

The Effects of High-Intensity Functional Training on Aerobic Capacity, Metabolic Adaptation and Neuromuscular Responses in Young Female Volleyball Players

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SUMMARY

The aim of the study is to evaluate the effects of High Intensity Functional Training (HIFT) program on aerobic capacity, metabolic adaptation and neuromuscular responses in young female volleyball players. 22 licensed female athletes (16.41 ± 1.29 years old) who played volleyball actively for at least two years in the regional women's volleyball league voluntarily participated in the study. Participants were divided into two groups as experimental (EG; n=11) and control group (CG; n=11) by random sampling method. CG only participated in routine volleyball training for 12 weeks. EG participated in the 12-week HIFT program, which included sprinting, plyometric, functional body weight, resistance and aerobic exercises two days in a week. Measurements were taken before and after the training program as pre-test and post-test. Anthropometric measurements (height, body weight, body fat percentage, body mass index) of the participants were taken. Metabolic (Lactate) and aerobic capacity measurement (Maximum oxygen consumption ($VO_2\max$)) of the participants were taken with the Yo-yo Intermittent Recovery (level-1) Test protocol. Moreover, neuromuscular tests (Counter Movement Jump (CMJ) and 10x20m repetitive sprint fatigue index) were applied. Statistical analysis of the data obtained was done using the SPSS 22.0 statistical package program. As a result of the study, a statistically significant difference was observed in the CMJ and Yo-yo Intermittent Recovery (level-1) Test in CG, and in the CMJ, 10x20m repetitive sprint fatigue index, Yo-yo Intermittent Recovery (level-1) and $VO_2\max$ tests in EG at the end of 12-week HIFT program ($p < 0.05$). In addition, when EG and CG were compared, it was determined that there was a statistically significant difference in the favor of EG between the CMJ test and 10x20m repetitive sprint fatigue index post-test mean values ($p < 0.05$). As a conclusion, it can be said that 12-week HIFT is a training method that can positively affect the aerobic capacity, jump force and neuromuscular responses of young female volleyball players. Therefore, HIFT can be used to improve the performance of young female volleyball players and added to their annual training regimen.

Keywords: HIFT, Volleyball, Athletic Performance, CMJ, Repeated Sprint, $VO_2\max$

INTRODUCTION

Volleyball is a team sport involving short-term high-intensity activities that use combined skills, with high tempo, based on mobility, quickness, strength and endurance. Volleyball competitions last an average of 90 minutes and the duration of high-intensity activities during the competition requires well-developed aerobic and anaerobic energy systems of volleyball players. During the competition in volleyball, high-intensity sprinting, jumping and changing direction activities are frequently performed. Therefore, volleyball players need well-developed maximal aerobic power ($VO_2\text{max}$), anaerobic power, lower and upper extremity muscle strength, agility, balance and speed (Hakkinen, 1993; Gabbett and Georffieff, 2007). Performance in sports requires optimal development of aerobic and anaerobic metabolism, muscle strength and muscle strength (Ramos-Campo et al., 2018). Recently, interest in short-term and high-intensity training programs has increased in sports performance improvement research (Buchheit, 2013; Feito et al., 2018a; Neto and Kennedy, 2019). There are studies in the literature that high-intensity functional training (HIFT) is a safe, effective and time-efficient training strategy to improve sportive performance (Gibala, 2007; Mate-Munoz et al., 2017; Heinrich et al., 2014, İlkım et al. 2021). HIFT is defined as training performed at high intensity, plyometric, functional body weight exercises, multimodal resistance exercises and aerobic exercises with more than one energy system for a specified period of time to improve general physical fitness, cardiovascular endurance and sportive performance (Feito et al., 2018). HIFT is based on a predetermined time to perform a set of repetitions with a short rest interval between exercises or to complete each exercise in the shortest possible time (Crawford et al., 2018; Tibana et al., 2018).

