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High-Intensity Interval Training in Middle-Distance NCAA Division I 800/1500m Collegiate Athletes

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ABSTRACT

Background: High-intensity interval training (HIIT) has grown in popularity, with studies demonstrating improvements in aerobic and anaerobic performances within Sedentary and Recreationally active adults. Little research has been comprised on collegiate, middle-distance runners (800m/1500m). **Objective:** This research study aimed to investigate the impact of four-weeks HIIT cycling training on collegiate 800/1500m runners performance, and determine whether HIIT can be used as an alternative training method for student athletes**. Methods:** Twelve middle-distance runners were recruited, with six athletes completing the intervention. Athletes completed pre-testing, which included a 1500m time trial, a GXT, stride length and frequency measurements, and MVIC, using Biopac electromyography (EMG). After pre-testing, athletes completed four weeks of HIIT twice per week. The HIIT consisted of four 20-second bouts with 4 minutes recovery. Following the completion of the training intervention, post-testing was performed for all measures. A paired t-test was used to determine differences between pre- and post-performance tests. An ANOVA was used to determine changes in heart rate and RPE during the GXT. **Results:** Significant changes were demonstrated between the pre- and post-muscle activation tests of the quadriceps ($p=0.05$). Significant changes were seen with both HR ($p<0.05$) and RPE ($p<0.05$) throughout the GXT. No other significant differences were demonstrated between pre- and post-performance tests, concluding four-weeks HIIT does not alter 800/1500m performance. **Conclusion**: From the results of this study, HIIT could be used as an alternate method for training for 800/1500m runners. Further reasearch should be conducted toto further understand the impacts of HIIT on middle distance athletes.

Key words: High-Intensity Interval Training, Running, Track and Field, Endurance Training

INTRODUCTION

High-intensity interval training (HIIT) has shown to be of growing interest within research, with early research demonstrating increases in ventilatory threshold (VT), lactate threshold (LT), and $\dot{V}O_{2max}$ within trained runners (Acevedo & Goldfarb, 1989). In addition to the aforementioned variables, there have also been observed increases in power output (Zieman, et al., 2011;Astorino, Allen, Roberson, & Jurancich, 2012; Buckley, et al., 2015). The above mentioned factors determine both aerobic and anaerobic performance. However, many of these studies have focused on the effects of HIIT on sedentary and recreationally active populations, therefore leaving to question whether similar aerobic and anaerobic adaptation can occur within middle-distance athletes (Astorino, Allen, Roberson, & Jurancich, 2012; Buckley, et al., 2015; 2015; Zieman, et al., 2011; Whyte, Gill, & Cathcart, 2010). Studies have demonstrated increases in performances with sports such as judo, soccer, taekwondo, and canoeing (Frachini, et al., 2016; Howard & Stavrianeas, 2017; Monks, Seo, Kim, Jung, & Song, 2017; Yang, Lee, Hsu, & Chan, 2017). However, little has been done examining the effects that HIIT could have on middle-distance runners running the 800 or 1500m. Due to HIIT showing increases in both anaerobic parameters of performance (LT and power output), as well as aerobic parameters of performance ($\dot{V}O_{2max}$)(Acevedo & Goldfarb, 1989; Astorino, Allen, Roberson, & Jurancich, 2012; Esfarjani & Laursen, 2007), it is hypothesized that similar adaptations will occur within middle-distance runners and improve their performance. Further, training protocols of HIIT within the literature are shown to last roughly 30 minutes on average, with intervals as short as 10 seconds demonstrating significant improvements within 5 km running time trials (Astorino, Allen, Roberson, & Jurancich, 2012; Hazell, Macpherson, Gravelle, & Lemon,

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2010). If performance is demonstrated to be maintained or increased, this would offer a time-efficient method of training for student athletes who have busier schedules, since many studies have shown a total training time of 30 minutes.

