JOMH
Journal of Men's Health

Original Article
DOI: 10.15586/jomh.v16i2.211

VERY SHORT-TERM HIGH-INTENSITY INTERVAL TRAINING IN HIGH SCHOOL SOCCER PLAYERS

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Submitted: 4 December 2019. Accepted: 25 March 2020. Published: 4 May 2020.

ABSTRACT

Background and objective

To analyze the body composition, anaerobic power, and fatigue in high school soccer players resulting from very short-term, high-intensity interval training (HIIT) for 3 weeks during off season.

Methods

Forty-four high school soccer players, with a mean age of 17.2 ± 1.0 years, were included in the study. The sample consisted of a single group, and the tests measured body composition using the impedance method, anaerobic power using a Wingate cycle ergometer, and strength with an isokinetic device. The training was carried out 5 days/week over a 3-week period for a total of 15 sessions. Training included stretching and warming up, sprint anaerobic cycle training, and running HIIT such as sidestep, zigzag run, ladder run, box jump, and plyometrics.

Results

Post-training muscle mass (+2.0%, $p < 0.001$) and fat ratio (−12.7%, $p < 0.001$) improved significantly compared to pre-training observations. However, bodyweight and body mass index (BMI) did not change significantly. The Wingate test, measuring peak power in three and five sets showed greater improvement compared to the initial test (+10.7% and +19.0% respectively). A significant decrease was observed for fatigue in three and five sets (−8.5% and −12.4% respectively). The isokinetic strength test showed significant differences in flexion(+8.5%, $p = 0.002$) and extension (+9.4%, $p < 0.001$) at 60°/s.

Conclusion
Short-term HIIT can improve fatigue rate, anaerobic power, and muscle strength of athletes as well as increase their muscle mass.

Key words: *anaerobic power; high-intensity interval training; soccer; strength*

INTRODUCTION

Soccer is a physically and physiologically demanding sport that requires the repetition of many changeable activities, including running, jumping, turning, and sprinting. The energy system is broadly divided into aerobic and anaerobic, and most athletes train to match their sports-specific exercise (e.g., sprinter-anaerobic, marathon-aerobic). Soccer requires athletes to exert repeatedly maximal or submaximal actions below 30 m for 90 min.[1] The ratio of aerobic to anaerobic fitness in soccer players is about 30–70%.[2] For these reasons, soccer training usually includes physical exercise that aims to enhance both aerobic and anaerobic fitness. Typically, high-intensity interval training (HIIT) is included in training regimes. HIIT can be defined as repeated periods of intense exercise and incomplete recovery.[3] The exercise intensity of HIIT sets is near maximum, with the maximum oxygen uptake (VO_2max) being between 50% and 75% at rest.[4]

Several studies have suggested that interval aerobic training increases VO_2max in athletes.[5,6] If a taekwondo player starts HIIT, their aerobic fitness improves by 8.8% in college.[7] Additionally, in adolescents, HIIT has been shown to improve VO_2max by 2.6 mL/kg/min and lower the body mass index (BMI) by -0.6 kg/m^2.[8] However, most pre-HIIT studies have been conducted for at least 4 weeks, with the interval training focusing on aerobic fitness. Therefore, this study has the following characteristics.[1,9] The training was conducted during off-season for 3 weeks. Over this time, athletes did not participate in any training, including soccer, except for HIIT at the training center. The variables measured were anaerobic capacity and isokinetic strength.

METHODS

Forty-four male, high school soccer players participated in this study. They visited an athletic professional training center to receive physical checkup and off-season management. All participants performed daily training once a day for 3 weeks. The participants had a mean age of 17.2 ± 1.0 years, mean height of 172.1 cm, and a mean weight of 64.0 kg with no history of injury or surgery in the previous 6 months. Five athletes with a history of an injury in the previous 6 months were not included in the analysis and underwent rehabilitation. The training session was conducted 5 days per week for 3 weeks. A total of 15 sessions were held, and the weekend was set as recovery day. The study coordinator informed the athletes and coach about the research and obtained their consent.

Anthropometric measurements and body composition

Body composition was measured with bioelectrical impedance Inbody 770 (Inbody Inc., Republic of Korea). This device was used to measure the body fat percentage, skeletal muscle percentage, height, and weight of each participant. Before the measurement, foreign objects, as well as participant's hands and feet, were cleaned with alcohol. Participants were measured with their arms and legs kept in an open position. Body fat and muscle variables were used as absolute (kg) and relative values (absolute/bodyweight) × 100 in the analysis.

