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Aerobic and anaerobic performance changes following three training phases in men's soccer players.

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AEROBIC AND ANAEROBIC PERFORMANCE CHANGES FOLLOWING THREE TRAINING PHASES IN MEN'S SOCCER PLAYERS

By

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A Thesis Approved on

3/28/11

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DEDICATION

This thesis is dedicated to my parents

Isabelle Nogueira and Michel Jouaux,

and

my friend Courtney Blackburn,

who have supported my projects in the United States.

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ABSTRACT

AEROBIC AND ANAEROBIC PERFORMANCE CHANGES FOLLOWING THREE TRAINING PHASES IN MEN'S SOCCER PLAYERS

Tony Jouaux

May 14, 2011

The aim of this study was to determine if playing 5 soccer matches in 4 weeks after 8 weeks of strength, conditioning and soccer training further improves aerobic and anaerobic performances.

Ten college soccer players (20.1 ± 1.2 yr) completed three different training phases. Maximal aerobic testing, skinfold 7-site and counter movement jump (CMJ) were performed at the beginning of the study (T1), at the end of 8 weeks of training (T2) and at the end of the 13 weeks of the study (T3).

Repeated measures ANOVA followed by a Post-Hoc test Least Significant Difference indicated that CMJ increased by 6.8% from T1 to T3 while no further change was noticed in body composition, maximal aerobic power and anaerobic threshold at T3.

Along with strength and soccer training, playing 5 soccer matches after 8 weeks of training may play a role in the development of anaerobic power.

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CHAPTER 1

INTRODUCTION

Success in soccer is closely related to tactical and technical skills as well as physiological capacities. Aerobic and anaerobic biochemical pathways are highly taxed during soccer practices and games leading to physiological adaptations. Aerobic endurance performance is determined by maximal oxygen uptake (VO_{2max}), lactate threshold (LT) and running economy (C_R) [1]. Among elite soccer players, VO_2max is reported to be between 55-68 $ml.kg^{-1}.min^{-1}$ [2-4]. These values demonstrate the necessity of aerobic capacity for soccer performance [5]. The importance of maximal aerobic power was further demonstrated by studies illustrating the positive correlation between maximal aerobic power and competitive ranking [2, 6]. Enhancing maximal aerobic power increases distance covered, work intensity, number of sprints and involvements with the ball during a soccer match [7].

After several weeks of the off-season period, soccer players present different fitness levels. The pre-training VO_2max dictates the magnitude of VO_2max improvements in response to a training program [8]. From the start of pre-season to the early weeks of the competitive playing season (7 to 10 weeks), VO_2max increases significantly [7, 9-11]. As a match is played below VO_2max (80 to 85% VO_2max) [7, 12-15] anaerobic threshold may seem to be predictive of soccer performance. Anaerobic threshold or lactate threshold (LT) is defined as the workload, VO_2 or heart rate where lactate production starts to exceed lactate clearance [16]. LT is closely related to ventilatory threshold (VT) because the increase in blood lactate concentration causes a decrease of the metabolic acids buffer (bicarbonate ions) leading to an increase in CO_2 production [17]. Breath analysis may allow detection of the increase in production of CO_2 and indirectly determine anaerobic threshold by plotting on equal axes the volume of oxygen intake (VO_2) with the volume of carbon dioxide output (VCO_2) [18]. An increase in anaerobic threshold may allow a player to maintain a higher average intensity without accumulation of lactate during matches [19]. Several studies reported anaerobic threshold changes after training or competitive period without alteration of VO_2max [9, 17, 20].

Jumping performance is considered as a good predictor of anaerobic power. Arnason et al. reported positive correlation between vertical jump height and competitive ranking in an Iceland soccer league [21]. In other studies, soccer players' vertical jump height has been assessed between 55.6 – 63.4 cm [22, 23]. Studying differences in jumping performances from amateur to elite soccer players, Cometti et al. did not report any difference in vertical jump between soccer levels concluding that soccer practices may not be enough stimuli to increase vertical jump [24]. Strength training and plyometric training should therefore be supplemented to increase strength and vertical jump performance [24].

Using soccer exercises to develop energy systems associated to the technical and tactical aspects of soccer [25] may appear to be the most efficient way of improving soccer performance. In fact, improving energy systems without soccer technical and tactical purposes [7, 11, 26] may be limited to develop soccer players. High intensity aerobic training on treadmill [7], soccer-specific dribbling track [11, 26] and small-sided soccer games [25] have been used to develop energy systems related to soccer performance. Findings from these studies are not consistent resulting either on an increase in VO_2max [7, 9-11] or an increase in anaerobic threshold [9, 17, 20]. There is also a lack of information on the effect of playing and accumulating soccer matches to further increase maximal aerobic power, anaerobic threshold and anaerobic power. As in-season fitness development is mostly determined by the accumulation of soccer games, it seems crucial to understand the physiological changes due to the specific stimuli of soccer matches.

The purpose of this study was to determine if playing five soccer matches in four weeks after eight weeks of strength and high-intensity training further improves maximal aerobic power, anaerobic threshold and anaerobic power. No study has assessed the physiological performance changes of playing five soccer games after eight weeks of strength, conditioning, speed and soccer training. According to a review article from Bassett et al., VO_2max increases in the first eight weeks and then plateaus while lactate threshold continues to increase [27]. Based on this statement, we hypothesized that early improvements in fitness may be based on increase of VO_2max and anaerobic threshold but further performance enhancement may be caused only by improvement of anaerobic threshold. We also hypothesized anaerobic power to increase after eight weeks and further at the end of the entire training period.

CHAPTER II

LITERATURE REVIEW

Metabolism Contribution to Soccer Performance

In 1974 Fox and Mathews presented a cross-sectional study to compare energy systems contribution across several sports. These authors reported soccer as 60% ATP-CP, 20% glycolytic and 20% aerobic [28]. In 1994 different data have been reported with 2% anaerobic and 98% aerobic contributions [9]. To explain these differences and understand the contribution of energy systems during a soccer game, effort analysis have been performed. Soccer games are characterized by intermittent physical activities in which intensities vary. Explosive type efforts such as sprints, jumps, duels and shooting represent a small percentage of the total time of the game (5%) [29]. However, these situations are crucial for game winning situations. The other 95% correspond to low intensity efforts (35% walking, 40% slow speed running and 20% moderate speed running) [29]. Both aerobic and anaerobic energy systems play a crucial role, but during a 90-minute soccer game, ATP production seems to be mainly aerobic.

