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SEASONAL IMPROVEMENTS IN VO_{2MAX} AMONG WOMEN'S COLLEGE SOCCER PLAYERS WITH ONE-DAY PER WEEK AEROBIC INTERVAL TRAINING.

SEZONSKO IZBOLJŠANJE V $VO_{2\ MAX}$ PRI ŠTUDENTKAH NOGOMETAŠICAH OB ENKRAT TEDENSKEM AEROBNEM INTERVALNEM TRENINGU

ABSTRACT

The purpose of this study was to determine the effectiveness of a one-day per week interval training program on maximal aerobic capacity in women's collegiate soccer athletes before and after a competitive season. The one-day per week running program was adapted from previously published recommendations for improving aerobic capacity and performance in soccer athletes. Sixteen collegiate soccer athletes (age 19.43 years) were evaluated prior to and immediately following their competitive season for anthropometric measures and maximal oxygen consumption using an incremental treadmill test. Pre- and post season means were compared and evaluated with a Students' t-test. There were no changes in body mass (60.30 $\pm$ 5.93 vs. 60.52 $\pm$ 5.59), or percent body fat (15.46 $\pm$ 2.64 vs. 15.16 $\pm$ 2.7) but $VO_{2\,max}$ increased significantly from 50.89 $\pm$ 3.04 to 53.11 $\pm$ 3.01 ml/kg/min. There were no changes in maximum heart rate or maximum ventilation. In conclusion, our data demonstrated that a one-day per week training program can significantly increase aerobic fitness in women's collegiate soccer athletes. Considering the importance of aerobic capacity in soccer performance in developing women's soccer athletes and that collegiate seasons do not provide sufficient time for technical, tactical training as well as in-season conditioning, this research demonstrates that a one-day per week training program can generate aerobic improvements in an efficient manner.

Key Words: Seasonal, Aerobic Capacity, Soccer (Football), Training

POVZETEK

Cilj te raziskave je bil ugotoviti učinkovitost programa aerobnega intervalnega treninga enkrat tedensko za maksimalno aerobno sposobnost pri študentkah nogometašicah pred tekmovalno sezono in po njej. Naš tekaški program, ki je potekal enkrat tedensko, je bil pripravljen na podlagi predhodno objavljenih priporočil za izboljšanje aerobne sposobnosti in uspešnosti nogometašev. Ocenili smo šestnajst študentk nogometašic (starost: 19,43 let) pred tekmovalno sezono in takoj po njej, pri čemer smo opravili antropometrične meritve in meritve maksimalne porabe kisika na tekočem traku, s povečevanjem obremenitve. Rezultati pred sezono in po njej so bili primerjani in ocenjeni s Studentovim t-testom. Sprememb ni bilo pri telesni masi (60,30 + 5,93 oz. 60,52 + 5,59) ali odstotku telesne maščobe (15,46 + 2,64 oz. 15,16 + 2,7), vendar pa se je $VO_{2\ max}$ močno povečal s 50,89 + 3,04 na 53,11 + 3,01 ml/kg/min. Pri maksimalni srčni frekvenci ali maksimalni ventilaciji ni bilo sprememb. V zaključku so naši podatki pokazali, da lahko program enkrat tedenskega treninga močno poveča aerobne sposobnost študentk nogometašic. Glede na pomembnost aerobne sposobnosti pri nogometu in v razvoju nogometašic ter glede na dejstvo, da študentske sezone ne ponujajo dovolj časa za tehnične in taktične treninge ter priprave med sezonami, nam ta raziskava kaže, da lahko program treningov, ki potekajo enkrat tedensko, učinkovito izboljša aerobno moč.

Ključne besede: sezonski, aerobna sposobnost, nogomet, trening

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INTRODUCTION

Soccer is characterized as an intermittent team sport that requires significant aerobic capacity (VO_{2max}) to be successful in both male and female athletes at the top level of soccer (2,3,6). A high VO_{2max} has been shown to be well correlated with total distance covered and high intensity running during a soccer match (14). It has also been shown to enhance recovery from high-intensity intermittent runs (23), which likely results in more high intensity running for top class female soccer athletes compared to high level players (17,18). It has been suggested that aerobic power in female players is likely more important than in their male counterparts because VO_{2max} is positively correlated with high intensity running for females (18).

