Metabolic Conditioning Among Soccer Players

Matthew R. Rhea,[1] Danielle M. Lavinge,[1] Paul Robbins,[2] Jonathan Esteve-Lanao,[3] and Tracy L. Hultgren[4]

[1]*A.T. Still University, Mesa;* [2]*Athletes' Performance, Tempe, Arizona;* [3]*European University of Madrid, Madrid, Spain; and* [4]*Advanced Fitness Training, Chicago, Illinois*

Abstract

Rhea, MR, Lavinge, DM, Robbins, P, Esteve-Lanao, J, and Hultgren, TL. Metabolic conditioning among soccer players. *J Strength Cond Res* 23(3): 800–806, 2009—To reduce the risk of overuse injuries, yet obtain optimal fitness development among soccer players, research comparing different training strategies is required. This study compared conventional group conditioning (GRP) to individualized training (IT) during the preseason among female college soccer players. Both groups participated in soccer practices; however, players were randomly assigned to supplemental conditioning differentiated by the use of player-specific heart rate training in the IT group. Changes in maximal oxygen consumption, anaerobic threshold, and rate of recovery were analyzed before and after 12 weeks of conditioning. Data analysis identified significantly ($p < 0.05$) greater improvements in the IT group in all 3 variables, despite considerably less training volume. Based on these data, it is apparent that catering training to the fitness level of each individual player can have a positive impact on training adaptations.

Key Words oxygen consumption, oxygen uptake, anaerobic threshold

Introduction

Soccer is a physically demanding sport characterized by a range of demands on the cardiorespiratory and neuromuscular systems. Competitive situations are different for each position, depending on the system of play and size of the field, but consistently involve repeated sprints, lengthy runs, and short periods of recovery. Such requirements place great demands on the body's ability to produce energy, maintain appropriate intra-muscular pH and temperature levels, and remove by-products of energy production. Maximal oxygen consumption ($\dot{V}O_{2max}$), anaerobic threshold (AT), and rate of recovery are no doubt potential differentiating factors among players at all levels.

In an attempt to develop optimal conditioning among soccer players, coaches and teams have used a variety of training methods. Traditional conditioning for soccer has involved the use of long continuous aerobic exercise, interval training, and soccer-specific drills. Because of the demands of both competition and training, overuse injuries among soccer players are common (11). It can be expected that the greater the total training time or volume, the greater the risk of injuries, such as stress fracture, shin splints, and tendonitis. Limiting the cumulative stress of year-round conditioning and competition is a requirement for maintaining the health of soccer players. Efforts to establish conditioning programs that limit the amount of training time and volume, whereas still eliciting the desired and optimal training adaptations, are important and essential.

One approach that could limit the overall stress of both conditioning and competition would be to combine fitness training with soccer-specific practice. By combining the two, it would be expected that total stress on the body would be lessened because of the avoidance of additional endurance training volume. If such a reduction in training stress was also accompanied by maximal fitness development, the optimal scenario would be achieved. Conversely, if additional exercise was required, teams using only soccer-specific drills would fail to achieve maximal physical preparation for competition.

Previous research (1,3,6,7) has examined the use of soccer-specific drills as the sole means of exercise among soccer players. These studies have shown that monitoring heart rate (HR) during training sessions and requiring soccer players to reach 80–95% of maximum HR for 3–4 minutes with subsequent rest breaks is effective at improving $\dot{V}O_{2max}$. However, none of these studies used a control or comparison group, and therefore, it is uncertain whether the effectiveness of the conditioning is greater than simply playing and practicing the sport. Other research (4) has shown improvements in $\dot{V}O_2$ similar to the previously cited studies with the only exercise being soccer competition and practice. Whereas improvements in fitness were noted in this previous research, it is uncertain if such training optimized fitness development for each individual player. Additionally, none of the previously cited studies used a true individualized training program based on the current fitness level of each player.

Another potential means for achieving optimal fitness adaptations while limiting the amount of training required is

Address correspondence to Matthew R. Rhea, Mrhea@atsu.edu.

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to develop individualized training programs that would optimally overload the physiological system of each player in the most efficient amount of time. Based on the training principle of individuality (10), it is proposed that each individual athlete will respond optimally to a program designed for their specific physiological capabilities and needs. Group training, where a conditioning session is designed for the team as a whole, may only be effective for a small portion of the athletes (i.e., those whose current fitness capabilities are matched and optimally overloaded by the workout). For those players who are not optimally overloaded by the stress, it is likely that their adaptations will be less than desired.