Previous HIFT studies were mostly conducted on sedentary individuals and sedentary participants (Carnes et al., 2018; Teixeira et al., 2020; Mcweeny et al., 2020). Carnes et al. (2018), in a study comparing the running performance between 12-week endurance training and HIFT in recreational runners, it was stated that there was a similar improvement in 5 km running performance in both training groups. Teixeira et al. (2020) compared 6-week HIFT with a traditional resistance training with 30 sedentary participants, and significant improvements were seen in muscle strength measurements in both training groups. In addition, it was observed that aerobic power and upper body muscular endurance improved more in the HIFT group. When the literature was reviewed, no study was found that examined the effects of HIFT on the sportive performance of young female volleyball players. Due to the limited number of studies on the subject, it is emphasized that more comprehensive studies are required to determine whether HIFT is an appropriate training strategy at different levels and in different sports (Henrick et al., 2012; Barfield et al., 2012; Neto and Kennedy, 2019). We think that this study will contribute to the expansion of the HIFT method in the literature. In this study, it is aimed to reveal the efficiency of high-intensity functional training by examining the effects of high-intensity functional training on aerobic capacity, metabolic adaptation and neuromuscular responses in young female volleyball players.

Materials and Methods

This study was carried out with the following study group after the approval of Marmara University Faculty of Medicine Clinical Research Ethics Committee with protocol number 09.2021.06 and dated 08.01.2021. The universe of the study consists of licensed athletes aged 15-18 playing in the regional women's volleyball league in the Trakya Region. The sample group of the study consists of 22 volunteer female athletes between the ages of 15-18, who play in the regional women's volleyball league in Kırklareli, with at least 2 years of active license.

Table 1. Demographic characteristics of the female volleyball players

Group	n	Variable	$\bar{x} \pm ss$
CG	11	Age (year)	16,64±1,29
		Height (cm)	166,27±7,55
		Body Weight (kg)	55,06±7,97
		Body Fat Percentage (%)	20,14±4,62
		BMI (kg/m ²)	20,01±2,68
EG	11	Age (year)	16,18±1,17
		Height (cm)	167,45±5,47
		Body Weight (kg)	58,55±4,57
		Body Fat Percentage (%)	20,86±3,99
		BMI (kg/m ²)	20,29±2,07

After the first tests and measurements of the 22 athletes participating in the study were taken, the experimental group (EG; n=11) who participated in the high-intensity functional training program for 12 weeks, 2 days a week in addition to the volleyball training with the random sampling method, and those who continued only routine volleyball training for 12 weeks. The control group (CG; n=11) was divided into 2 groups.

Before starting the measurements and training, the participants were given detailed information about the content, importance, purpose, application and possible risks of the study, and then signed a voluntary consent form stating that they voluntarily participated in the study. Before all tests and measurements, it was stated that the participants should not participate in intense vigorous physical activity 48 hours before, do not consume alcoholic beverages within 24 hours, should not consume drinks containing caffeine 4 hours before, and eat at least 2 hours before the tests. The measurement methods and devices to be applied to the participants were explained in detail. The same warm-up protocol was applied to all participants before starting the measurement, testing and training.

High Intensity Functional Training

The high-intensity functional training program applied in the study; It has been designed by paying attention to many parameters such as training volume, frequency, intensity, rest intervals, recovery time and participant characteristics. Experimental group participants did 6 exercises including sprint, plyometric, functional body weight, resistance, multi-joint functional and aerobic exercises, exercise duration 30-45 seconds, no rest between exercises, 4-6 sets, rest 1-2 minutes between sets and 30-45 participated in a high-intensity functional training program at an intensity of 90% of the maximal number of repetitions per second. The volume of training was gradually increased over 12 weeks. It was emphasized that the speed of movement was important in the exercises and the repetitions were completed as fast as possible.

Number of exercises	Exercise	Exercise intensity	Exercise duration	Resting between the sessions	Number of Sets	Rest time between the sets
6	Sprint	90% of maximal repetitions for 30-45 seconds	30-45 seconds	no regular rest intervals	4-6 sets	1-2 minutes
	Plyometric					
	Functional body weight					
	Strength					
	Aerobic					
	Multi-joint functional resistance					

Figure 1. Content of High-Intensity Functional Training

Anthropometric Measurements

Height Measurements: The height of the participants was taken in 'cm' with a Holtain Ltd, UK brand stadiometer measuring ± 1 mm (Mitchell, 2006). Body Weight, Body Fat Percentage and Body Mass Index measurements: The body weight and body fat percentage measurements of the participants were obtained using a bioelectrical impedance (Tanita Body Composition Analyzer MC-780MA) analyzer with a sensitivity of 0.01 kg. The body mass index of the participants was calculated by dividing the body weight by the square of the height (kg/m^2) (Duz, Kocak and Korkusuz, 2009).