In the United States, the women's collegiate soccer season is 14 (12 competitive plus 2 weeks preseason) weeks long followed by up to 4 weeks of playoffs. Teams typically compete twice per week with one easy recovery practice between games and practice three times per week with one mandatory day off. This compressed schedule due to the academic calendar leaves insufficient time for extensive technical and tactical training, proper physical development and permit recovery from training and competition. Several studies have examined seasonal changes in characteristics of soccer athletes (5,6,13,16,20) showing an increase, decrease or no change in maximal oxygen consumption. Moreover, as much as 30% of a athletes on a college soccer team will be compose of incoming first year students whose prior playing experience was at the u-18 level, a competitive level known for less high intensity running (25). Moreover, Manson et al. have shown that VO_{2max} levels differ according to age with older athletes having a high aerobic capacity (17).

Aerobic conditioning is an essential training component for success in soccer and Helgerud et al. have shown that enhancements of maximal oxygen uptake (VO_{2max}) lead to an increase in soccer performance, distance covered, and number of sprints during a match (10). Therefore, it is now a common recommendation for fitness training in developing (ages 17-21) women's soccer athletes to focus on aerobic high intensity training with an emphasis on the players ability to recover (14,20).

While many studies report gains in fitness characteristics of soccer athletes during preseason training when aerobic conditioning activities may be scheduled several times per week, only two studies have demonstrated effective aerobic development using a two-day per week interval training program conducted during a competitive season (7,10). Considering the short and condensed collegiate season and the competing priorities of technical and tactical training, multiple competitive games, necessary recovery, and a required day off, it may be difficult to regularly conduct two weekly high-intensity conditioning sessions in order to develop aerobic capacity. Therefore, in this tracking study, we examined the effectiveness of a one-day per week conditioning program that combines aerobic and interval training on seasonal changes in VO_{2max}.

METHODS

Experimental Approach to the Problem.

In order to track seasonal changes in maximal aerobic capacity and body composition, we employed a longitudinal pre-test, post-test using a single elite Division I soccer team. Because our team size is small we were not able to utilize a control group. Athletes were evaluated 3 days

prior to the start of preseason and no less than 7 days following the completion of the competitive season. All athletes were assessed for body weight, % fat mass via skinfold testing and maximal oxygen consumption via a graded treadmill exercise protocol. During the season, the athletes completed a one-day per week aerobic interval conditioning program. Subjects maintained their normal dietary intake during the season.

Subjects.

Sixteen female division I soccer athletes, ranging 18-21 years (average age 19.43 years), agreed to participate in a study passed by the Universities' Institutional Review Board. All athletes completed medical screening and provided an informed consent prior to testing.

Procedures

All procedures were conducted in a controlled constant temperature exercise physiology lab. All athletes were familiarized with the tests prior to formal testing.

VO_{2max} testing. Aerobic capacity was determined using a incremental VO_{2max} test on a motor driven treadmill. Athletes were advised they could terminate the test at anytime because of fatigue or discomfort. During this test, respiratory gas exchanges were measured breath by breath using a calibrated Parvo Medics True One metabolic analyzer. Before each test, O_2 and CO_2 analyzers were calibrated with a standard gas mixture. Respiratory gases and heart rate (Polar Electro) were recorded every 15 seconds. Each player performed a 15 minute warm up prior to treadmill testing. Following warm up, the velocity of the first stage was 7 mph for two minutes at 0% grade, subsequent stages increased the incline by 2% every 2 minutes until 6% and then 1% after that until VO_{2max} was reached. VO_{2max} was defined as the average VO_2 for the last minute of completed exercise and expressed as $ml \cdot kg^{-1} \cdot min^{-1}$. VO_{2max} was achieved when at least two of the following criteria were met: 1) a plateau in VO_2 despite increasing intensity, 2) a respiratory exchange ratio over 1.10 during exercise, 3) no further increase in heart rate with increased workload and athlete achieved greater than 90% of age predicted heart rate maximum.

Body Composition. Body mass (kg) was measured in shoeless athletes in light clothing. Percentage of body fat was estimated using 4-site skinfold measurements using Lange skinfold calipers and calculated using recommended formulas (26).

Session RPE. In order to gauge the internal load of the conditioning sessions we collected session RPE for practice and games over the course of 3 consecutive weeks.

Training Program. The typical weekly practice and game schedule is as follows.