In the field, long continuous and interval-type training is often prescribed for the entire team with little consideration for the individual needs of each athlete. When steps are taken to individualize training, HR values based on age-predicted maximal HR are used. Unfortunately, neither situation truly establishes a training condition based on the individual needs, nor fitness status, of each player. Exercise testing must be conducted to precisely determine a player's specific level of fitness. In the case of soccer, $\dot{V}O_{2max}$, AT, and HR recovery (HRrec) are 3 variables that can vary greatly between athletes competing at similar levels of play. During testing, aside from documenting current fitness status in these three areas, the identification of the individual's HR at AT becomes an invaluable piece of information for individualized exercise prescription. Once it has been determined at what intensity the athlete crosses the AT, and documented by a specific HR value, an individualized training program can be created.

Little evidence exists, however, to make a determination regarding the effectiveness of individualized training for soccer players. Research is required to examine the benefits of individualized exercise prescription as compared to soccer-specific group training. Whereas individualized prescription may be more expensive and require more development time on the part of the fitness professional and coach, the cost-to-benefit ratio would be favorable if such an approach were significantly more effective in developing fitness capabilities across an entire soccer team. The purpose of this experimental study was to compare changes in metabolic performance measures among university soccer players given individualized HR training programs as compared with general team conditioning. The methods and procedures used in this research were reviewed and approved by an institutional review board for research with human subjects.

Methods

Experimental Approach to the Problem:

To compare changes between individualized and group metabolic conditioning, college soccer players were recruited to participate in this training study. To our knowledge, this is the first study to examine the effect of individualized metabolic training on college athletes. This investigation tracked aerobic performance variables during the preseason among female college soccer players with the only difference between groups being the form of metabolic training performed. One group performed conventional group conditioning, whereas the other participated in individualized training.

Subjects

Twenty female soccer players (age, 20.4 ± 1.8 years) competing at the university level were recruited to participate in this 12-week study, which occurred during the preseason (3 months before the first game). Potential participants were questioned regarding injuries or conditions that would impair their participation in vigorous physical conditioning and fitness testing. Participants reported consistent physical conditioning (aerobic exercise and resistance training) for at least 1 year before beginning this study. Participants were randomly assigned to 1 of 2 training groups: Group Conditioning (GRP) or Individualized Training (IT). All apparently healthy volunteers provided informed consent before beginning the study. Each participant agreed to participate in all training sessions, with exclusion set at <95% participation

Table 1. Metabolic training interventions.

Group	Weeks 1–4	Weeks 5–8	Weeks 9–12
Group training			
Soccer drills	2 d·wk^{-1}	2 d·wk^{-1}	4 d·wk^{-1}
Long run*	3 d·wk^{-1}(30 min)	3 d·wk^{-1}(45 min)	3 d·wk^{-1}(60 min)
Intervals†	2 d·wk^{-1}(8–12 reps)	2 d·wk^{-1}(13–16 reps)	2 d·wk^{-1}(17–20 reps)
Individualized training			
Soccer drills	2 d·wk^{-1}	2 d·wk^{-1}	4 d·wk^{-1}
Intervals‡	4 d·wk^{-1}	5 d·wk^{-1}	5 d·wk^{-1}

*Self-paced: individual athlete determined running pace.
†Intervals involved sprinting between 50 and 200 m with rest intervals between 20 and 60 seconds.
‡Intervals determined by heart rate (Figure 1).

