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VO2 Maximum of College Athletes

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Abstract:

The purpose of this study was to evaluate and compare the VO2 max values of college soccer players at the University of New Mexico to data available from other collegiate teams. These values are beneficial for athletes, trainers, and coaches alike. Performance in athletics has improved significantly over the past 20 years as demonstrated by faster times and increased fitness levels. This is due to multiple factors including changes in nutrition, coaching, and equipment. Methods used in this study include a review of the literature specific for collegiate soccer athletes that were published after the year 2000. In addition, data from athletes from men's and women's soccer teams at the University of New Mexico are included in our results. VO2 max values were obtained using a maximal exercise test performed on a treadmill. The compilation of a table from the gathered data on VO2max values of collegiate soccer players specific for gender and level of competition will be of significant value for training personnel and athletes involved in soccer and collegiate athletics. We have provided the first normative VO2 max values compiled from an extensive literature search as well as providing data we obtained from athletes at the University of New Mexico.

Introduction:

The VO2max test provides important information on the capacity of the long-term human energy system. This measurement has significant physiologic meaning in that attaining a high VO2max requires a high level of respiratory, cardiovascular, and neuromuscular functions. Therefore, VO2 max is an important measurement of fitness for athletes and coaches. It has been established that VO2 max is correlated with performance, especially in endurance sports. Foster et al. (1978) state that VO2 max is more highly correlated with performance than is muscle fiber composition or skeletal muscle enzyme activity. Other researchers who have studied cyclists and runners have

concluded that VO₂ max, often in combination with other physiologic markers, is a good indicator of performance^{1,2} There are numerous published charts of normative values for maximal oxygen uptake (VO₂max) that categorize aerobic fitness by percentiles based on age and gender. The most commonly used is a table of percentile values with specific reference to age and sex published by the American College of Sports Medicine.³ However, most of these charts are based on the general population of the United States and therefore are not relevant for use in collegiate athletes. Additionally, it is difficult to find a current normative value table for those under age 20. A literature review found some tables giving normative values for athletes in various sports, but there are several problems with these. The tables appear to be good for educational purposes to illustrate comparisons between athletes from various sports and with sedentary people and those with disease, but are not specific to athletes who are currently a member of a team and competing. For instance, tables published in Exercise Physiology textbooks currently used in university-level classes often use data that mixes professional, elite, collegiate, and Olympic athletes (Robergs p.113), or data compiled from studies that are up to 40 years old (McCardle p. 119).^{4,5} Thus, there is a need for a new table that compares VO₂ max among collegiate athletes, particularly for those in endurance-type sports.

It is well established that VO₂ max changes with changes in training.⁶⁻⁹ One premise for collecting this data is that training for specific events such as soccer has improved since the norm tables for VO₂ max were published for this population. Studies that confirm that changes in training lead to increased VO₂max in essentially all populations include subjects as varied as female runners and preadolescent boys.^{10,11} The progress in human performance in sporting events has accelerated in the past 20-30 years, especially in women. Joyner (1993) shows the change in the average running velocity for both men and women is still increasing in a linear manner.¹² NCAA records show that there have been big improvements in athletic ability at the collegiate level, with marked improvements in running speed. For instance, in 1960, the record for the 400m dash was 45.7 seconds while in 2002, it was 44.53 seconds, more than a second faster. Similar trends can be seen for other sporting events.¹³ There have also been significant nutritional advancements leading to performance improvements for athletes. The introduction of supplements have at least a small part in increasing performance in sports.

These substances, especially creatine, which has the most conclusive data regarding positive effects, have led collegiate athletes to include supplements to their diet that claim to increase muscle size, speed or muscle strength.^{14, 15} These increases in sporting performance have been attributed to a combination of the use of nutritional supplements, better coaching, more effective training regimens, and more competitive opportunities, especially for women.¹² Since these documented changes have occurred at the college level, there is a clear need for the development of an up-to-date VO2 max table for collegiate athletes who participate in endurance-type sports.

Literature Review

The literature reviewed includes studies published from the year 2000 to the present that tested and reported measured (not estimated) VO2 max of collegiate soccer athletes aged 18-29. These data were compiled with the VO2max data that we collected from male and female soccer players from the University of New Mexico to contribute to the final soccer-specific table of updated normative values.

In our review of literature we found a lack of studies specifically designed to establish norms for collegiate soccer players. However, there are a number of studies where the VO2 max of college-age soccer players was measured as a part of the data collection in studies with other purposes. Accordingly, searching for studies that included measured VO2 max information included a PubMed search for terms “VO2 max”, “oxygen consumption”, “exercise testing”. Each of these search topics were further modified with “AND soccer” published since 2000. These search topics yielded a number of articles which were evaluated for inclusion of the following data: VO2 max in mL/kg or L/min (if weight was included), method of testing, age range, number of participants, and level of competition. Those studies that were included were those that used a treadmill exercise protocol to establish VO2, age range of 18 to 26 (29?), and included athletes either at the collegiate level or the equivalent (see discussion below). Table 1 outlines the studies found that met the criteria for males and Table 2 includes those for females.