Wingate test

The Wingate test, which was used to measure anaerobic power, was conducted using a friction-loaded cycle ergometer (Monark model 864 Crescent AB, Sweden). The seat height and handlebars were adjusted for each subject, as appropriate. The Wingate test consisted of 30 s maximal revolutions per minute (rpm) against constant resistance relative to bodyweight (0.075 kg × bodyweight).[10] Initially, the examiner instructed the subject to maintain 80 rpm with minimum resistance. When the examiner gave a "3-2-1-go" signal, the athlete cycled at maximum rpm under the applied load. The assistant recorded the highest rpm and the rpm every 5 s and calculated the peak power (PP, watt), peak power per weight (PP/kg, watt), and fatigue index (%) at the end of the test. The analysis used one set three sets and five sets of records.

Isokinetic strength test

The flexion and extension strength of the knees were measured using an isokinetic dynamometer (Humac Norm, CSMi, USA). The knee extension and flexion peak torque of each lower limb were evaluated using the isokinetic contraction test. The inspection process and method were carried out according to the manual provided by the machine company.[11] The posture was measured from 90° flexion in the sitting position to 0° extension. Gravity correction of the lower extremity was performed at 45°. Before starting the test, subjects performed three to five light and heavy contraction repetitions to familiarize themselves with the machine. After enough practice, the subjects performed three repetitions of the knee extension maximum contraction at 60°/s and 180°/s. After the test, sufficient recovery time was provided. The last test was performed using 25 repetitions at 240°/s. The unit values are expressed as Newton meter (Nm) in 60°/s, average watt 180°/s, and total Joule in 240°/s.

Training programs

Daily training took about 1 h and 30 min, including 30 min of warm-up, 20 min of cooling down, and main HIIT for 60 min. The time and set composition of HIIT were based on literature.[4] Two methods of HIIT, bicycling and running, were done once every 2 days. The training was of 60 min and comprised three sets of 15-min training blocks. A 5-min rest period was provided between each set. Training and recovery included 20 s of maximum training + 60 s of rest, up to a total of 10 min per set. HIIT intensity was performed at a estimated maximum heart rate of ≥90% and recovery heart rate ≥ 60%. The estimated maximum heart rate formula is 220-ages. For example, if a player is 18 years old, 220-18 = 202. The estimated maximum heart rate is 202. Participants' heart rates were assessed using a wearable monitoring system.

Running HIIT included sidestep, zigzag run, ladder run, box jump, plyometrics and short splint. For the bicycle HIIT, cycling was repeated at full speed for 20 s and recovery for 60 s.

Statistical analyses

SPSS version 25.0 (SPSS Inc., Chicago, IL, USA) was used to carry out statistical analyses. All data are presented as mean values with standard deviation. A paired t-test was used for comparing pre-training and post-training results. The significance level was set to a $p < 0.05$ and <0.001.

RESULTS

The body composition of the athletes after training significantly improved in terms of muscle mass (+2.0%, $p < 0.001$), muscle mass ratio (+1.3%, $p < 0.001$), and body fat ratio (−12.7%, $p < 0.001$). However, bodyweight (+0.6%, $p = 0.093$) and BMI (+0.5%, $p = 0.098$) did not change significantly compared to pre-training (Table 1).

The cycle ergometer measurements for anaerobic capacity are shown in Table 2. Peak power was not significantly different in one set, but there was a significant increase in three sets (+10.7%, $p = 0.040$) and five sets (+19.0%, $p = 0.004$). Simple peak power was not considered as body weight. As power is influenced by bodyweight, the following equation was used: peak power/bodyweight (PP/kg). Anaerobic power significantly improved

TABLE 1 Training Effects for the General Characteristics of Subjects (Mean Values ± SD)