Table 1. Weekly Training Schedule and Session RPE (daily averages)

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Activity	Off	*Aerobic Interval Training	Soccer Training	Soccer Training	Game	Light Soccer Training	Game
Average Session RPE (6-20		14.21	14.22	12.89	15.92	9.81	16.19

The one day per week training program was administered every Tuesday following a rest day on Monday resulting in 16 training opportunities (2 preseason, 12 competitive season sessions and 2 during playoffs). The training day was reserved exclusively for aerobic interval running with no ball work. All subjects completed at least 12 training sessions. The training program consisted of repeat high-intensity aerobic intervals of varying length and pace between 90-120% of maximum aerobic speed based upon the work of Dupont et al. (7). Maximal aerobic speed was estimated from teams average VO_{2max} measurements. The interval sessions changed each week to prevent training monotony but were developed and conducted using the following guidelines. The distance of the interval varied from 60 to 600 meters and was carried out in individual sets of 4-8 repetitions per set. Athletes typically completed between 4-8 sets (i.e. shorter intervals were performed in greater repetitions). The total distance of running was not less than 4000 meters and did not exceed 5000 meters An active rest at 50-60% of heart rate maximum as described by Helgerud et al. was used for recovery between interval sessions (10). Total time for interval work (# intervals x interval time) was not less than 16 minutes per training session as described by Helgerud and not more than 25 minutes when including recovery runs. Heart rates were monitored during training in order to ensure that training heart rates exceeded 90% of maximum heart rate during interval training.

Statistical Analyses

Data is shown as means $\pm$ standard deviation. All anthropometric and physiological data were analyzed using paired *t*-tests. Statistical significance was set at the $p \leq 0.05$ level.

RESULTS

There were no changes in body mass or % body fat when comparing pre to post season values (Table 2). Aerobic capacity expressed as VO_{2max} increased significantly from preseason to post season ($p < 0.05$) (Table 3). No changes were observed in maximum heart rate or maximum ventilation (VE) (Table 3).

Table 2. Comparison of Anthropomorphic Characteristics from Preseason to Post Season.

	Preseason	Post Season
Body Mass (kg)	60.30 + 5.93	60.52 + 5.59
% Body Fat	15.46 + 2.64	15.16 + 2.70

Table 3. Comparison of Physiological Variables from Preseason to Post Season.

	Preseason	Post Season
O_2 ($L \cdot min^{-1}$)	3.06 + 0.26	3.22 + 0.27*
$VO_{2\,max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	50.89 + 3.04	53.11 + 3.01*
Heart Rate Max ($b \cdot min^{-1}$)	190 + 10.49	192 + 10.64
VE max ($L \cdot min^{-1}$)	99.76 + 13.02	98.41 + 11.09

* $p < 0.05$.

DISCUSSION

Maintaining or improving performance characteristics over a competitive season is a key to success in any aerobically based sport. Several reports on NCAA Division I female athletes have shown a decrease or no change in maximal oxygen consumption from beginning to end of a competitive season (13,20,23). The data from this study showed that a one-day per week aerobic high intensity interval training program can improve maximal aerobic capacity during a competitive season in Division I soccer athletes.

Our report shows that body mass and percent body fat were unchanged throughout the season. This is in agreement a report from Magal et al. on NCAA Division III men's athletes (16), but different from NCAA Men's division I athletes (23) that showed an increase in both body mass and no change in percent body fat. A similar study conduced with NCAA Division I women's athletes also showed no change in body mass, but reported a significant increase in percent body fat (20). Differences such as these are likely to be explained based on differences in the volume and composition of the total weekly training load and total caloric intake unique to each training environment.

Previous seasonal studies on collegiate soccer athletes have reported an increase, no change or a decrease in maximal oxygen consumption (16,20,23). Two reports from professional teams in Europe showed no difference in maximal oxygen consumption across the length of a competitive season (5,8). This report shows a significant increase by almost 5% and is similar to that reported in a recent study on Division III male athletes (16), but different from that reported on Division I female soccer athletes who reported an almost 7% decrease in absolute maximal oxygen consumption (20).