Determinants of Soccer Performance

Maximal aerobic power, determined by maximal oxygen uptake, varies among soccer players; However, high values (55-68 $ml.kg^{-1}.min^{-1}$) have been reported [30]. This simply emphasizes the contribution of aerobic metabolism to soccer performance [5].

Wisloff et al. (1998) found positive correlation between VO_2max and the competitive ranking of two different soccer teams in the professional Norwegian League (Rosenborg and Strindheim) [2]. The players were tested in the same day of the pre-season training phase. The main limitations of this study are that only two teams were compared and other determinants (technical and tactical differences between teams) for soccer performance were not taken into account. To accentuate the relationship between VO_2max and soccer performance, Helgerud et al. (2001) developed players' VO_2max for 8 weeks and then analyzed the distance covered, the number of sprints, and the involvement with the ball in a game post-training compared to a game pre-training. Distance covered, number of sprints, and involvement with the ball increased along with VO2 max during the soccer match post training. In this study an experimental group performed extra conditioning to develop VO_2max while a control group performed traditional soccer training.

The development of VO_2max may seem important for the game of soccer but a game is clearly not played at VO_2max. Average game intensity is reported to be around anaerobic threshold (80 to 85% VO_2max) [7]. Soccer training still contains VO_2max training sessions because an increase in VO_2max increases anaerobic threshold. Anaerobic threshold may seem to be a better indicator of training adaptations due to physiological limitations in developing VO_2max among athletes with high VO_2max values.

Anaerobic power (fast energy release) corresponds to game winning situations. To demonstrate the importance of this energy system, Arnason et al. (2004) used the same method as Wisloff i.e. to determine the relationship between vertical jump and ranking performance [21]. Using a linear regression model, team jumping performances were compared to team success in the two highest leagues in Iceland. Positive correlation between jump height and team success was found using 17 teams (306 players).

Seasonal Variations of Physiological Capacities in Soccer Players

Throughout a soccer season, physiological adaptations occur. Without any training intervention, several longitudinal studies have been carried out to determine the variation of VO_2max and anaerobic threshold throughout a soccer season [17, 20, 31, 32]. Access to professional soccer players for research may be limited when training interventions need to be done. In 2001 in Spain, Casajus tested Zaragoza Soccer Club (Spanish First Division) [20]. Testing was done after pre-season (5 weeks of training) and beginning of the second round of the championship (after winter break). Within this time period, 19 soccer games were played and no VO_2max changes were reported. Anaerobic threshold increased from 77 to 79% of VO_2max. The starting VO_2max value often determines the improvement in VO_2max [8]. The age of the team averaged 26.3 ± 3.15 (mean ± standard deviation) years old. This may be an important factor because younger players (16 to 20 years old) may be more responsive to VO_2max development than at this maturational age.

With an English professional team, Edwards et al. reported that VO_2max is a less sensitive indicator of training status than either lactate threshold or ventilatory threshold [17]. After testing before pre-season and at the end of the season, no change in VO_2max was observed while lactate threshold increased. The time period in this study was a full

10 months and would not have detected any variations that occurred throughout the season.

Without testing VO_2max, McMillan et al. (2005) reported that lactate threshold increased in the first weeks of training and then plateaued even with accumulation of games and training [31]. No information about the number of games and/or the type of training was given.

Metaxas et al. (2006) reported changes in VO_2max with a group of young players (18 years old) [32]. Testing was carried out before pre-season, at the end of pre-season, in the middle and at the end of the season. VO_2max increased from the start to the end of pre-season. After pre-season, VO_2max plateaued. Once again no clear information was given about training and number of games played between each testing point. Physiological adaptations from specific training may not be identified with studies looking at changes throughout a soccer season.

Changes in Physiological Capacities: Training Intervention in Soccer Players

Specific training interventions have been done to develop physiological qualities related to soccer [7, 11, 26]. As an extension of soccer training, performing 4 sets of 4 minutes of running at 90-95% of HRmax twice a week for 8 weeks developed VO2max [7]. The control group did not carry out extra conditioning for these 8 weeks and they did not improve VO_2max. Based on the results of this study, performing traditional soccer training without extra-conditioning may not develop VO_2max. No information was given about the soccer trainings that were performed. To be able to divide training groups for research in soccer, studies are most often done with youth players (18 years old). The results of this study may not be applicable for older professional players.

Using a soccer specific dribbling track, McMillan et al. (2005) showed that VO_2max increased and that this was due to the use of 4 sets of 4 minutes on the dribbling track [11]. No control group was used during this study using professional young players (17 years old). The length of the study was 10 weeks with 6 weeks of pre-season and the first 4 weeks of the competitive season. Without using a control group, it may appear hard to determine that physiological adaptations are coming from the use of dribbling track. Training adaptations may have come from accumulation of training, games and dribbling track.

After analyzing studies using running drills and dribbling tracks, another study presented the use of small sided soccer games to develop soccer fitness. Comparing the effects of small sided games versus running drills on physiological adaptations, no significant difference between both methods were shown. VO_2max increased with both methods. The time period of this study was 4 weeks of pre-season and 8 weeks during the regular season. VO_2max increased from baseline to 4 weeks and then plateaued. Anaerobic threshold increased as well from baseline to 4 weeks and then further increased at the end of the 12 weeks period.

In these three studies among young players, VO_2max has been increased using 4 sets of 4 minutes at 90-95% of HRmax. No difference between the training methods (running drills, soccer specific dribbling track and small sided games) were shown. The intensity at which the exercises are carried out seems to be the main determinant to increase VO_2max. From a soccer standpoint, the use of small sided soccer games to develop fitness may seem to be the most beneficial. This exercise combines the technical and tactical aspects of the game. The soccer dribbling track does not have any tactical benefit while the running drills only develop aerobic performance but not soccer performance. There is also lack of information on the physiological effects of playing and accumulating 11-a-side soccer games after a pre-season training period.

CHAPTER III

METHODS AND MATERIALS

Experimental Approach to the Problem

Experimental design is presented in Table 1. A longitudinal study was used to assess maximal aerobic power, anaerobic threshold, anaerobic power and body composition changes throughout the off-season training in college men's soccer. A total of 14 soccer players began the study. The off-season consisted of three different training phases for a total of 12 weeks of training with a non-training week between weeks eight and nine. The first training phase was composed of soccer, conditioning, strength and speed training sessions each completed twice per week for four weeks. At the second phase, soccer practices were performed five times per week along with two weekly strength training sessions for four weeks. At the third phase, four soccer and two strength training sessions were weekly completed for four weeks. Five soccer games were played during the third training phase. Training time was limited to eight hours per week for the first phase and 20 hours per week for the second and third phases. Maximal aerobic power, anaerobic threshold, anaerobic power and body composition were assessed before the first phase (T1), after the second phase (T2) and at the end of the last phase (T3).