Various techniques for HIIT have been used, incorporating different modes of exercise of cycling, running, and swimming (Kriel, Askew, and Solomon, 2018; Sperlich, et al., 2010). While these studies have been conducted in a sport-specific manner, it is not uncommon for athletes to cross-train, as cross-training is thought to reduce injuries within athletes, and more specifically over-use injuries within runners (Drew,Cook and Finch, 2016). Evidence shows that runners have a higher rate of stress-related injuries, including stress fractures and responses, and shin splints (Wright, Taylor, Ford, Siska, Smoliga, 2015). Wright et al., (2015) demonstrated that runnerss account for 15-20% of injuries being produced from stress fractures, with the main cause due to the impact of running on hard surfaces. When an athlete becomes injured, detraining can occur which negatively impacts performance upon return to competition. To reduce the detraining effect athletes are encouraged to cross-train, with many runners choosing cycling to maintain fitness. Due to HIIT demonstrating both aerobic and anaerobic performance improvements, it is suggested as a possible replacement for cross-training within middle-distance runners.The current literature is mixed regarding the impacts that cycling training may have on runner's muscle activation (Quigley and Richards, 1996; Hausswirth, Bigard, Berthelot, Thomaidis, and Guezennec, 1996; Hue, Le Gallais, Chollet, Boussana, and Prefaut, 1997, Connick and Li, 2015). Quigley and Richards (1996) states that cycling training, does not impact running kinematics, however, Connick and Li (2015), showed that stride kinematics alters from cycling, within triathletes.

This study aimed to examine whether HIIT cycling cross-training for middle-distance runners would deliver an effective alternative method for time-constraint collegate middle-distance athletes, and to examine whether, cycling alters muscle activation of the lower limbs. The study also examined whether stride length or frequency would be impacted by this change in training methodology. To our knowledge no other studies have examined the impacts of HIIT cycling cross-training on a runner's muscle activation, stride length or stride frequency. Due to stride frequency and stride length being a vital part for performance, both are important to best evaluate and determine whether any performance changes will be caused through alterations of stride length and stride frequency.

The present study hypothesized that HIIT cycling on collegiate Division I middle-distance runners' overall 1500m timed performance would improve and that there would be no significant changes in stride length, but increased muscle activity and stride frequency.

METHODS

Participants and Design of Study

A Quasi-Experimental, study was conducted evaluating a four-week HIIT cycling intervention in middle-distance Division I collegiate runners with both pre-and post-testing, no control group was used for this study. The independant variables used within the study were a graded exercise treadmill test, 1500 m time trial, changes in running kinetics, and maximal voluntary isometric contraction (MVIC) test on the quadriceps, hamstrings, tibialis anterior, and medial gastrocnemius. Each of these tests measured performance parameters: time to volutional exhaustion (minutes), time to complete 1500m (minutes), muscle activation via EMG and stride length (m) and Stride Frequency (strides/min). Following pre-testing, participants completed four weeks of HIIT, with two training sessions per week, consisting of four 20-second modified Wingate tests with four-minutes of active recovery between bouts. The four-week HIIT intervention was in replacement of two days of their middle-distance run days (6-10 km runs). At the completion of the intervention, participants completed post-testing, and results were compared to pre-testing measurements utilizing a within-subjects design. The HIIT was conducted prior to their peak season, having completed little to no lactate threshold training. Prior to testing Ethical Approval was given from Mississippi State University Ethical Board (16-251).

All 800/ 1500m athletes were recruited from the local University's Track and Field team, therefore 12 Division Division I 800/1500 m (female: 8, male: 4) runners were recruited for this study. The following formula was used to determine sample size, with a standard deviation of 0.29 and ES of 0.45 (Kadam & Bhalerao, 2010):

$$n = \frac{2(Z\alpha + Z_{1-\beta})^2 \sigma^2}{\Delta^2}$$

Each athlete, read, understood and signed a consent form, prior to partcipation, which outlined the purpose and prodecure of the study, if they were to decide to participate within the study. Participants were excluded from the study if they had suffered from an injury within 6 months. To be included, participants must be 800 or 1500m runners, training 7 days per week. Athletes training included, three recovery runs at 4:30 minute per kilometer pace (females) and 4:00 minute per kilometer (males), as well as two to three high intensity workouts varying from lactate threshold track sessions to $\dot{V}O_2$ aerobic sessions. Further, athletes would complete two resistance-training workouts per week. Resistance-training included whole body exercises, conducted by the team strength coach. Figure 1. demonstrates the enrolment of athletes throughout the study, which left a total of six athletes for data analysis.

