization test.

In contrast to HIFT studies with overweight/obese participants (Fealy et al., 2018; Sperlich et al., 2017), body composition in the present study was unaffected by both training interventions. This may be due to a shorter intervention time in the present study (4 weeks vs. 6-9 weeks) and in particular the different participant characteristic regarding body weight and activity status. This is supported by a recent meta-analysis (Batacan et al., 2017) which revealed no significant effect of HIIT on body composition in individuals with normal weight. However, in obese and overweight populations a significant improvement was found. Nevertheless, the authors of the meta-analysis mention the paucity of data available regarding the effects of HIIT on body composition in normal weight populations.

Some limitations of the present study have to be acknowledged. The findings of the present study were obtained from a relatively small sample size due to drop-outs. Furthermore, the variety of HIFT routines makes analysis of our functional training difficult to compare with previous work. As a result, we cannot guarantee that the HIFT applied in this study is superior to other functional/circuit training programs. We also did not control dietary intake during the study, however we advised participants not to change their usual nutritional habits during the intervention period. Finally, we did not conduct a formal familiarization test regarding the muscular endurance test. However, it should be stated that all subject were sport students and were familiar with all muscular endurance exercise tests.

Practical applications

For enhancing CRF, HIIT-F seems to be an effective alternative to traditional endurance training modalities. Additionally, HIIT-F elicits lower HR responses than the same training performed as running, which in terms of exercise adherence may be of great advantage. This kind of training program may be well suited to moderately trained individuals, as we demonstrated in the present study, but may also be applied to competitive athletes to provide an alternative training strategy or to bring variation in the everyday training routine, with the potential to improve CRF. Moreover, the results have useful practical application for healthy subject, but may also have important clinical implications and therefore deserve further investigation.

Conclusion

In conclusion, either running or functional low-volume HIIT results in similar improvements to VO_2max and certain aspects of muscular endurance. Hence, exercise modality seems not to affect the training responses regarding CRF and muscular endurance. Despite a lower cardiovascular strain, functional HIIT elicits similar improvements to running HIIT. Both modalities can be employed for improving VO_2max and certain aspects of muscular endurance.

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Key points

- Exercise modality (running vs. functional exercises) does not affect the training responses regarding cardiorespiratory fitness and muscular endurance in moderately trained participants
- Despite a significant lower cardiovascular strain in the functional protocol the cardiorespiratory improvements were the same for both groups
- Body composition was unaffected by both training interventions

✉ **Verena Menz**
Department of Sport Science, University of Innsbruck, Fürstenweg 185, A-6020 Innsbruck, Austria

AUTHOR BIOGRAPHY

Verena MENZ
Employment
Researcher at the Department of Sport Science, Univ. of Innsbruck, Austria
Degree
PhD
Research interests
High-intensity interval training, exercise and high-altitude physiology,
exercise physiology
E-mail: verena.menz@uibk.ac.at

Natalie MARTERER
Employment
PhD candidate at the Department of Sport Science, University of Innsbruck, Austria
Degree
MSc
Research interests
Exercise physiology, high-altitude physiology
E-mail:
natalie.marterer@student.uibk.ac.at

Sachin Bharat AMIN
Employment
PhD candidate at the Department of Sport Science, University of
Innsbruck, Austria
Degree
MSc
Research interests
Exercise and extreme environmental physiology
E-mail: Sachin.Amin@uibk.ac.at

Alexander Bradley HANSEN
Employment
PhD candidate, Department of Sport Science, Univ. of Innsbruck, Austria
Degree
MSc
Research interests
Extreme environmental and high-altitude physiology
E-mail: alexander.hansen@uibk.ac.at

Martin FAULHABER
Employment
Associate Professor at the Department of Sport Science of the Univ. of Innsbruck
Degree
PhD
Research interests
Exercise and high-altitude physiology, epidemiology of alpine sports
E-mail: martin.faulhaber@uibk.ac.at

Justin Stevan LAWLEY
Employment
Professor at the Department of Sport Science of the University of Innsbruck
Degree
PhD
Research interests
Environmental and exercise physiology
E-mail: justin.lawley@uibk.ac.at