Table 1

Experimental Design

	First Phase of Training	Second Phase of Training		Third Phase of Training	
T1	4 Weeks: Emphasis on Strength and Conditioning ** Training Time Limited to 8 hours/week*	4 Weeks: Emphasis on Soccer-Specific Training ** Training Time Limited to 20 hours/week*	T2 1 Resting Week	4 Weeks: Emphasis on Soccer Games and Soccer-Specific Training ** Training Time Limited to 20 hours/week*	T3

VO_2max, Body Composition and Vertical Jump will be tested at T1, T2 and T3.

Subjects

In the year of this study, the subjects played college soccer for a team ranked in the top 25 of the NCAA 1st Division, won the Big East 2009 regular season title and participated in the NCAA 1st division tournament. Subjects were required to be members of the soccer team and be injury-free eight weeks prior to the beginning of the study. Goal keepers were excluded due to the different training stimulus received during training sessions and soccer matches. Fourteen male soccer players volunteered to participate in the study. After four dropouts due to injury and withdrawal, ten subject's responses were analyzed.

Procedures

All subjects signed consent forms approved by the University of Louisville Institutional Review committees. No formal testing familiarization was used because the subjects were familiar with vertical jump and maximal exertion exercise due to performance testing assessed by the University of Louisville strength and conditioning staff throughout the year. Subjects were asked to avoid sport drinks, caffeine and food three to four hours prior to testing. At T1, T2 and T3, vertical jump and body composition were assessed the day prior to VO_2max test. Vertical jump and body composition were assessed in the Marshall Center (Louisville Sports Performance, University of Louisville, Louisville, KY) while VO_2max test was done at the University of Louisville Exercise Physiology Laboratory. All the tests were administered by the same experimenters.

Maximal Aerobic Power

VO_2max was measured via a TrueOne 2400 Parvo Medics indirect calorimetry system (ParvoMedics, Sandy, UT) using an Astrand protocol on a motorized treadmill [33]. Five minutes running at 8 km/h with a mouthpiece, nose clip and heart rate transmitter was used as a warm up and a familiarization to the apparatus prior to the test. Selected speed was 12 km/h throughout the test for each subject. The first stage was run at 0% grade for 3 minutes. Following the first stage, 2 minute stages were performed until exhaustion. 2% grade increment was added at the end of each stage. Rating of perceived exertion using the 6-20 Borg scale [34] and heart rate (Polar Electro Oy, Kempele, Finland) were collected at the end of each stage. VO_2max was determined by averaging the two consecutive highest VO_2 measurements obtained over 15 seconds intervals [33]. VO_2max or VO_2peak were included into data analysis. VO_2max was expressed in two units ($ml.kg^{-1}.min^{-1}$ and in $ml.kg^{-0.75}.min^{-1}$), because the oxygen cost of running at a standard pace does not increase in direct proportion to body mass, a dimensional scaling has been utilized by Bergh et al. [35]. Using body mass raised to the power of 0.75 may be a better indicator of performance capacity when running. Several soccer studies used this correction of VO_2max to avoid overestimation of work capacity in light individuals and underestimation in heavy individuals [2, 30, 36, 37].

Anaerobic Threshold

Anaerobic threshold was visually identified using the simplified V-slope method [38] based on the V-slope method described by Beaver et al. [18]. Carbon dioxide output (VCO_2) was plotted against oxygen uptake (VO_2) on equal axes. The method of anaerobic threshold detection consisted of drawing a line parallel to the line drawn by the points of VCO_2 vs. VO_2 during incremental exercise. At anaerobic threshold, VCO_2 begins to increase more rapidly than VO_2 [38]. The point at which VCO_2 departs from the line is used as the anaerobic threshold because increase in VCO_2 is related to the buffering of lactic acid by bicarbonate ions [18]. VO_2 corresponding to this point was determined as the oxygen consumption at anaerobic threshold. Two independent reviewers were selected to detect anaerobic threshold without knowledge of prior results or the identity of any subject. Average value from the determinations of each reviewer was used for analysis.

Anaerobic Power

Vertical jump was measured using a Vertec device (Sports Imports, Columbus, OH). Maximal standing vertical reach was measured stretching the arms. Counter movement jump (CMJ) was performed from a continuous movement starting from a standing position, then squatting down to a knee angle of approximately 90° and finally, extending the knee. Three trials were given for each subject and the highest jump height was recorded. Maximal jump height was calculated by subtracting the jump height by the standing reach.

Body Composition

To measure the thickness of subcutaneous adipose tissue, a Harpenden skinfold caliper (Baty International, West Sussex, United Kingdom) was utilized. The Jackson-Pollock and the Siri equations were used to estimate body density from the sum of 7-site and percentage of body fat respectively [39, 40]. For the Jackson-Pollock equation, "male athletes from 18-61 years old" was the population subgroup selected. "White male from 18-59 years old" was the selected group for the Siri's formula. Body composition was assessed by the same experienced experimenter (10 years of experience using the 7-site skinfold method) at T1, T2 and T3. Body mass was measured to the nearest 0.1 kg using a HD-351 digital weight scale (Tanita Corporation, Tokyo, Japan).

Strength and Conditioning Program

Strength and power development were performed twice a week throughout all the training phases. The main exercises used are presented in Table 2. Two conditioning exercises were performed per week for a total of 8 exercises for the first phase of training. Time spent over 90% of heart rate maximal (HRmax) was controlled by heart rate transmitters (Polar Electro Oy, Kempele, Finland). In the second and third phases of training, small sided soccer games (4vs.4 to 6vs.6) twice a week were used to develop energy systems related to soccer performance. Field dimension and number of players were used as variables to dictate the intensity of the exercise. Heart rate data were not collected during these exercises. However, several authors showed that small-sided soccer games elicit high cardiovascular stimulus [41] leading to improvement in aerobic performance [26].