Performance Testing

Pre- and post-testing included a graded exercise treadmill test to volitional exhaustion (TTE), a 1500 m time trial and maximal voluntary isometric contraction (MVIC) testing. Testing was conducted during the participants transition period from the indoor to outdoor track season. The modified Fox/Costill protocol was used for the incremental test, with participants starting at 6.5 km/h. Each stage lasted three minutes and increased in speed by 1.5km/h until the participants reached 11 km/h after which speed remained constant with percent gradient being increased two percent every minute. Subjects stopped once they reached volitional exhaustion and TTE was recorded. A

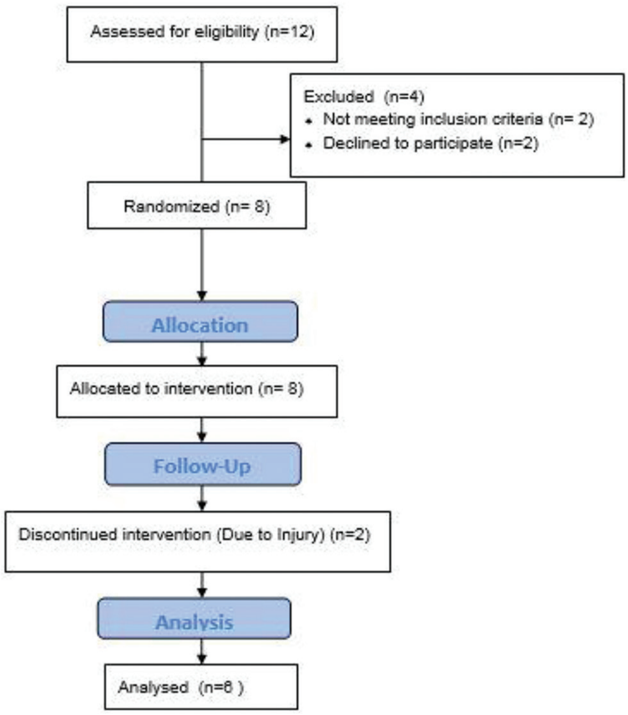

Figure 1. Enrolment of Participants throughout the study.

COSMED T150 treadmill (COSMED USA Inc., Chicago, IL), with participants attached to a safety harness, was used for the incremental treadmill test. Heart rate (HR) (FT1, Polar Electro Inc., Lake Success, NY, USA) and rate of perceived exhaustion (RPE), using the modified Borg RPE 10-point scale, were measured at each stage of the incremental treadmill test.

Subjects completed a 1500 m time trial on a 400 m standard tartan outdoor track (Mississippi State University, USA), at least 48 hours following the treadmill test. Subjects were asked to run the 1500 m at race pace and wore the same footwear for both pre- and post-intervention 1500 m time trial. Prior to testing, subjects completed a standardized warm up in the following order: two-mile run, 20 m skips, 20 m side steps, 20 m karaoke and a three minute up-tempo run. The time trial was conducted at the same time day for both testing sessions. During the 1500 m time trial, stride length and frequency were measured. Stride frequency was calculated by counting each left leg stride, with a hand-held clicker (Coolestone, Leavenworth, WA, USA). The total strides counted were then divided by the time taken (seconds) to complete the 1500 m run. Stride length was measured from the heel of the left foot to the heel of the left foot, along a 10 m stretch of the track, using dartfish technology (Alpharetta, GA, USA) to screenshot and determine the stride length.