	Pre-training	Post-training	change	t	p
Age (years)	17.2 ± 1.0	-	-	-	-
Height (cm)	172.1 ± 3.0	-	-	-	-
Weight (kg)	64.0 ± 4.7	64.4 ± 4.6	0.4 (+0.6%)	−1.759	0.093
BMI (kg/cm²)	21.6 ± 1.7	21.7 ± 1.6	0.1 (+0.5%)	−1.730	0.098
Muscle mass (kg)	35.3 ± 4.0	36.0 ± 3.9	0.7 (+2.0%)	−6.294	<0.001*
Muscle ratio (%)	55.2 ± 1.5	55.9 ± 1.6	0.7 (+1.3%)	−5.709	<0.001*
Fat mass (kg)	8.2 ± 1.4	7.2 ± 1.7	-1.0 (-12.2%)	5.898	<0.001*
Fat ratio (%)	12.8 ± 2.8	11.2 ± 3.0	-1.6 (-12.7%)	6.026	<0.001*

**p < 0.001; BMI, body mass index.*

TABLE 2 Training Effects for the Wingate Test by Cycle Ergometer (Mean Values ± SD)

Variable	Pre-training	Post-training	Change	t	p
Peak power 1 set (watt)	779.4 ± 201.2	843.1 ± 124.2	63.7 (+8.2%)	−1.304	0.206
Peak power 3 set (watt)	706.2 ± 194.4	781.8 ± 98.2	75.6 (+10.7%)	−2.079	0.040*
Peak power 5 set (watt)	645.6 ± 192.5	768.3 ± 123.4	122.7 (+19.0%)	−3.203	0.004*
PP/BW 1 set (watt)	12.2 ± 1.3	13.1 ± 1.0	0.9 (+7.5%)	−0.579	0.569
PP/BW 3 set (watt)	11.0 ± 1.0	12.1 ± 0.8	1.1 (+10.0%)	−2.425	0.025*
PP/BW 5 set (watt)	10.1 ± 1.8	11.9 ± 1.2	1.8 (+18.3%)	−3.248	0.004*
Fatigue index 1 set (%)	45.7 ± 11.6	42.1 ± 6.4	−3.6 (−7.9%)	1.703	0.104
Fatigue index 3 set (%)	55.5 ± 8.9	50.8 ± 8.6	−4.7 (−8.5%)	2.723	0.013*
Fatigue index 5 set (%)	54.1 ± 9.0	47.4 ± 10.2	−6.7 (−12.4%)	2.774	0.012*

**p < 0.05; PP/BW, peak power per bodyweight.*

in the three and five sets, with peak power per weight increasing by +10.0% ($p = 0.025$) and +18.3% ($p = 0.004$).

Peak power is important for increasing one's ability to maximum rpm. The fatigue index relates to the ability to sustain high rpm. Therefore, the lower the value, the better the anaerobic capacity. The fatigue index from pre- to post-test significantly changed by −8.5% ($p = 0.013$) and −12.4% ($p = 0.012$) for the three and five sets respectively. There were no significant changes in any variables of 1-set HITT (Table 2).

When comparing pre- and post-test isokinetic results, we found that extension and flexion strength had a statistically significant improvement for the 60°/s. The results tended not to be different for 180°/s and 240°/s variables (Table 3).

DISCUSSION

It could be difficult for athletes to discontinue their normal training regimes during experiments. Additionally, restricting control group athletes from training for experimental purposes is more difficult.

Therefore, although this study was a short-term, single-group study, its research design was composed of training only with HITT for 3 weeks. The primary measurement indexes used were the impedance analysis, Wingate test, and isokinetic strength test.

TABLE 3 Training Effects for the Muscle Strength and Power by Isokinetic Test (Mean Values ± SD)

	Pre-training	Post-training	Change	t	p
Ext 60°/s (Nm/kg)	270.2 ± 27.2	295.7 ± 34.3	25.5 (+9.4%)	–8.335	<0.001**
Flx 60°/s (Nm/kg)	155.9 ± 19.7	169.2 ± 18.6	13.3 (+8.5%)	–3.622	0.002*
Ext 180°/s (watt)	291.9 ± 42.7	303.3 ± 41.3	11.4 (+3.9%)	–1.072	0.296
Flx 180°/s (watt)	199.1 ± 25.7	205.7 ± 24.7	6.6 (+3.3%)	–0.848	0.406
Ext 240°/s (Joule)	3868.5 ± 384.3	3876.4 ± 485.0	7.9 (+0.2%)	–0.097	0.923
Flx 240°/s (Joule)	2359.3 ± 423.9	2429.1 ± 361.4	69.8 (+3.0%)	1.028	0.316