Table 2

Strength and Conditioning Program during the Three different Training Phases

First Phase of Training	
Day 1 - Strength and Power	*Power Snatch* *Front Squat* *Overhead Press* *Core Exercises*
Day 2 - Work Capacity (Circuit)	*Romanian Deadlift* *Box Jump Variations* *Medicine Ball Throw Variations* *Clean High Pull* *Push Press* *Pull-Up* *Push-Up*
Second Phase of Training	
Day 1 - Strength and Power	*Snatch* *Front Squat* *Dumbbell 1-Arm Row*
Day 2 - Strength	*Split Squat* *Reverse Back Extension* *Pull-Up* *Push-Up*
Third Phase of Training	
Day 1 - Power	*Dumbbell Muscle Snatch* *Inverted Row* *Core Exercises*
Day 2 - Power	*Clean High Pull* *Pull-Up* *Core Exercises*

The main exercises used during the study are presented in table 2.

Statistical Analyses

Results are reported as means and standard deviation (mean ± SD) calculated using Microsoft Excel (Microsoft, Redmond, WA, USA). Statistical analyses were completed with PASW statistics (Version 18, SPSS, Chicago, IL). Repeated measures ANOVA followed by a Post-Hoc test Least Significant Difference (LSD) were performed to determine differences between time for each dependent variables. Significance was set at $p<0.05$.

CHAPTER IV

RESULTS

Means and standard deviations for each testing are presented in Table 3 and 4. At the beginning of the study, subjects were 20.1 ± 1.2 yrs, 177.2 ± 5.1 cm and 75.2 ± 7.0 kg (means ± standard deviations).

Anaerobic Power

Following these three phases of training, vertical jump increased by 6.8% from T1 to T3 (61.8 ± 4.9 cm to 66.0 ± 7.5 cm respectively, $p=0.029$) (Table 3). No change was noticed at T2 compared to T1 and T3.

Anaerobic Threshold

Oxygen uptake at anaerobic threshold did change with training at $P<0.05$ (Table 3). Related to body weight, an increase of 5.8% was revealed from T1 to T2 (48.4 ± 4.6 $ml.kg^{-1}.min^{-1}$ to 51.2 ± 3.6 $ml.kg^{-1}.min^{-1}$ respectively, $p=0.005$). No change was noticed at T3 compared to T1 and T2. Using the dimensional scaling, change was observed with an increase of 5.1% from T1 to T2 (142.4 ± 12.7 $ml.kg^{-0.75}$.min-1 to 149.7 ± 10.2 $ml.kg^{-0.75}$.min-1 respectively, $p<0.05$). No change was observed at T3 when compared to T1 and T2.

Maximal Aerobic Power

No change was noticed in VO_2max in both units ($ml.kg^{-1}.min^{-1}$ and $ml.kg^{-0.75}.min^{-1}$) between the three testing points (Table 3). To ensure that maximal effort was given by the soccer players at each testing, HRmax and respiratory exchange ratio (RER) were collected. No change in HRmax and RER was noticed confirming that the same effort was performed at each test.

Body Composition

No significant change was reported in body weight, percentage of body fat, fat mass and fat free mass over the three testing points (Table 4).

High-Intensity Aerobic Training

During all high-intensity aerobic exercises carried over the first training phase, all subjects reached values over 90% HRmax. Average time spent over 90% HRmax per conditioning exercise was 11'23 ± 1'51 (min'sec). For the eight conditioning exercises, average total time spent over 90% HRmax was 91'10 ± 14'29 (min'sec).

To conclude, anaerobic power increased by 6.8% from T1 to T3. Oxygen uptake at anaerobic threshold increased by 5.8% from T1 to T2. No further change was noticed at T3. Maximal aerobic power and body composition did not change throughout the study.

Table 3

Means ± Standard Deviation for different Physiological Variables Tested

	T1	T2	T3	%Δ
Maximal Aerobic Power				
RER	1.14 ± 0.04	1.15 ± 0.03	1.14 ± 0.03	
HRmax (bpm)	195.4 ± 10.9	193.9 ± 6.8	195.2 ± 9.3	
VO_2max ($ml.kg^{-1}.min^{-1}$)	58.0 ± 4.5	58.7 ± 3.5	58.3 ± 4.3	
VO_2max ($ml.kg^{-0.75}.min^{-1}$)	170.2 ± 12.1	172.1 ± 9.2	170.7 ± 12.5	
Anaerobic threshold				
VO_2 ($ml.kg^{-1}.min^{-1}$)	48.4 ± 4.6	51.2 ± 3.6 †	50.2 ± 3.8	5.8% *(T2vsT1)*
VO_2 ($ml.kg^{-0.75}.min^{-1}$)	142.4 ± 12.7	149.7 ± 10.2 †	147.2 ± 10.6	5.1% *(T2vsT1)*
Anaerobic Power				
CMJ (cm)	61.8 ± 4.9	64.8 ± 7.6	66.0 ± 7.5 *	6.8% *(T3vsT1)*

T1, T2 and T3 correspond to before the start of the training period, after 8 weeks of training and at the end of the 12 weeks training period, respectively. Significant difference (†: P=0.005 between T1 and T2; *: P=0.029 between T1 and T3). %Δ is reported only for significant differences.

Table 4

Means ± standard deviations for anthropometry and body composition measurements

	T1	T2	T3
Anthropometry			
Age (yrs)	20.1 ± 1.2		
Height (cm)	177.2 ± 5.1		
Body Composition			
Body Weight (kg)	75.2 ± 7.0	73.5 ± 6.2	74.1 ± 7.0
Body Fat (%)	9.4 ± 3.6	8.1 ± 2.1	8.5 ± 2.1
Fat Mass (kg)	7.1 ± 2.9	6.0 ± 1.7	6.3 ± 1.7
Fat-Free Mass (kg)	68.1 ± 6.2	67.6 ± 5.6	67.8 ± 6.5

T1, T2 and T3 correspond to before the start of the training period, after 8 weeks of training and at the end of the 12 weeks training period, respectively.

CHAPTER V

DISCUSSION

The aim of this study was to determine if playing five soccer matches in four weeks after eight weeks of strength and high-intensity training further improves maximal aerobic power, anaerobic threshold and anaerobic power. The primary finding is that playing 5 soccer games in 4 weeks after 8 weeks of training further increased anaerobic power but did not further increase aerobic performance for soccer players. The first 8 weeks of strength and conditioning training along with soccer-specific training increased oxygen uptake at ventilatory threshold without any change in VO_2max. However, no further change in VO_2 at VT was noticed after playing 5 soccer games during an additional 4 weeks while anaerobic power increased.