Training Protocol

A four-week training protocol, consisting of four 20-second modified Wingate tests (all-out sprints) with four minutes active recovery between each sprint, were implemented twice a week (Zieman, et al., 2011). A Velotron bike (Seattle, WA) was used for the Wingate testing and data was collected using the Velotron Wingate software (RacerMate, Seattle, WA, USA). Prior to starting the protocol during each training session, subjects completed a warm up cycling for five minutes at 50 W for females and 75 W for males. Each sprint was set to 7.5% of the participant's body mass measured at the beginning of the study. The same weight was then used as resistance for each visit. Subjects had a 10-second count down prior to each sprint. Subjects were asked to remain seated while sprinting and to maintain maximal cadence. Between sprints, subjects completed an active recovery of cycling for four minutes at 50 W for females and 75 W for males. At the conclusion of the final sprint, a five-minute cool down was completed at 35 W or on a Woodway treadmill at a self-selected pace (Pro Model, Waukesha, WI, USA).

Electromyographic Analysis

A Biopac electromyography (EMG) system was used to measure muscle activity data, within seven days pre- and post- training intervention. After prepping the skin using alcohol wipes and an abrasive surface (sandpaper), two bipolar electrodes with a 1.5 cm inter-electrode distance were placed on the muscle bellies of quadriceps (vastus medialis), hamstrings (biceps femoris), tibialis anterior and medial gastrocnemius on the subjects' dominant lower extremity (Jang, et al., 2018). Dominant leg was determined through questioning participants which leg was deemed their dominant. Subjects were tested for maximal voluntary isometric contraction (MVIC) for each of the four muscles of the dominant lower extremity prior to, and after the four-week training. Subjects performed three trials of 3-s MVICs maximally contracting each muscle individually, in the mid-range of motion for the knee and ankle joints. Quadriceps MVIC was performed in knee extension and hamstrings MVIC in knee flexion. Tibialis anterior and medial gastrocnemius MVICs were performed during ankle dorsiflexion and plantar flexion, respectively.

Raw EMG data were filtered using a band-pass filter at 20-300Hz and rectified for further analysis. Mean and peak EMG for all four muscles were calculated from the processed data and were used as dependent variables to denote muscle activation levels during MVIC.

Statistical Analysis

A paired *t*-test was used to distinguish significant differences between: pre- and post-1500 m times, HR_{max}, RPE_{max}, stride length, and stride frequency. An 11x2 (stage x time) repeated measures analysis of variance (RMANOVA) was used to distinguish significant differences between the incremental stages and pre- and post-intervention for both HR and RPE. A two-way (day x week) RMANOVA was used to determine differences between mean and peak power outputs for Wingates. The dependent EMG variables (mean and peak) for each of the four muscles were analyzed using a one-way RMANOVA. If any significant main effects were found, they were followed up with a post-hoc pairwise comparison with a Bonferroni correction. Partial eta squared was calculated for all RMANOVAs. All statistical analyses were performed with an alpha level set at

$p \leq 0.05$ and conducted in SPSS (v24, IBM corporation, Armonk, NY, USA).

RESULTS

Subject Descriptive Data

Six participants completed the study, (3 male and 3 female) with their descriptive data presented in Table 1. All participants were within the collegiate middle-distance team and competed in the south-eastern conference championships.

The table demonstrates the demographics of the participants used within the study. Both males and females were combined within the demographics.

Performance Testing

There were no significant differences in any of the performance measures. The 1500 m times demonstrated no differences between pre- and post-time trials (t = 1.36, p = 0.23, CI = -0.15 to 0.50), with no differences between stride length (t = 2.11, p = 0.09, CI = -0.27 to 0.03) or stride frequency (t = 0.29, p = 0.780, CI = -0.05 to 0.04) being observed pre- and post-testing. Performance testing measures are shown in Table 2.

Incremental Treadmill Test

No significant differences between pre- and post-testing for TTE (t = 0.87, p = 0.43, CI = -0.05 to 1.05), HRmax (t = 0.87, p = 0.45, CI = -10.645 to 18.64) or RPE_{max} (t = 0.17, p = 0.87, CI = -1.34 to 1.18) achieved during the incremental treadmill test.

Stage x time interaction effect regarding HR response demonstrated no significant changes (F = 0.37, p = 0.67, η^2 = 0.109). There was no main effect for time (F = 0.77, p = 0.45, η^2 = 0.204). A significant main effect was seen for stages (F = 66.78, p < 0.001, η^2 = 0.957). Stages 1 and 2 were significantly lower than Stages 8-11 (p < 0.05). There were no differences between Stages 3-11 (p > 0.05).