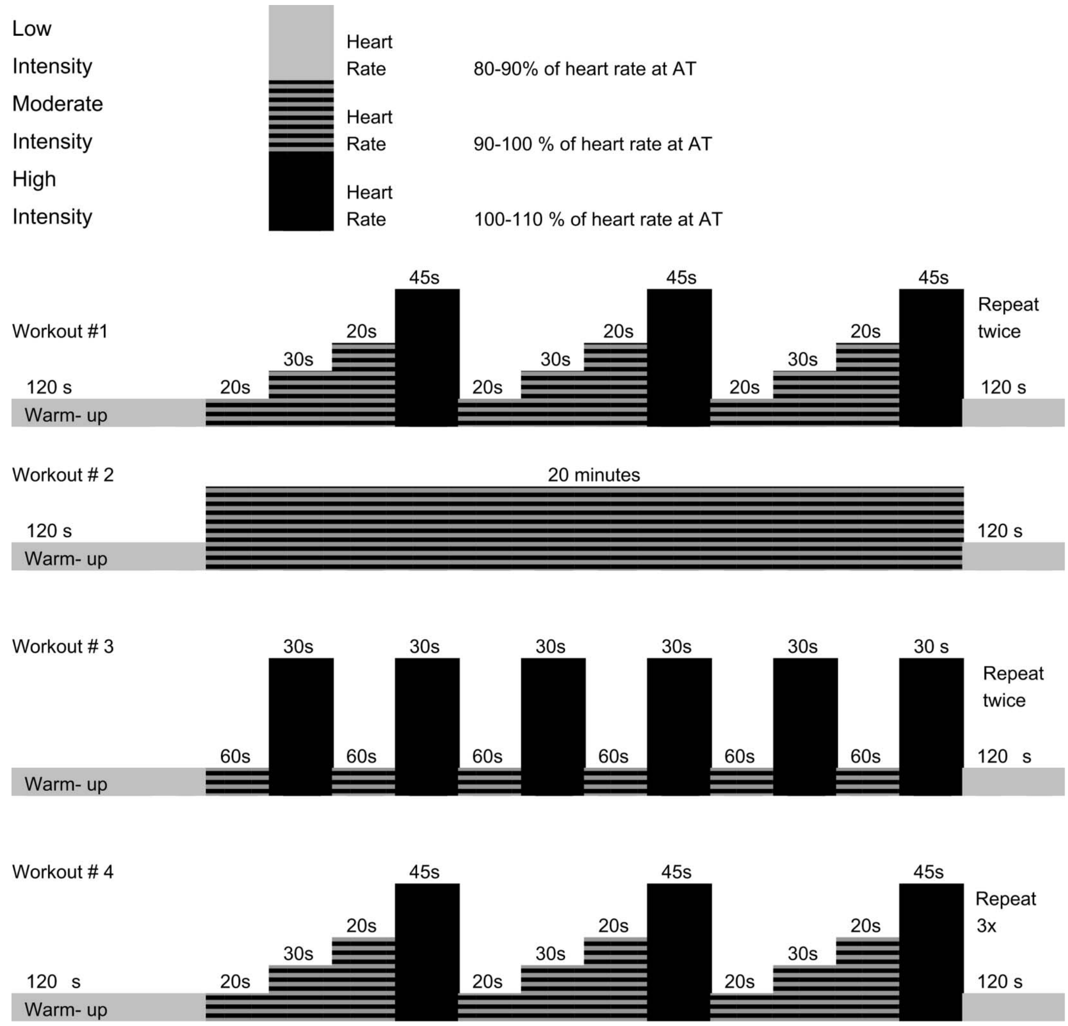

Figure 1. Sample individualized interval workout.

rate, and to refrain from any additional physical conditioning not prescribed in the training program.

Measurements

A graded exercise treadmill test was conducted with each player before and after the training program. The aerobic performance variables $\dot{V}O_{2max}$, AT, and HRrec were determined through the use of a portable metabolic machine (iMETT®, Micromed, Brazil) and Polar S625X HR monitor (Polar Electro Inc., Lake Placid, N.Y.), which was worn by the participant during the exercise test. The accuracy of the iMETT® device has been previously established (2,8). Testing

Table 2. Maximum oxygen consumption ($\dot{V}O_{2max}$) and anaerobic threshold (AT) results (mean ± *SD*).

Group	Pre-$\dot{V}O_{2max}$	Post-$\dot{V}O_{2max}$	Pre-AT	Post-AT
Group ($n = 10$)	50.07 ± 3.53	51.98 ± 3.17*	67.87 ± 8.27	72.30 ± 6.80*
Individualized ($n = 10$)	48.83 ± 4.23	56.26 ± 3.15*	67.92 ± 8.24	81.71 ± 6.12*

*Groups differ significantly ($p < 0.05$).

Table 3. Heart rate (HR) recovery results (mean ± *SD*).

Group	Pre-HRrec	Post-HRrec
Group	40.50 ± 9.90	48.60 ± 4.45*
Individualized	35.60 ± 9.56	56.40 ± 7.31*

HRrec = 1-minute heart rate recovery in $b \cdot min^{-1}$.
*Groups differ significantly ($p < 0.05$).