Anaerobic Power

Soccer training, strength training and high-intensity aerobic training did not alter Counter Movement Jump (CMJ) in the first eight weeks. However, an increase in CMJ was found at the end of the third phase of training when strength training, soccer training and soccer matches were performed for 4 weeks. The release of energy from ATP-CP energy system is of importance in soccer matches during high intensity bouts. Playing soccer matches may improve this energy system along with the two other energy systems that determine soccer performance. The increase in anaerobic power may also have been induced by neuromuscular adaptations from strength training as no increase in fat free mass was revealed throughout the study. Neural adaptations describe multiple factors that may contribute to increase force. Selective activation of motor units, synchronization, selective activation of muscles, ballistic contractions, increased reflex potential and increased co-contraction of antagonists may have been a part of the neural adaptations [42]. Sending nerve impulses to recruit motor units, the central nervous system plays an important role into neural adaptations. Schmidtbleicher stated that trained athletes are able to increase the recruitment and the firing rate of motor units more rapidly when compared to untrained athletes [43]. These changes are possible explanations of the gain of strength showed by the increase in CMJ in the last training phase.

<u>Anaerobic Threshold</u>

The results are consistent with those of previous investigators that anaerobic threshold may be a better indicator of training-induced adaptation than VO_2max [17, 20, 31, 37]. Testing pre-season and then after a competitive season, Edwards et al. reported an increase in oxygen consumption at VT (50.73 ± 4.83 $ml.kg^{-1}.min^{-1}$ vs. $52.59 \pm 4.13 ml.kg^{-1}.min^{-1}$, $P<0.05$) without any change in VO_2max [17]. Using running velocity at lactate threshold and velocity at 4 $mmol.l^{-1}$ blood lactate concentration, McMillan et al. showed improvements from pre-season training (July) to the early weeks of the competitive season (October) [31]. McMillan et al. did not assess VO_2max. Contrary to our finding, Casajus reported changes in the running speed at anaerobic threshold without any change in VO_2 at anaerobic threshold [20]. A limitation of this study may be that testing was performed 5 months apart. With the accumulation of training and soccer matches within a 5 months period, fitness changes with variations of VO_2 at anaerobic threshold could have occurred. Edwards et al. also had a long period between the two testing points (8 months). However, they revealed changes in VO_2 at anaerobic threshold [17]. The main difference between these two studies is the fitness level at the first testing point. Edwards tested at the beginning of pre-season and then at the end of the season while Casajus had his two testing points in the middle of the season but separated by 5 months. Another important contradiction to our study is the finding of Helgerud et al. [7]. They reported no change in VO_2 at anaerobic threshold after 8 weeks of soccer training for the control group while an experimental group increased VO_2 at anaerobic threshold performing high intensity aerobic training twice a week in addition to regular soccer training. A limitation of this study may have been that the soccer training performed 4 times a week for 1.5 hour did not reach the intensity that is required to develop anaerobic threshold and VO2max. Also, the starting value of VO_2 at anaerobic threshold of the control group was 49.5 ± 3.3 $ml.kg^{-1}.min^{-1}$ while the experimental group was 47.8 ± 5.3 $ml.kg^{-1}.min^{-1}$. Mean and standard deviation differences between both groups may have affected the magnitude of improvement with a disadvantage for the control group that carried out only soccer training.

Maximal Aerobic Power

Our study did not detect any changes in VO_2max after the 12 training weeks. Numerous studies reported changes in VO_2max after high intensity aerobic training performed for 8 weeks or even longer with soccer players [7, 10, 11]. Following 8 weeks of aerobic high intensity interval training (4 x 4 minutes at 90-95% of HRmax with 3 minutes jog between) with elite junior soccer players, Helgerud et al. showed significant changes in VO_2max increasing from 58.1 ± 4.5 $ml.kg^{-1}.min^{-1}$ to 64.3 ± 3.9 $ml.kg^{-1}.min^{-1}$ (P<0.01) [7]. Performing 10 weeks of soccer training associated to high intensity aerobic interval training using a soccer specific ball dribbling track twice per week (4 x 4 min at 90-95% of HRmax), McMillan et al. showed a significant increase in VO_2max in professional youth soccer players (63.4 ± 5.6 $ml.kg^{-1}.min^{-1}$ to 69.8 ± 6.6 $ml.kg^{-1}.min^{-1}$) (P<0.001) [11]. Their 10 weeks training period were split into 6 weeks of pre-season and 4 weeks of competitive season. Absolute (58.0 ± 4.5 $ml.kg^{-1}.min^{-1}$ to 58.3 ± 4.3 $ml.kg^{-1}.min^{-1}$) and relative (170.2 ± 12.1 $ml.kg^{-0.75}.min^{-1}$ to 170.7 ± $ml.kg^{-0.75}.min^{-1}$) maximal aerobic power did not change pre to post training. Following the intermission, athletes present different fitness levels depending on their personal activities during the break. Pre-training level usually determines the amplitude of improvement in VO_2max [8]. VO_2max level at the beginning of our study (58.0 ± 4.5 $ml.kg^{-1}.min^{-1}$) was not higher than VO_2max reported at the beginning of two different studies that showed significant improvement in VO2max (58.1 ± 4.5 $ml.kg^{-1}.min\text{-}^{1}$ and even 63.4 ± 5.6 $ml.kg^{-1}.min^{-1}$) [7, 11]. However, these two studies were done among young soccer players with average age of 18.1 ± 0.8 yrs [7] and 16.9 ± 0.4 yrs [11] compared to 20.1 ± 1.2 yrs for our study. Maximal aerobic power training-induced adaptations may be greater among young athletes. Heredity also plays an important part in the variation of VO_2max, thus restricting or expending the potential for improvement [44]. Unchanged VO_2max may also be explained by the lower average time spent over 90% of HRmax during conditioning exercises used in our study when compared to the time spent over 90% HRmax doing 4x4 min at 90-95% HRmax [45]. In our first 8 weeks period, conditioning exercises were carried over 4 weeks while the next 4 weeks were composed by soccer-specific aerobic training (small-sided games). Soccer-specific aerobic training has been shown to be as effective as interval running in enhancing aerobic fitness in junior soccer players [26].