Yo-yo Intermittent Recovery (level-1) Test, VO_2max and Lactate Measurement: Participants' VO_2max values were placed on the participants with portable gas during the Yo-yo Intermittent Recovery (level-1) Test (Bangsbo, 1994; Krstrup et al., 2003). It was measured with the CORTEX MetaMax 3B gas analyzer, which measures the gas fraction (FEO_2) in each expiratory air by attaching the analyzer. The blood lactate values of the participants were measured with the Lactate Scout brand portable lactate measuring device, by taking the blood analyzer that was pierced from the fingertip with the help of a lancet. Lactate was measured again for each participant before starting the warm-up before the Yo-yo Intermittent Recovery (level-1) Test and 2 minutes after the test was terminated (Hazır et al., 2010; Bishop, 2001).

Jumping - Counter Movement Jump (CMJ) Measurement: The Newtest Powertimer 300-series jump platform was used to measure the CMJ of the participants. The participants were asked to jump up with maximum force after making a quick squatting motion from the hands at the waist to the knees in the normal upright position on the jumping platform, and the data of the time to stay in the air and the height of the jump were recorded.

10x20m Repetitive Sprint Test: Participants were asked to run the 20 m distance between the start and finish lines 10 times with 30 seconds of passive rest intervals, the Newtest Powertimer 300-series photocell stopwatch was placed at the start and finish lines, and the test time for each sprint was measured. With the repeated sprint test of the participants, the total sprint time, the fastest sprint time, the slowest sprint time were determined and the percentage of performance decline (fatigue) scores were calculated according to the formula below (Hazır et al., 2019).

Ideal Sprint Time = Sprint Sprint x Best sprint time.

Fatigue= (100x (total sprint time / ideal sprint time))-100

Statistical Analysis

Statistical analyzes of the data were made using the SPSS 22.00 package program. The normality test of the data was determined by the Shapiro-Wilk test, and the data showed a normal distribution. Independent Sample T Test was used to compare the test results of the groups, and Dependent Sample T Test was used for the first and last test comparison of each group. Data are presented as mean (\bar{x}) \pm standard deviation (ss). The significance level of the data was determined as $p < 0.05$.

Findings

Table 2. Results of Dependent Sample (pretest-posttest) T-Test of Groups and Between-Groups (pretest-posttest) Independent Sample T-Test

Parameters	Groups	N	Pre Test	Post Test	t	p
			$\bar{x} \pm ss$	$\bar{x} \pm ss$		
CMJ (cm)	CG	11	29,32 \pm 3,79	31,09 \pm 3,46*	-2,269	,047
	EG	11	29,15 \pm 2,90	34,30 \pm 3,30*†	11,477	,000
	p		,906	,038		
10x20m Repetitive Sprint Fatigue Index	CG	11	3,35 \pm 1,00	2,94 \pm 1,06	,889	,395
	EG	11	3,31 \pm 1,02	1,75 \pm 0,39*†	4,524	,001
	p		,934	,002		
Lactate (mmol/L)	CG	11	9,04 \pm 1,56	9,12 \pm 2,02	-,119	,908

	EG	11	8,96±1,18	8,47±1,47	1,125	,287
	p		,903	,402		
Yo-yo Intermittent Recovery Test (level-1) Distance (m)	CG	11	520,00±135,06	723,64±169,19*	-5,481	,000
	EG	11	527,27±71,15	781,82±155,29*	-7,730	,000
	p		,876	,411		
VO ₂ max (ml/kg/min)	Control Group	11	37,82±3,49	38,00±3,19	-1,491	,167
	Experimental Group	11	36,45±2,62	38,00±2,90*	-9,815	,000
	p		,312	1,000		

Data are presented as mean±standard deviation ($\bar{x}\pm ss$).

*p<0.05 (Dependent Sample t-test (pre-test, post-test) results).

†p<0.05 (Independent Sample t-test pre-test, post-test results between groups).