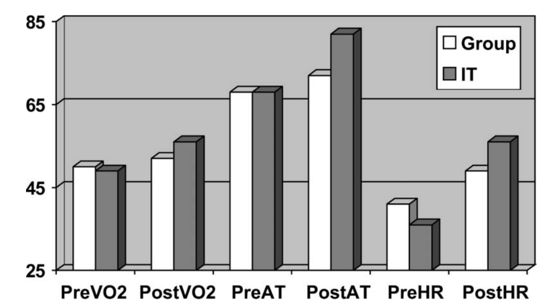

Figure 2. Changes in aerobic fitness variables.

was conducted at the same time of day for pre- and post-testing and followed similar sleep and eating habits by the participants. In addition, participants had avoided involvement in aerobic exercise for 3 days before the test.

After a warm-up consisting of stretching and light aerobic exercise, a HR monitor was placed on the participant's torso for observation throughout the test, and testing procedures were explained to the participant. The test began with the treadmill speed set at $6.4\ km \cdot h^{-1}$ at 0% incline. At 1 minute, and at every minute thereafter, speed or incline was alternately increased by $2\ km \cdot h^{-1}$ or 2% grade, respectively. Participants were encouraged to continue the test for as long as possible and the test continued until the participant requested to stop. At pretest, this protocol was repeated with each participant 2 days apart for the purposes of establishing reliability. Repeated-measures analysis of variance ($p > 0.05$) and intraclass correlation coefficient >0.90 established the reliability of this test and the baseline measures.

Heart rate of recovery was determined by the drop in HR after 1 minute after termination of the maximal test. The investigator recorded the player's HR immediately after the test was terminated and once again exactly 1 minute after termination. The difference between the 2 measures was calculated to represent the rate of recovery (HRrec) for the individual, with larger differences representing superior recovery.

Procedures

All training sessions during this 12-week conditioning program were observed by a trained exercise professional. The principle difference between the 2 training protocols was the use of individualized training prescription in the IT group (Table 1). Both groups participated in team practices composed of soccer-specific drills 2–4 days per week and ranged from 45 to 90 minutes in duration. Drills requiring vigorous activity were used and included 2 vs. 2, 4 vs. 4, and 6 vs. 6 games, dribbling drills, and match-like team work. In addition, resistance and plyometric training sessions were held twice per week. These sessions were standardized between the 2 groups such that the only difference between conditioning was the metabolic training performed.

In addition to soccer-specific practice, the GRP group participated in team conditioning with training variables set by the exercise professional for the group as a whole. The IT group was given workouts (similar workouts for each player) based on the individual HR performance identified during fitness testing. Each player's HR at AT was the basis for determining the various training zones which were used during the prescribed interval training program.

GRP training consisted of a mixture of long continuous running and sprint intervals. The bulk of the training sessions (3 of the 5 training sessions per week) were long continuous running sessions at a pace set by each individual player. In weeks 1–4, the length of these training sessions was 30 minutes. In weeks 5–8 and 9–12, training sessions were extended to 45 and 60 minutes, respectively. Players were told to run as far as possible in the prescribed time. GRP interval training sessions (2 sessions per week) involved 50–200 meter runs with 20–60 seconds of rest in between. Distance for each run was increased progressively every 4 weeks (50, 75, and 100 m) with progressively less rest provided (60, 40, and 20 seconds). Participants were asked to run at full speed for each sprint. The number of repetitions in each interval workout was increased by 1 repetition each week, starting with 8 repetitions, throughout the 12-week program.

IT training consisted of interval workouts (Figure 1), which were designed to mimic soccer-specific conditions while also taking into consideration the training intensity appropriate for each player. A sequence of intervals (work followed by recovery) was completed within each training session. Intervals ranged from 5 to 120 seconds with 20–120 seconds of rest. Intensity for intervals and recovery were calculated based on the player's HR at AT. Three zones were created: low intensity (85 –95 % of HR at AT); moderate intensity (100 –110 % of HR at AT); and high intensity (111 -Peak% of HR at AT). Workouts were alternated from low to moderate to high intensity (based on the predominant zone used) from day to day. Players wore a HR monitor during each training session and were given a workout map for each session. Training was performed on a FreeMotion® Incline Trainer® treadmill (Model # FMTK7256P) with each session monitored by the principle investigator. Players were instructed to