We found there was a paucity of data specifically evaluating female college-aged soccer players. After extensive searching, we yielded just 3 studies. There were a larger

number of studies evaluating male soccer players of college age; however all of the studies found were based in Europe and evaluated players who were part of developmental professional leagues rather than college athletes. We did not find any studies that reported measured VO₂ max of male college soccer players in the United States. The decision to include this data as equivalent to college players in the United States was based on the performance of US collegiate teams against European reserve and first division teams. Many college teams traditionally travel to Europe for preseason training and play various teams in Europe. These games are consistently competitive and results tend to be close and varied between US and European teams (i.e. Maryland vs. English and Scottish reserve teams). Based on this knowledge, the studies including college age athletes from Europe who were not professional were included (4 studies). There were also 4 studies that did not specify other than “competitive players” which were included since they met the rest of the search criteria.

Of the studies publishing VO₂ max for female soccer players, 2 of them were from colleges in the United States and one of them did not specify.¹⁶⁻¹⁸

Based on data compiled from this review, the range of average VO₂ max values for males was found to be between 54.5 and 61.9 ml/kg*min (see table 1 for details concerning each study). In comparison, the range of average values for females was - 42.2- 61.8 ml/kg*min (see table 2).

Table 1- Studies reporting VO₂ max of college aged male soccer players

Author, year	Method	Participants	Age (years)	Avg VO ₂ max (ml/kg*min)
Arnason A. et al 2004 ¹⁹	Treadmill	226 Division 1 players in Iceland	23.6±4	61.9 ±.7
Metin G. 2003 ²⁰	Treadmill, Bruce protocol	25 “competitive” players in Turkey	19±3	54.69
Baldari C. 2004 ²¹	Treadmill	12 “competitive” players who had been consistently training x5 years	22±1	62.3±7.4
Kemi O.J. 2003 ²²	Treadmill	10 male soccer players	21±3.1	5.1 L/min *
Santos-Silva P.R. 2007 ²³	Treadmill	11 “high performance” Brazilian soccer players	18±.5	54.9±3.9
Metaxas T.I. 2005 ²⁴	Treadmill	35 “elite young” players	18±1	63.59 (no range given)
Labsy Z. 2004 ²⁵	Treadmill	“trained” soccer players		56.9±3.6

Helgerud J. 2001 ²⁶ Treadmill 19 “elite junior” soccer players 18±.8 58.1±4.5

* Average mass was 73.3±9.1 and VO2 max was calculated to be 69.6 mL/Kg*min

Table 2: Studies reporting VO2 max of college aged Female soccer players

Author, year	Method	Participants	Age (years)	VO2 max in ml/kg*min
Clark M. 2003 ¹⁶	Treadmill, Bruce protocol	9 female players from Notre Dame University	19.7±.7	Preseason: 42.2±4.9 Postseason: 50.0±4.5
Krustrup P. 2005 ¹⁷	Treadmill	14 “elite female players”	19-25	Ave: 57.8, range: 53.8-61.8
Miller T. A. 2007 ¹⁸	Treadmill	26 players from Texas A&M University	College	Preseason: 49.24±4.38 Postseason: 44.87±4.61

Materials and methods

Subjects:

18 healthy male and female (10 males and 8 females) competitive athletes from the University of New Mexico soccer teams, aged 18-23 years old, volunteered to participate in this study. Potential subjects first completed a health and exercise questionnaire to provide information about their health regarding our inclusion and exclusion criteria for safe participation in the study (appendix A). Additionally, female athletes were required to have a negative pregnancy test prior to testing. The content of the questionnaire also included the physical activity status of the subject, position played, as well as any acute illness or injury, and health habits or traits that would preclude exercise testing. The PI reviewed each health/exercise questionnaire and made an assessment as to whether to proceed with exercise testing., Any questions, had they arisen, would have been directed to Dr. Ann Gateley, who provided medical oversight of the study . Subject exclusion criteria included any health condition or injury that would preclude safe maximal exercise testing as well as the following: 1) Positive pregnancy test; 2) age under 18 yr or over 29 yr; 3) intense exercise prior to, or the day of the testing; or 4) dehydration. Subjects were instructed to eat lightly prior to the exercise test, and to refrain from intense exercise. Additionally they were required to ensure they

were well hydrated the day prior to exercise testing and to drink 4 ml/kg body weight of water on the day they were scheduled for exercise testing.