There was no significant stage x time interaction effect for RPE (F = 0.86, p = 0.46, η^2 = 0.165). RPE demonstrated no significant main effect for time (F = 1.37, p = 0.30, η^2 = 0.160). However, a significant main effect was found between stages for RPE (F= 34.16, p = 0.001, η^2 = 0.999). Post-hoc comparisons revealed that Stages 1-7 were significantly lower than Stage 11 (p < 0.05) and Stage 9 was significantly lower than Stage 10 and 11 (p < 0.05). HR and RPE data for each stage are presented in Table 3.

Power Output

There was no significant day x week interaction for mean power output (F = 0.52, p = 0.68, η^2 = 0.093), main effects for days (F = 0.49, p = 0.83, η^2 = 0.010) or weeks (F = 0.76, p = 0.54, η^2 = 0.131). Day x week interaction for peak power output (F = 2.39, p = 0.11, η^2 = 0.323) or main effects for days (F = 0.07, p = 0.80, η^2 = 0.014) or weeks (F = 0.36, p = 0.78, η^2 = 0.067), also showed no significant changes. Peak power and mean power output are shown in Figure 2.

Table 1. Descriptive data recorded of participants that complted the study

Descriptive data	Mean±SD
Age (years)	20.80±2
Height (cm)	182.00±6.58
Body Mass (kg)	65.39±7.22

Table 2. Performance measurement Pre- and Post-Intervention

Measurement	Pre-training	Post-training
Time to Exhaustion (min)	20.14±1.22	19.71±1.28
Max RPE (0-10)	9.30±0.99	9.50±0.84
Max HR (bpm)	188.30±7.80	183.80±3.09
1500 m time (min)	5.01±0.66	4.83±0.53
Stride frequency (stride/s)	1.49±0.06	1.49±0.08
Stride length (m)	3.20±0.33	3.32±0.33

*data presented as mean±standard deviation

Table 3. Heart rate and rating of perceived exertion during incremental treadmill testing

Stage	Pre-test HR	Post-test HR	Pre-test RPE	Post-test RPE
1	74.2±13.30	79.3±4.92	1.0±0	1.7±0.5
2	101.8±12.38	97.0±6.16	1.0±0	1.7±0.5
3	125.5±20.42	118.5±27.81	1.6±0.7	1.9±0.7
4	131.8±21.12	124.8±24.45	2.1±1.0	2.1±1.0
5	140.5±18.87	132.8±19.70	2.5±0.6	3.0±1.3
6	144.0±12.93	139.0±18.24	2.8±0.9	3.2±1.2
7	152.0±12.12	147.0±18.67	3.4±0.7	3.2±1.3
8	158.8±12.53	153.5±14.84	4.4±1.4	3.8±1.6
9	167.5±13.38	163.5±8.06	5.3±2.0	4.8±1.8
10	173.8±10.44	168.5±7.59	6.4±2.0	6.7±2.3
11	178.3±9.24	174.3±7.63	7.5±1.6	7.4±2.1

Data are presented as mean ± standard deviation. HR=heart rate, RPE= rating of perceived exertion.

EMG Results

There were significant differences in mean quadriceps muscle activity (F = 7.06; p = 0.05, η^2 = 0.585] and post-hoc comparisons revealed significantly greater mean muscle activity in the quadriceps muscle for post-training (Figure 2). Although peak quadriceps muscle activity also increased post-training, it was not statistically significant [F = 4.70; p = 0.08, η^2 = 0.484] (Figure 3). No other significant differences were seen between pre- and post-training for the hamstrings, medial gastrocnemius, or tibialis anterior.