According to Bassett et al., maximal aerobic power and ventilatory threshold were expected to increase in the first 8 weeks while only ventilatory threshold was expected to further increase with training [27]. In our study, neither change in maximal aerobic power nor ventilatory threshold was further seen after the last training phase. After our first 8 weeks of training, the increase in VO_2 at ventilatory threshold may indicate that peripheral instead of central physiological adaptations seemed to occur. In fact, skeletal muscle metabolism (peripheral physiological adaptations) plays an important role in determining submaximal exercise performance while maximal aerobic power is mainly controlled by cardiac output (central physiological adaptations) [46, 47]. Trained individuals seem to be limited centrally with maximal stroke volume defined as a limiting factor in increasing VO_2max [48].

Body Composition

Despite strength, conditioning and soccer trainings, body composition did not statistically change throughout our study. Starting value of percentage body fat was low (9.4 ± 3.6 %BF) when compared to another study (10.8 ± 1.8 %BF) [49]. This starting value is usually an important factor of the variation that may be obtained. Carling et al. reported statistical changes throughout a soccer season when comparing the level at the start of pre-season to the level at mid-season. However, 6 months of training were performed between the start of the season and mid-season compared to 3 months of training in our study.

Limitations of the Study

The results of this study must be interpreted cautiously for a number of reasons. First, no control group was used in the current study due to the coaches' requests to avoid developing only half of the team. The low sample size (14 subjects) was due to the number of field players available during the spring season. The high dropout (4 subjects) was due to injuries and dropout from the soccer team. Another limitation is that at the second testing point, testing was performed at the end of the afternoon following a morning training session while the last testing point was performed 3 days of rest after the last soccer game. This was due to the college athletes' schedule. Testing at the end of the afternoon with a morning session may limit players to perform at their bests. In fact, VO_2peak instead of VO_2max may be reached due to muscle soreness and fatigue due to the morning session. After 3 resting days, more chance of reaching VO_2max may be possible.

Heart rate control during soccer training sessions would have been beneficial to know the time spent over 90% HRmax. Based on the findings of Impellizzeri et al. [26], we inferred that the use of soccer exercises would allow players to spend consequent time over 90% HRmax but during our study, no heart rate measurement of soccer training was taken. Also, heart rate measurements during the games played in the last phase of training would have been a good indicator of an increase in aerobic performance. In fact, a game is played at an intensity close to anaerobic threshold. An increase in game intensity would have been an indicator of an increase in anaerobic threshold. However, the intensity of a soccer game is also dictated by the score, the quality of the opponent, the possession of the ball and other factors. In the last phase of training, five soccer games along with strength training were performed. Results presented an increase in anaerobic power after the last phase of training. Because soccer games were played along with soccer training and strength training, anaerobic power enhancement may be a consequence of either soccer games, soccer training or strength training. Using this study design, no clear conclusion on the effects of soccer games may be possible. To determine the physiological effects of soccer matches, further research may use a control group (soccer training + strength training) and an experimental group (soccer training + strength training + 5 soccer matches). With this study design, the effects of soccer games on aerobic and anaerobic performance would have been determined. Future hypotheses may be that the addition of soccer matches to soccer training and strength training may increase aerobic and anaerobic performances when compared to a control group performing only soccer training and strength training.

Conclusion and Practical Applications

Along with strength training, playing soccer matches after eight weeks of strength, conditioning and soccer trainings may play a role in the development of anaerobic power. This study supports the idea that in soccer anaerobic threshold may be a better indicator of training-induced adaptations than VO_2max. Anaerobic threshold may be more predictable of performance in soccer because matches are played at an intensity close to anaerobic threshold.

In professional and college soccer, 11-a-side matches are planned early in pre-season to increase aerobic and anaerobic performance of soccer players. Before starting to accumulate soccer matches, coaches should focus on developing VO_2max and anaerobic threshold of their players by using high-intensity aerobic and anaerobic soccer-specific training. To be able to play matches at high intensity, time should be spent toward developing VO_2max and anaerobic threshold prior to start accumulating soccer matches. Without doing high-intensity aerobic training, the ability to play soccer games at a high intensity may be limited. Accumulation of 11-a-side games early in the season does not leave time to do high-intensity training and therefore limit the fitness' development of soccer players. The use of small-sided games has been shown to develop maximal aerobic power. Our study insisted on the benefits of using soccer drills to develop fitness. Without NCAA (National Collegiate Athletic Association) regulations (limited time for soccer-specific training in the first 4 weeks), training sessions would have been based only on soccer specific drills to develop VO_2max and anaerobic threshold. The use of small-sided soccer games and well-planned soccer drills may develop players' fitness and soccer performance by enhancing targeted energy system.

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APPENDICES

SUBJECT INFORMED CONSENT DOCUMENT

TITLE OF RESEARCH STUDY

Maximal Oxygen Consumption Changes during the Off-season in College Men's Soccer Players

IRB assigned number:

Investigator(s) name & address: Dean E. Jacks, PhD

Site(s) where study is to be conducted: University of Louisville, Exercise Physiology Laboratory, Crawford Gymnasium Room #2, Louisville, KY 40292

Phone number for subjects to call for questions: 502-852-8352

Introduction and Background Information

You are invited to take part in a research study because we are trying to study the changes in maximal oxygen consumption during the off-season in college men's soccer age 18-23. The study is being conducted under the direction of Dean E. Jacks, PhD. Approximately 25 local subjects will be invited to participate. Your participation in this study will last for approximately 24 weeks and will consist of 4 visits, lasting 45-60 minutes each.

Purpose

The purpose of this study is to evaluate the changes in maximal oxygen consumption, body composition and vertical jump during the off-season training in college men's soccer.

Procedures

1. You will be asked to write down the details of your medical history. This should take 15-30 minutes.
2. You will be asked to undergo a skinfold test to determine your body fat level. This should take 5-10 minutes.
3. You will be asked to perform three trials of counter movement jump to determine vertical jumping performance. This should take 10-15 minutes.
4. You will be asked to run on treadmill with increasing intensity of effort until the point of fatigue with a mouthpiece and nose clip on (Test of Maximal Oxygen Consumption). The actual test will take approximately 15 minutes while the 4 procedures listed above will take 45-60 minutes from start to finish.
5. You will be asked to repeat this procedure at 4 different occasions over the 24 weeks.
6. You will be asked to participate to all strength and conditioning training and soccer training elaborated by strength and conditioning coach and soccer coaches for the length of the study.

Potential Risks

There are no known physical risks linked with completing the medical history form.

The following table summarizes the risks associated with the experimental procedures associated with the study:

Test	Risk
Test of Maximal Oxygen Consumption	Possible physical risk: abnormal heart rhythm (in less than 1 out of 30,000 tests) death (in less than 1 out of 150,000 tests)
Skinfold	
Counter movement jump	Possible risk of muscle pull

Other possible risks to you may include:

To our knowledge there are no known psychological, social, economic, and/or legal risks associated with this research.