DISCUSSION

The aim of this study is to examine the effects of high-intensity functional training on aerobic capacity, metabolic adaptation and neuromuscular responses in young female volleyball players. Our study findings show a greater improvement in CMJ, 10x20m repetitive sprint fatigue index, Yo-yo Intermittent Recovery (level-1) distance and VO₂max tests in the experimental group after the 12 HIFT program (Table 2). In addition, when EG and CG were compared, it was determined that there was a statistically significant difference in favor of EG between CMJ, 10x20m repetitive sprint fatigue index post-test mean values (p<0.05).

Metabolic Adaptation

Blood lactate concentration is one of the main metabolic markers. HIFT increases fatigue by maximizing metabolic stress (Neto and Kennedy, 2019). When Table 2 was examined, no statistically significant difference was found between EG and CG blood lactate concentration levels (p>0.05). Most studies investigating the metabolic responses of high-intensity functional training have investigated acute blood lactate responses (Fernandez-Fernandez et al., 2015b; Mate-Munoz et al., 2017). There is consensus that the level of acute blood lactate concentration is high immediately after a HIFT session (Fernandez-Fernandez et al., 2015b; Murawska-Cialowicz et al., 2015; Tibana et al., 2018a, 2019; Maté-Muñoz et al., 2017, 2018). While some studies have stated that there are differences between HIFT sessions of different duration (Tibana et al., 2016; Mate-Munoz et al., 2017, 2018; Timón et al., 2019), some studies have stated that there is no difference (Fernandez-Fernandez et al., 2015b; Durkalec-Michalski et al., 2018; Tibana et al., 2018a, 2019). Presumably, the intensity of HIFT sessions affects the level of acute lactate concentration. There is no standard set listening time

between reps and sets in HIFT. The trainings are usually chosen based on the fitness of the participants to do as many repetitions as possible in a specified time or to complete the specified number of repetitions in the shortest amount of time. This maximizes metabolic stress and can increase fatigue, keeping acute blood lactate levels high.

Chronic metabolic blood lactate concentration responses to HIFT are unclear in the literature. There seems to be a limited number of studies examining the chronic effect of HIFT on blood lactate concentration (Murawska-Cialowicz et al. 2015; Cadegiani et al., 2019). Supporting our study findings, Murawska-Cialowicz et al. (2015) reported nonsignificant changes in blood lactate level after 3 months of HIFT training. However, Cadegiani et al. (2019) compared the athletes training in functional/nonfunctional overreaching and overtraining syndrome, it was stated that blood lactate levels were lower than those who overtrained. Participant population, diet and experience can be an important factor in these results.

Aerobic Capacity Performance

When Table 2 is examined, there is no significant difference in $VO_2\text{max}$ mean values of CG participants ($p>0.05$), while there is a statistically significant difference in EG mean values ($p<0.05$). Our study findings show that the 12-week HIFT program contributes positively to the aerobic capacity performance of young volleyball players. In the literature, there are studies reporting that HIFT improves $VO_2\text{max}$ in parallel with our study results (Heinrich et al., 2012, 2014; Tibana et al., 2018b). It was reported that $VO_2\text{max}$ values of the participants improved after another 8-week HIFT program, which reported similar results (Smith et al. 2013; Cosgrove et al., 2019; Carneiro et al., 2017; Brisebois et al., 2018).

In a study comparing HIFT and endurance training, it was seen that the HIFT program also improved aerobic capacity performance (Buckley et al., 2015; Feito et al. 2018b). Carnes et al. (2018), in a study comparing the 12-week endurance training program and the HIFT program in recreational runners, it was observed that there was a similar improvement in the $VO_2\text{max}$ values of endurance training participants in both training groups. Teixeira et al. (2020), in his study with 30 sedentary participants, compared the 6-week HIFT program and a traditional resistance training, and stated that the aerobic capacity of the HIFT group participants improved better. When the studies reporting these results are evaluated, it can be said that HIFT is an alternative training method to traditional resistance programs and endurance training programs (Carnes et al. 2018; Teixeira et al., 2020).

Not supporting our study findings, Crawford et al. (2018) states that there is no significant difference in $VO_2\text{max}$ values of 25 volunteer participants after 6 weeks of HIFT training in their study. The lack of change in $VO_2\text{max}$ may be due to the participant population or the training period being limited to 6 weeks.