**p < 0.05, **p < 0.001; Ext, Extensor; Flx, Flexor.*

First, the body composition variables showed no significant changes in bodyweight. However, muscle mass increased by 0.7 kg, but body fat decreased significantly by −1.6%. These results are in part similar to previous studies. In a meta-analysis, studies measured the effects of training over short (8 weeks) to more extended periods (1 year).[12–15] The results showed that weight loss was effective by training only without restricting diet, and the fat-free mass (FFM) was prevalent only in a group that underwent resistance exercise training. The diet restriction group had a decrease in FFM.[16–18] However, even in a short 3-week training period, an improvement in lean body mass was observed.[19] In this study, no significant differences were found regarding BMI, which is different from previous studies performed in adolescents.[8] The reason why BMI was not significant in this study was probably due to short training periods and no dietary interventions.

Peak power per bodyweight increased by 1.1 and 1.8 watts in three and five sets respectively. These results indicate that significant changes in three and five sets improved the ability to sustain anaerobic power with endurance. The significantly improved fatigue index supports this result. Lower the depth value, better the endurance of excellent anaerobic power. The fatigue test, which measures how much rpm could be maintained in 5 and 30 s per set, was not significant in 1 set. However, in three and five sets, the fatigue test was significant.

The isokinetic test, which measures muscle strength, was significant only at 60°/s. The extension increased by 25.5 Nm, and flexion increased by 13.3 Nm. This result is similar to a previous study in which 4-week training improved peak torque of the quadriceps with isokinetic strength at 60°/s.[20] Akima et al. measured the isokinetic muscle strength and muscle hypertrophy over a 2-week short training session.[21] While muscle hypertrophy was not expected, improvement in strength was observed.[21] This result could be due to neural adaptation.[22]

In the review papers regarding adolescents, studies that were conducted from 6 weeks to several months reported the most positive effects of HIIT.[8] However, some studies have analyzed short-term training results to test the effects of short-term exercise.[9,23–25] have reported that after 2 weeks of short-term training, both low-volume sprint-interval training group and high-volume endurance training group displayed improved expression of cytochrome oxidase (COX) and improved muscle adaptation and exercise performance.[26,27] These results show that the results of training are positive regardless of the intensity and time. Their findings are similar to those of this study.

In addition, 2 weeks of training with soccer players showed that the muscle Na+–K+ pump was different between the activity and inactivity groups.[28] Furthermore, football players who had been training for 4 weeks showed an increased anaerobic threshold by 1.3% and decreased heart rate by −1.8%.[29] Most of the studies have shown positive results for high-intensity training in spite of short durations, and the current study has also shown similar results.[30,31] Some of the effects of training were not significant. This might be due to the relatively short period of training, particularly since the baseline was set at a point when the performance ability of players was already high. However, soccer has been reported to require 30% aerobic capacity and 70% anaerobic capacity.[2] The results of this study indicate that athletes' physical stamina changes in accordance with the characteristics of soccer in which stamina must be maintained for longer periods repetitively. Besides, this study also demonstrated that the training was sufficient, even for a shorter period. Another study examining the short-term HIIT effect also reported very positive results. A 2-week HIIT increased the duration of exercise from 26 to 51 min and improved COX activity. Also, muscle glycogen content increased during rest and exercise.[24] In the same study, biopsy results showed improvements in the total protein content of pyruvate dehydrogenase, peroxisome proliferator-activated receptor-F coactivator 1 alpha, and maximal activity 3-hydroxyacyl-CoA dehydrogenase.[24] Sprint interval training with a bicycle increased muscle glycogen content by 50% and the maximum activity of citrate synthase.[25] While these studies reported short-term HIIT, significant improvement in physical and biochemical variables was still prevalent.

There are several limitations to this study. As mentioned above, the experiment was conducted over a short period of 3 weeks and comprised a single group only. In addition, it is unknown whether improvement in laboratory-based physical fitness results in improved soccer performance. In adolescents, the relatively high HIIT intensity should be reviewed in terms of sports science and the potential for injuries. In the future, research is expected that could focus on preventing physical injury and improving physical performance.

CONCLUSION

Three weeks of HIIT improved isokinetic knee strength. The results indicate improvement in the Wingate fatigue rate and body fat as well as increase in total power and muscle mass.

CONFLICT OF INTEREST

The authors have no potential conflict of interest to declare with respect to the research, authorship, and publication of this article.

FUNDING

The authors received no financial support for the research, authorship, and publication of this article.

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