There is a risk of muscle soreness or injury such as muscle pull or strain.

In addition, you may suffer harms that we have not seen before.

Benefits

The possible benefits of this study include obtaining a measure of your fitness level (VO2peak), measurements of your body fat level (from the skinfold test) and vertical jump (from counter movement jump using Vertec). Additionally, you will likely see changes in performance throughout the off-season soccer and strength and conditioning trainings. Further, there will be benefits to soccer training if we see significant changes depending on specific training phases.

Alternatives

The alternative to participation is not to participate.

Research Related Injury

If you are injured by being in this research study, the principal investigator will arrange for you to get medical treatment. The study site has not set aside money to pay for treatment of any injury. You and your insurance will be billed for the treatment of these injuries. Before you agree to take part in this research study you should find out whether your insurance will cover an injury in this kind of research. You should talk to the principal investigator or staff about this. If you are injured, there is no money set aside for lost wages, discomfort, disability, etc. You do not give up your legal rights by signing this form. If you think you have a research related injury, please call Dean E. Jacks, PhD at 502-852-8352.

Compensation

You will not be compensated for your time, inconvenience, or expenses while you are in this study.

Costs

If you are injured by the research, there may be additional cost for participating in the research. Otherwise there will be no additional cost to you.

Confidentiality

Total privacy cannot be guaranteed. We will protect your privacy to the extent permitted by law. If the results from this study are published, your name will not be made public. The following may look at your research and medical records:

- The University of Louisville Institutional Review Board, Human Subjects Protection Program Office, Privacy Office and others involved in research administration at the University
- People who are responsible for research and HIPAA oversight at the institutions where the research is conducted
- Government agencies, such as: (List all that apply)
    - Office for Human Research Protections,
    - Office of Civil Rights

Security

Your data will be kept private by being stored in secured locked file cabinets and secured password protected computer files which only members of research team will have access.

Voluntary Participation

Taking part in this study is completely voluntary. You may choose not to take part at all. If you decide not to be in this study, you won't be penalized or lose any benefits for which you qualify. If you decide to be in this study, you may change your mind and stop taking part at any time. If you decide to stop taking part, you won't be penalized or lose any benefits for which you qualify.

When filling out questionnaires you can decline to answer any question. However, declining to answer certain questions may make you ineligible for the study.

You will be told about any new information learned during the study that could affect your decision to continue in the study.

Termination

Your principal investigator has the right to stop this study at any point. Your principal investigator may take you out of this study with or without your okay. Reasons why this may occur include: Non-compliance to the study protocol.

Participation in Other Research Studies

You may not take part in this study if you are currently in another research study. It is important to let your doctor know if you are in another research study.

Contact Persons

If you have any questions, concerns, or complaints about the research study, please contact Dean E. Jacks, PhD at 502-852-8352.

Research Subject's Rights

If you have any questions about your rights as a research subject, you may call the Human Subjects Protection Program Office at (502) 852-5188. You may discuss any questions about your rights as a research subject, in private, with a member of the Institutional Review Board (IRB). You may also call this number if you have other questions about the research, and you cannot reach the study doctor, or want to talk to someone else. The IRB is an independent committee made up of people from the University community, staff of the institutions, as well as people from the community not connected with these institutions. The IRB has reviewed this research study.

Concerns and Complaints

If you have concerns or complaints about the research or research staff and you do not wish to give your name, you may call the toll free number 1-877-852-1167. This is a 24 hour hot line answered by people who do not work at the University of Louisville.

Acknowledgment and Signatures

This informed consent document is not a contract. This document tells you what will happen during the study if you choose to take part. Your signature indicates that this study has been explained to you, that your questions have been answered, and that you agree to take part in the study. You are not giving up any legal rights by signing this informed consent document. You will be given a copy of this consent form to keep for your records.

Do you want your primary care physician notified that you are a subject in this study?
❒Yes ❒No

____

Printed Name of Signature of Subject/Legal Representative
Date Signed
Subject/Legal Representative

____

Printed Name of Person Signature of Person Explaining
Date Signed
Explaining Consent Form Consent Form (if other than the Investigator)

____

Printed Name of Investigator Signature of Investigator
Date Signed

LIST OF INVESTIGATORS PHONE NUMBERS

Dean E. Jacks, PhD 502-852-8352

DATASET

Subject #	Age (yrs)	Height (cm)	Body Weight (kg)		
			T1	T2	T3
1	20	173	71.8	71.8	73.2
2	18	182	71.8	73.2	74.1
3	22	181	80.5	80.5	81.8
4	21	176	74.5	72.3	73.2
5	21	169	64.1	61.8	60.9
6	20	182	76.8	74.5	75.5
7	20	183	87.3	83.2	86.4
8	19	180	70.0	69.5	69.1
9	19	175	70.9	69.5	69.5
10	21	171	84.1	79.1	77.3
MEAN	20.1	177.2	75.2	73.5	74.1
STDEV	1.2	5.1	7.0	6.2	7.0

Subject #	Body Fat (%)			Fat Mass (kg)			Fat-Free Mass (kg)		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	8.4	7.4	9.5	6.0	5.3	7.0	65.8	66.5	66.2
2	6.2	7.3	7.2	4.5	5.3	5.3	67.4	67.8	68.8
3	11.2	10.3	11.5	9.0	8.3	9.4	71.4	72.2	72.4
4	10.7	9.5	9.0	8.0	6.9	6.6	66.6	65.4	66.6
5	14.5	10.7	10.9	9.3	6.6	6.6	54.8	55.2	54.3
6	8.1	7.2	7.5	6.2	5.4	5.7	70.6	69.2	69.8
7	8.8	7.7	7.3	7.7	6.4	6.3	79.6	76.8	80.1
8	5.4	5.8	6.0	3.8	4.0	4.1	66.2	65.5	64.9
9	5.0	4.7	5.6	3.5	3.3	3.9	67.4	66.3	65.7
10	15.4	10.6	10.7	13.0	8.4	8.3	71.1	70.7	69.0
MEAN	9.4	8.1	8.5	7.1	6.0	6.3	68.1	67.6	67.8
STDEV	3.6	2.1	2.1	2.9	1.7	1.7	6.2	5.6	6.5