Neuromuscular Responses

Differences in neural activation as a result of resistance training programs provide adaptation to anaerobic power increase together with changes in muscle size (Figueiredo et al., 2018; Schoenfeld et al., 2019). Fatigue, which occurs due to many factors, including neural and muscular, varies according to the type and intensity of exercise (Girard et al., 2011). In

repetitive sprints without full recovery, changes in the neuromuscular structure of the muscle are observed (Spencer et al., 2006). Repeated sprinting is considered an important performance component in team sports and is widely used to evaluate performance. Padulo et al., 2016; Kin-isler et al., 2008 ; Fernandez-fernandez et al., 2015a). In our study, neuromuscular responses to the HIFT program were evaluated with CMJ and 10x20m repetitive sprint fatigue index. When Table 2 is examined, it is seen that there is a statistically significant difference between the mean values of CMJ and 10x20m repetitive sprint fatigue index ($p < 0.05$). Our findings show that HIFT has a great effect on the anaerobic capacity system by making a positive contribution to the fatigue and recovery times of young female volleyball players due to less rest and more repetitions during the exercise. It is also known that training volume is a determining factor in strength gains (Colquhoun et al. 2018; Saric et al., 2019). High-intensity anaerobic exercise (jumps, sprints, etc.) and muscle strengthening exercises (push-ups, squats, etc.) used in HIFT show that it improves neuromuscular responses (Heinrich et al., 2015; Haddock et al., 2016; Feito et al. 2018b).

Our study results show parallelism with the results of many studies in the literature conducted with different groups. It has been shown that participation in the HIFT program improves muscle strength and anaerobic capacity performance (Buckley et al., 2015; Smith et al., 2013; Feito et al., 2018b). In another study, it was stated that there were significant improvements in muscle strength and strength measurements after HIFT training (Heinrich et al., 2012, 2015; Smith et al., 2013). In a study comparing the effects of 6-week HIFT and a traditional circular training with sedentary women, it was stated that the HIFT program provided similar improvements in muscle strength and performance (Sobrero et al., 2019). Athletes participating in the 8-week HIFT program improved their muscle strength performance in bench press and leg press exercises (Brisebois et al., 2018). Studies comparing the HIFT program with a fitness program (Jeffery, 2012) and a traditional resistance training program (de Sousa et al., 2016) showed that HIFT participants had better anaerobic fitness.

Hermassi et al., who did not support our study findings in the literature. (2017) showed no significant change in repetitive sprint parameters after 10 weeks of resistance-type circular training program twice a week with male handball players. It may be caused by the exercises applied in functional training and the participant population. Teixeira et al. (2020) showed that the 6-week HIFT program with 31 participants did not increase performance at vertical jump height in their study in which they analyzed the physical performance effects of HIFT. The duration of the applied training may have an effect on this different result. Hollerbach et al. (2021) showed that there was no significant difference in vertical jump between traditional resistance and HIFT training groups. Barfield and Anderson (2014) also found no difference between the two groups in vertical jump values, which is another strength parameter. A study comparing HIFT training with a conventional strength training found no difference in vertical jump performance (Costa, Feye & Magallanes, 2021). This result shows that the HIFT method can provide the gains of a traditional strength training.

Result

As a result, 12-week HIFT applied 2 days a week in addition to volleyball training improved the aerobic capacity, anaerobic capacity and jumping power of young female volleyball players. Our study shows that the use of high-intensity plyometric, functional body weight, multimodal resistance and aerobic exercises without a fixed rest interval in the training program contributes positively to the metabolic and neuromuscular responses of the athletes. HIFT can be used as an alternative training method to traditional circular resistance training and high-intensity interval training methods in team sports, as part of the annual training program, to improve or maintain performance during pre-season or competition. This issue can be of great importance to trainers. However, the fact that the participants of this study are young women who do sports at an amateur level can be considered as a limitation. Future studies can be conducted with adult elite athletes to evaluate the effects of high-intensity functional training method. In addition, the effects of HIFT on metabolic adaptation can be examined with longer-term training planning. However, the HIFT method is very intense and can cause extreme fatigue in young female volleyball players. Therefore, in HIFT planning, the volume, duration and intensity of the training should be prepared according to the characteristics of the athletes.

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