DISCUSSION

The current study investigated whether collegiate runners would benefit from a short-term HIIT intervention, specifically in regards to running performance. To our knowledge

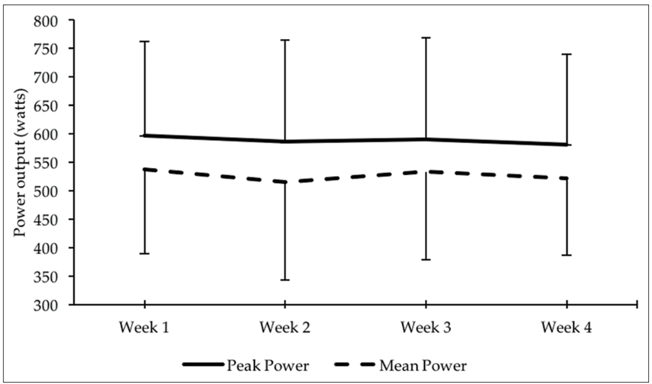

Figure 2. Peak and mean power output across 4-weeks of high-intensity interval training. Data represents peak and mean power outputs (mean ±standard deviation) averaged across both training days each week for four weeks

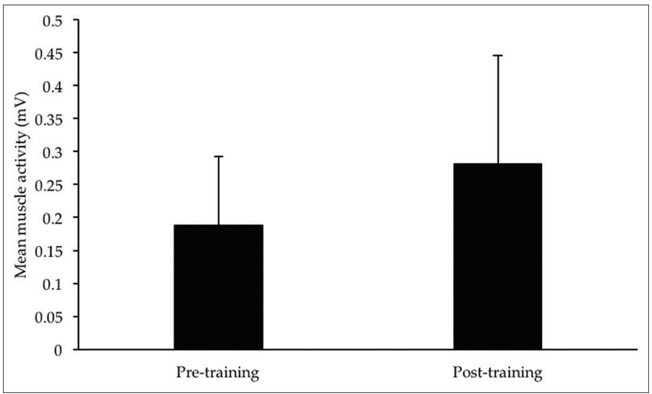

Figure 3. Electromyographic mean muscle activity (mV) in quadriceps during maximal voluntary isometric contraction (MVIC) before (pre-training) and after (post-training) 4-weeks of high-intensity interval training. *represents significant difference from pre-training ($p<0.05$). Data is represented as mean ± standard deviation

this was the first study to examine the effects of HIIT on collegiate middle-distance runners using a cross-training technique. The study demonstrated four main findings: (1) no significant changes were shown within running performance after four weeks of HIIT; (2) HIIT significantly increased vastus medialis activation, which is vital for leg extension; (3) no significant changes were observed with mean or peak power output for cycling; and (4) no significant changes were seen within stride length and stride frequency of the athletes. Although there were no performance adaptations, it should be noted there were no detriments in performance, suggesting HIIT may be a viable cross-training modality for a runner, due to maintenance of performance.

Astorino et al. (2012) demonstrated six sessions of HIIT over a 2-3 week period increases $\dot{V}O_{2max}$ in young active athletes (baseline $\dot{V}O_{2max}$ 45.6ml.kg^{-1}.min^{-1} in males and 41.1ml. kg^{-1}.min^{-1} in females). A recent study (Silva et. al., 2017) demonstrated four weeks of HIIT did not affect performance within 5 km runners but increased lactate threshold, and $\dot{V}O_{2peak.}$ In another investigation, 24 active males were trained utilizing a cycling HIIT program and demonstrated no change in $\dot{V}O_{2max}$, however, the study demonstrated power output at $\dot{V}O_{2max}$ with time to exhaustion at power max being significantly higher post-HIIT (Bayati, Farzad, Gharakhanlou, & Agha-Alinejad, 2011). While several research studies have demonstrated increases in performance, there have been few HIIT studies utilizing cross-training as a training method, as well as using highly-trained athletes. The well-trained individuals used within the current study may have already been near their physiological ceiling suggesting cross-training would only maintain performance levels and would not increase these factors.