Subject #	VJ (cm)		
	T1	T2	T3
1	62.2	63.5	66.0
2	58.4	55.9	62.2
3	63.5	63.5	58.4
4	55.9	62.2	63.5
5	54.6	58.4	61.0
6	61.0	59.7	59.7
7	67.3	80.0	81.3
8	62.2	64.8	66.0
9	71.1	76.2	77.5
10	62.2	63.5	64.8
MEAN	61.8	64.8	66.0
STDEV	4.9	7.6	7.5

Subject #	RER			HRmax (bpm)		
	T1	T2	T3	T1	T2	T3
1	1.14	1.17	1.14	189		190
2	1.17	1.21	1.15	196	197	190
3	1.11	1.12	1.12	190	189	186
4	1.11	1.12	1.13	192	196	199
5	1.17	1.18	1.19	224	208	217
6	1.18	1.16	1.14	193	194	196
7	1.15	1.15	1.09	196	193	192
8	1.09	1.12	1.14	193	188	192
9	1.15	1.11	1.11	198	196	203
10	1.08	1.11	1.17	183	184	187
MEAN	1.14	1.15	1.14	195.4	193.9	195.2
STDEV	0.04	0.03	0.03	10.9	6.8	9.3

Subject #	VO2max (ml.kg-1.min-1)			VO2max (ml.kg-0.75.min-1)		
	T1	T2	T3	T1	T2	T3
1	65.8	62.3	65.4	190.7	182.0	191.6
2	58.1	57.8	52.2	169.8	169.7	153.2
3	60.2	60.5	59.9	180.3	181.7	179.0
4	56.8	60.1	54.2	167.0	175.5	158.4
5	54.4	58.0	56.3	153.0	162.8	157.0
6	60.4	62.4	60.4	179.1	183.5	177.6
7	51.9	53.1	55.0	158.5	162.4	167.2
8	60.5	60.8	62.5	174.8	176.1	180.7
9	60.3	59.1	61.5	174.3	170.9	177.7
10	51.2	52.5	55.3	154.8	156.8	164.1
MEAN	58.0	58.7	58.3	170.2	172.1	170.7
STDEV	4.5	3.5	4.3	12.1	9.2	12.5

Subject #	VO2VT (ml.kg-1.min-1)			VO2VT (ml.kg-0.75.min-1)		
	T1	T2	T3	T1	T2	T3
1	55.4	53.6	57.5	161.3	156.1	168.3
2	51.8	51.4	46.6	150.8	150.3	136.6
3	52.5	54.6	49.3	157.1	163.4	148.1
4	44.5	49.5	46.5	130.9	144.4	135.9
5	45.4	49.5	48.9	128.5	138.8	136.7
6	49.3	54.2	50.6	146.1	159.2	149.2
7	43.0	46.2	46.9	131.3	139.4	143.0
8	50.1	55.2	54.3	145.0	159.5	156.5
9	50.9	52.9	53.9	147.7	152.8	155.7
10	41.3	44.8	47.9	125.0	133.5	142.0
MEAN	48.4	51.2	50.2	142.4	149.7	147.2
STDEV	4.6	3.6	3.8	12.7	10.2	10.6

CURRICULUM VITAE

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Education

2009 – May 2011: Master of Science in Exercise Physiology, University of Louisville, KY, USA

2008: Related course work: English as a Second Language, University of Kentucky; Lexington, KY, USA

2007: Diploma with Honors: Strength and Conditioning Coach, University of Burgundy, CEP, Dijon, France

2007: Diploma: Brevet d'Etat Football (Soccer Coach diploma)

2007: Bachelor of Sport Training and Sport Management with Honors, University of Burgundy, Dijon, France (UFR STAPS)

Professional Experiences

2011 - Current: Strength and Conditioning Head Coach Chicago Fire Soccer Club (Major League Soccer)

2010: Strength and Conditioning Coach Internship Curriculum, Louisville Sports Performance, University of Louisville, KY, USA

2009 - 2010: Graduate Teaching Assistant in Exercise Physiology, Exercise Physiology Laboratory, University of Louisville, KY, USA

2009 - 2010: Assistant Strength and Conditioning Coach Men's, Women's Soccer and Field Hockey, NCAA 1st Division Louisville Sports Performance, University of Louisville, KY, USA

2009 - 2010: Energy System Development and Polar Team2 Specialist at Louisville Sports Performance, University of Louisville, KY, USA

2005 - 2007: Strength and Conditioning Coach Internship Curriculum, Centre d'Expertise de la Performance (CEP) Gilles Cometti, Dijon, Burgundy, France

2005 - 2007: Assistant Strength and Conditioning Coach Handball and Basketball, Centre d'Expertise de la Performance (CEP) Gilles Cometti, Dijon, Burgundy, France

Publications

Published

Robineau, J., Lacroix, M., Jouaux, T., Cometti, C., Babault, N. Impact du jeu-réduit sur les sollicitations énergétiques, cardiaques et musculaires du joueur de football. In: Science and Football, Recherches et Connaissances Actuelles, 2009 P.U.V (Presses Universitaires de Valenciennes).

Submitted

Jouaux, T., Dierking, J., Murray, T., Lambert, C., Swank, A. Heart Rate Monitoring: A Method of Assessing In-Season Fitness in Soccer. Strength and Conditioning Journal, 2010. Under Review
Robineau, J., Jouaux, T., Lacroix, M., Babault, N. Neuromuscular Fatigue Induced by a 90 minutes Soccer Game Modelling. Journal of Sports Sciences, 2010. Under Review

In Progress of Writing

Jouaux, T., Dierking, J., Murray, T., Lambert, C., Swank, A. Aerobic and Anaerobic Performance Changes following Three Different Soccer Training Phases. Journal of Strength and Conditioning Research. 2010. In Progress

Guest Lecturer

2010: Physiology of Training for HSS 486-501 Advanced Exercise Physiology at the University of Louisville, KY, USA

2010: Heart Rate Training for HSS 394 Introduction to Exercise Science at the University of Louisville, KY, USA

2010: Strength and Conditioning for Soccer Performance for Youth Soccer Camps Louisville Achievement Soccer Academy, Louisville, KY, USA

2010: In-Season Heart Rate Variations for Soccer at the University of Louisville for Men's and Women's Soccer Team and Coaching staff

2009: Assessing Athletic Performance for HSS396 Health/Fitness Instructor Lab at the University of Louisville, KY, USA

2009: Olympic Lifting Teaching Progression for HSS388 Principles of Athletic Conditioning at the University of Louisville, KY, USA