Table 4. Correlation analysis of independent variables

Fitness variable		$\dot{V}O_2$ Pre	$\dot{V}O_2$ Post	AT Pre	AT Post	HRrec Pre	HRrec Post
$\dot{V}O_2$ Pre	Pearson correlation	1	0.447*	0.261	0.256	−0.214	−0.057
	sig. (2-tailed)		0.048	0.266	0.277	0.365	0.810
	N	20	20	20	20	20	20
$\dot{V}O_2$ Post	Pearson orrelation	0.447*	1	0.429	0.703†	−0.276	0.352
	sig. (2-tailed)	0.048		0.059	0.001	0.239	0.128
	N	20	20	20	20	20	20
AT Pre	Pearson correlation	0.261	0.429	1	0.554*	−0.210	−0.143
	sig. (2-tailed)	0.266	0.059		0.011	0.374	0.547
	N	20	20	20	20	20	20
AT Post	Pearson correlation	0.256	0.703†	0.554*	1	−0.344	0.091
	sig. (2-tailed)	0.277	0.001	0.011		0.138	0.704
	N	20	20	20	20	20	20
HRrec Pre	Pearson correlation	−0.214	−0.276	−0.210	−0.344	1	0.058
	sig. (2-tailed)	0.365	0.239	0.374	0.138		0.809
	N	20	20	20	20	20	20
HRrec Post	Pearson correlation	−0.057	0.352	−0.143	0.091	0.058	1
	sig. (2-tailed)	0.810	0.128	0.547	0.704	0.809	
	N	20	20	20	20	20	20

AT = anaerobic threshold; HRrec = 1-minute heart rate recovery in b·min^{-1}.
*Correlation is significant at the 0.05 level (2-tailed).
†Correlation is significant at the 0.01 level (2-tailed).

adjust running speed and incline, as shown on their workout map, to bring their HR into the prescribed zone and then maintain that HR level for the specified period of time.

Statistical Analyses

Descriptive data (mean ± *SD*) for the various tests were computed and analyzed with the statistical software SPSS version 13 (SPSS Inc., Chicago, Ill.). Level of statistical significance was set at $p \leq 0.05$ for all analyses. To examine for normal distribution, Kolmogorov-Smirnov Tests were conducted on each independent variable. Data were found to be normally distributed suggesting the appropriateness of parametric statistics. However, because of the small number of participants in each group ($n = 10$), both parametric and nonparametric analyses were conducted. Analysis of variance with repeated measures was used to examine for changes in each variable across time and for interactions between groups. Mann-Whitney comparisons were then conducted to examine potential differences between groups at both pre- and post-tests. Pearson correlation analysis was conducted to examine for commonality between the 3 independent variables.

Results

No differences ($p > 0.05$) were observed between groups in any of the 3 variables at baseline testing. However, at post-test, the IT group performed significantly better on all 3 measures (Tables 2 and 3). The IT group improved $\dot{V}O_{2max}$ an average of 7.43 ml·kg^{-1}·min^{-1}, AT improved from 67.92% of $\dot{V}O_{2max}$ to 81.71%, and improved 1 minute rate of recovery from 35 to 56 b·min^{-1}. Each was found to be significantly greater than the improvement in the GRP group ($\dot{V}O_{2max}$: +1.91 ml·kg^{-1}·min^{-1}; AT: +4.43% of $\dot{V}O_{2max}$; Recovery: +8.1 b·min^{-1}). Both parametric and nonparametric analyses confirmed the differences between groups.

Discussion

The data in this study demonstrates a significantly greater benefit for IT (individualized training) compared with GRP (group conditioning). GRP did very little to enhance cardiovascular performance in the 3 areas examined. However, improvements of 13.2, 16.8, and 36.9% were observed in the IT group for $\dot{V}O_{2max}$, AT, and 1-minute HRrec, respectively (Figure 2). Eliciting such dramatic adaptations in cardiovascular performance among trained athletes immediately before a soccer season can be expected to have a significant impact on soccer performance. Additionally, these improvements were elicited in much less training time compared with the group training. Therefore, individualized training can also be expected to decrease the risk of lower-extremity overuse injuries among soccer players.

The underlying mechanisms explaining the added benefit of individualized training cannot be identified by the current study. However, it is apparent that the aforementioned principle of individuality stands correct. It is speculated that individualized training overloads the cardiovascular system more effectively and efficiently than group training. The average length of an individualized interval workout was only 18 minutes, with the longest workout lasting only 28 minutes. Identification of HR level at AT for each individual and designing training, whereby the different portions of the cardio-respiratory processes would be taxed with greater efficiency, resulted in significantly greater training effectiveness in much less time.