The current study demonstrated significant changes within the muscle activity of the vastus medialis from pre- to post-intervention. Compared to running, cycling has been shown to significantly increase muscle activity of the quadriceps, due to cycling being solely a concentric movement (Bijker, de Groot, & Hollander, 2002). This may also explain the lack of differences in gastrocnemius and hamstring activation from pre- to post-training. Furthermore, trained cyclists can generate higher force at a lower oxygen cost compared to novice cyclists (Coyle, Coggan, Hopper, & Walters, 1988). Due to our subjects status as well-trained runners, with little experience of cycling, the athletes demonstrated an adaptation to cycling through an increase in quadriceps activation. The EMG data from this study should be interpreted with caution as muscle activity was measured during static MVIC tests, while running is a dynamic movement. Although there were no increases in performance, increases in vastus medialis are still important for a trained runner, as the vastus medialis functions to create greater knee extension and stabilize the patella, potentially reducing risks in injuries while running (Westing , Cresswell, & Thorstensson, 1991). Further, it has been shown that cross-training in runners produces favorable neurological changes to the quadriceps, and decreases in running economy, however the current study demonstrated no changes in the latter.

Currently, coaches are under time constraints to fit sufficient training times within new NCAA training policies. The current policies dictate a maximum time of 20 hours per week in which athletes are allowed to train in- season, limiting their training time. Multiple interventions and training methods, demonstrate increases in performances for middle-distance runners, through conducting stretching routines, strength training and, plyometric training, however, due to the 20-hour time limit there does not appear to be enough time for the athletes to fully utilize all the different training methods (Saunders, et al., 2006; Ramirez-Campillo, et al., 2014; Paavolainen, Hakkinen, Hamalainen, Nummela, & Rusko, 1999; Guglielmo, Greco, & Denadai, 2009). The current study demonstrates the importance of HIIT and how it could be used to maintain performance for the six athletes within the study, being a time-efficient training method..

The current study implies that HIIT could be a possible training method for the collegiate mid-distance athletes used within this study, The study shows how training could be modified to be more time efficient for current NCAA athletes, whom struggle to balance their athletic training and school work. Athletes, coaches and other researchers can use

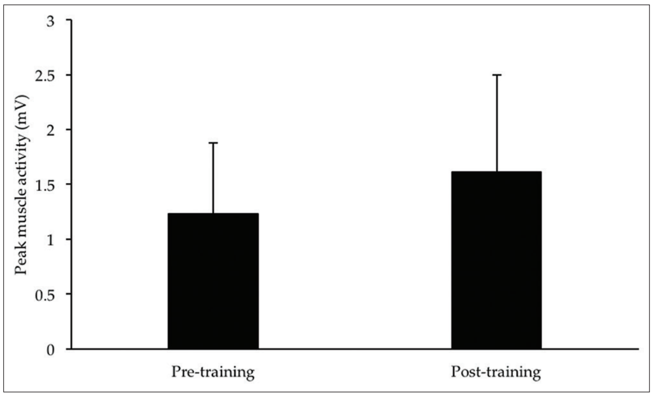

Figure 4. Electromyographic peak muscle activity (mV) in quadriceps during maximal voluntary isometric contraction (MVIC) before (pre-training) and after (post-training) 4-weeks of high-intensity interval training. Data is represented as mean ± standard deviation.

this study to understand the possible benefits from HIIT. The study highlights the importance for further research to be conducted within this area to maximise training possibilities for athletes. Although the number of participants that completed the study is a limitation, it should be noted that the population used was a homogenous group of highly-trained middle-distance (800/1500 m) runners. Therefore, future research should be conducted on a larger population of highly-trained athletes.

CONCLUSION

Overall, this study demonstrated a maintenance in six collegiate athlete performance, while conducting a four-week HIIT intervention. It could therefore be utilized by the athlete's coaches as an effective cross-training method, specifically if athletes are struggling with time constraints, and/or suffer from regular high-impact injuries related to running. However, as mentioned above, research with a larger sample size would enable a more Coaches who use this intervention within their training programs may choose to add an extra repetition within the workout or increase the number of bouts if they are using HIIT to increase performance. HIIT cycling can therefore be an effective method for coaches and athletes to utilize due to the low impact forces placed upon the athletes, and this method may enable athletes to conduct a high volume of intense workouts within the week, and/or, utilize increased free time from HIIT workouts to focus on other areas for the athletes.

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