Elite female soccer athletes demonstrate considerable variation in maximal oxygen consumption ranging from 47.9 ml/kg/min in elite Canadian University players (22) to 57.6 ml/kg/min in 10 more physically mature and older Danish national team athletes (average age: 25yrs) following a 15 month training program (12). What is distinct about this report is that significant gains in oxygen consumption were achieved during an NCAA competitive season, even starting from a very high baseline level. Similar gains were only reported in Division III men's soccer athletes and it was noted that those athletes may not fully adhere to their prescribed summer conditioning program and arrive at preseason with a very low base fitness level. Unlike the majority of Division III athletes, many Division I athletes undergo formalized summer condition programs and the value that we report for our preseason measurement is slightly higher than that reported for Division I female athletes following summer conditioning (20) and similar to the preseason values of the Division III men's soccer athletes (16). Considering that the United States collegiate soccer rules permit multiple substitutions in both the first and second halves of the game and that the average number of substitutions in a female soccer game is 15, aerobic conditioning may not be necessary for most teams who substitute frequently (9) to avoid fatigue.

Conditioning for soccer remains varied and complex given the strength, speed, agility, aerobic and technical requirements of the game. In the U.S., collegiate teams compete with far more constraints than professional or national team athletes. The U.S. collegiate competitive season is short and the number of contests average almost 2 (1.7) per week. Time for physical training is typically limited during the competitive season. Some programs rely solely on soccer training for fitness to continue technical and tactical skill development similar to those experienced

during a game, but those programs generally do not show increases in aerobic fitness levels (11). Training with the ball, typically, results in greater motivation to work hard. However, the intermittent and varied nature of the game of soccer training, often interrupted by coaching opportunities, or tactical requirements may not provide a sufficient physiological stimulus to improve or maintain aerobic development (7). Moreover, varying skill level and time on soccer specific tasks in developing women's soccer athletes may prevent athletes from receiving the full physiological stimulus.

The training program described herein was developed from previously published reports that outlined programs that led to significant gains in aerobic capacity. The seminal report by Helgerud et al. demonstrated that intentional aerobic interval training conducted twice weekly improved VO_{2max}, increased lactate threshold and running economy with no negative effect on strength power or sprint performance (10). Those improvements in aerobic capacity translated to improvements in competitive performance by doubling of the number of sprints, involvements with the ball and increasing the distance covered during a soccer match from 8.6 km to 10.3 km. Despite the aerobic nature of the training they demonstrated no change in sprint speed (10). Several reports have shown a positive relationship between VO_{2max} and repeated sprint ability (1,4,19). Because of the tracking nature of our study, we cannot fully argue that the one-day per week program was solely responsible for the observed gains in aerobic capacity. But considering that several other collegiate studies using female athletes show no increase of even significant declines across an entire season, we are confident that the training program contributed meaningfully to the outcome, Considering the role aerobic power plays in improving soccer performance, it is now recommended that an aerobic fitness base be fully developed, particularly in developing women athletes (14,21).

Because of weekly scheduling constraints, including the likelihood of two games, two conditioning workouts per week may be very difficult to achieve. Sprint like or other very high intensity training activities, while easy to integrate into practice, may only serve to further exacerbate the stress level of already intensely focused athletes. Since epinephrine and other stress hormones rise exponentially as the intensity of the activity increases beyond maximal aerobic speed (15) training with sprint activities during a competitive season may prove counter productive and lead to overtraining (13)

This report shows a one-day per week conditioning program developed using the guidelines for aerobic development as described by Helgerud (10) and implemented using an repeat interval model similar to that described by Dupont (7) is sufficient to significantly improve the aerobic capacity of a women's collegiate team during the a competitive season. Regardless of starting fitness level, soccer athletes can improve their maximal aerobic capacity when a well designed one day per week training program is thoughtfully integrated into the competitive season schedule.

PRACTICAL APPLICATIONS.

Aerobic capacity is a key component in soccer success at all competitive levels but is particularly important for developing and younger female athletes that aspire to play at the collegiate or semiprofessional level. Because of an extremely condensed and demanding schedule that may include two games per week, rigorous on-field training, and conditioning sessions that may include sprint, agility and strength work, it may be difficult to maintain or even develop aerobic

fitness. In fact, with a condensed season, it is likely that overtraining conditions may predominate. Many reports exist on how best to condition collegiate soccer athletes, but using very high intensity training activities may only serve to exacerbate athlete stress and lead to a decline in end of season performance. If soccer technical and tactical training are sufficiently intense, it may not be necessary to duplicate that intensity during conditioning sessions without the ball. While we did not measure sprint speed or repeat sprint ability, we would expect no decrease in these abilities as have been reported (10). Considering the intermittent, yet endurance nature of female collegiate soccer, time spent in endurance training may be an efficient way to improve soccer performance without overtraining athletes.

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