Whereas this study did not use a soccer-specific practice group (a group not performing any additional conditioning outside of practice), it can be suggested that soccer-specific practice alone does not elicit maximal aerobic adaptations. If no additional benefit existed to training outside of practice time, individuals in both groups would have demonstrated the same level of fitness change. However, as evidenced by the differences between the 2 test groups in the post-test results, significantly greater fitness adaptation was seen in the individualized training group. Therefore, it is apparent that soccer-specific drills alone, such as those as used in this study, will not elicit maximal fitness improvements.

It was previously determined (9) that only 2% of playing time during soccer competition is spent in possession of the ball. With this in mind, it seems illogical to expect that all conditioning come from soccer-specific practice, particularly if such practice fails to elicit maximal fitness development. Because of the fact that a player spends 98% of a soccer match positioning themselves to receive the ball or defend an attack (9), developing maximal fitness by participating in off-the-field conditioning that would develop physiological fitness in the most effective and efficient manner.

A final note of interest is the fact that, in general, correlation analyses identified each of the aerobic fitness measures in this study ($\dot{V}O_{2max}$, AT, and HRrec) as separate fitness components (Table 4). Of the separate fitness variables, only AT and $\dot{V}O_{2max}$ at post-test were found to be significantly correlated; however, only a moderate relationship ($r = 0.70$) was identified. The independence of each variable is of note because these measures are often thought to simply reflect the same fitness component (aerobic fitness). It is clear, however, that such measures are distinct and should therefore be addressed separately in training. Further research is required to determine normative data for such variables among soccer players of different levels of competition and to test methods for targeting each individual aerobic fitness component.

This research has demonstrated that the effectiveness of physical conditioning among soccer players can be enhanced by the conducting of testing to identify key fitness markers and the development of individualized training programs designed to enhance maximal $\dot{V}O_{2max}$, AT, and HRrec. In addition, the increases shown post-test were achieved by the IT group in approximately half the training time and with approximately half as much training volume as that of the GRP group, thus diminishing the risk of overuse injuries. Kraemer et al. (5) suggested that soccer players entering the season in a physiologically catabolic state, because of high-intensity preseason and in-season training, experience reductions in performance throughout the season. Limiting the total training time off-the-field is an important variable to reduce risk of overuse injuries and ensure season-long success. The added time and resources to develop such individualized programs to achieve such benefits seem justifiable.

This study suggests that the principle of individuality in training applies to metabolic training when maximal benefits are sought. Although our current study is limited to metabolic adaptations, this principle most likely applies to other areas of conditioning including resistance training. Whereas challenging to implement, particularly with large groups of athletes and limited coaching staff, individualized training will result in greater individual adaptations transferring to enhanced team performance.

Practical Applications

With the assistance of an exercise science specialist, individualized training programs are the most efficient and optimal way to meet the specific metabolic demands of soccer. Although individualized training programs may initially be more costly and time consuming to design, it is logical to assume, based upon this study's findings, that the advantages would outweigh any disadvantages or added costs. The ability to quickly, effectively and safely bring players to top metabolic conditioning, thus helping to ensure a strong start to the season and performance maintenance throughout the season, could have a profound impact on overall success.

In addition, the ability to quickly return an injured player match fitness could have similarly positive ramifications. It was previously shown in an injury audit undertaken by The Football Association (England) (12) that during two preseasons, there were 1,025 injuries, which resulted in an average of 22.3 days absent from play per injury. Based on current elite level salaries, such an extent of time missed after an injury results in millions of dollars lost with each occurrence. Enhancing return to optimal fitness is both a competitive and financial benefit to the organization.

The physiological improvements seen in individualized training programs are incomparable to the improvements seen in traditional training programs. Not only will an individualized training program significantly improve a player's overall fitness and reduce the incidence of overuse injury, it may also help players to be more compliant with the training regimen because of a decrease in training duration. Additionally, because an individualized program is based solely on a player's personal physiological needs and goals (i.e., developing or increasing maximal $\dot{V}O_{2max}$, AT, and HRrec), it is possible that this concept of replacing the traditional training program with an individualized training program may take soccer performance to a whole new level.

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