Procedures:

Details of the study including the purpose, procedures, risks and benefits were explained to each subject. Subjects then read and signed the university-approved informed consent (appendix B) and the HIPAA consent. These documents, approved by the University of New Mexico's Human Research Review Committee (HRRC), had been provided to potential subjects to read and review carefully before they were scheduled for testing. Once subjects completed the health history screening, and if the females had a negative urine pregnancy test result, then they continued with the study's testing protocol. Information on their training and position played was included on their health and exercise questionnaire.

Testing Protocols:

All physiological testing was conducted at the Exercise Physiology Lab at the University of New Mexico. Subjects were measured for their standing height to the nearest 0.1 cm using a stadiometer (Holtain Ltd. Crymych, Dyfed, Great Britain). Weight was measured in shorts and T-shirts without shoes and socks to the nearest 0.1 kg on a calibrated scale (Seca Corporation, Columbia, MD). Resting blood pressure (BP) was measured and recorded prior to the exercise test and maximal exercising BP was measured and recorded at the end of the test.

VO₂ max was assessed using graded treadmill protocols (Atterbom run for males; Intermediate run for females) chosen to elicit VO₂max in 8 to 12 minutes. Expired ventilation (V_e) and fractions of oxygen (F_eO₂) and carbon dioxide (F_eCO₂) in expired gas samples were collected breath-by-breath during the treadmill test using an open-circuit gas analysis system (TrueOne[®] 2400, Parvo Medics, Sandy, UT). Gas analyzers were calibrated with gases of known concentration and ventilation equipment calibrated with a syringe of known volume. Subjects' expired air was collected using a T-configuration one-way valve mouthpiece (Hans Rudolf, Inc., Kansas City, Missouri). The rate of oxygen uptake (VO₂) and carbon dioxide production (VCO₂) were automatically

calculated from V_e , FeO_2 , and $FeCO_2$. Heart rate (HR) was also measured beat-by-beat using a Polar (PolarUSA, Lake Success, NY) HR monitor integrated to the Parvo Medics metabolic cart. VO_2 max was determined using the highest VO_2 achieved after the breath-by-breath data were analyzed using an 8-breath running average technique. For this study, subjects were required to attain two of the following criteria in order to meet our criteria for a true VO_2 max: HR within 10 beats per min of predicted HR max, respiratory exchange ratio (RER) of at least 1.1, and an achievement of a plateau of VO_2 (VO_2 -time slope < 0.05 L.min⁻¹) during the last 30 s of the exercise test)

The exercise test was ended when the subject indicated fatigue. Upon exercise termination, the mouthpiece and nose clip were removed and data collection was terminated, however the subject stayed on the treadmill for approximately 2-5 minutes to cool down after exercise. HR and blood pressure were monitored during the cool-down phase.

Data Processing

To determine VO_2 max, the data were imported into the Microsoft Excel software program and breath-by-breath data were smoothed using an 8-breath running average to decrease variability from spurious breaths. The presence of a VO_2 plateau was assessed in the same software program where the slope of the VO_2 -time relationship in the final 30 s was computed. VO_2 -time slope values < 0.05 L.min⁻¹ were interpreted as a VO_2 plateau.

Statistics

All statistical procedures were run using SPSS for Windows™, SPSS, Inc., graphs were constructed with Prism Graphing Software (Tulsa, OK) and descriptive data was computed and presented as means and standard deviations.

Results

We collected results from the men and women's collegiate soccer team at the University of Mexico. We had 10 male soccer athletes who ranged in age from 19-23.

Their average VO2 max was 60.8 ml/kg*min and their VO2 max ranged from 49.9 to 63.9 ml/kg*min (see table 4). Standard deviation for this group was 4.1 ml/kg*min. The women's team ranged in age from 18-21 and had an average VO2 max of 51.0 ml/kg*min with a range of 43.6 to 57.8 ml/kg*min (see table 3). The standard deviation for their VO2 max was 4.9 ml/kg*min. When outlier data was excluded, the VO2 max for both groups improved significantly. The corrected men's VO2 max improved by 1.2 ml/kg*min to 62.0 ml/kg*min, whereas the women's VO2 max increased by 0.7 ml/kg*min to 51.7 ml/kg*min. In addition, we collected VO2 data from 2 members of the men's cross country team at the University of Mexico and their average VO2 max measured 79.4 ml/kg*min.

In this study we had a wide range of players included in our results: goal keepers, defenders, midfielders and forwards.

Table 3. Subject characteristics for UNM female athletes

subject number	Age (yrs)	Position	Height (cm)	Weight (kg)	VO2max (ml/kg/min)	Max HR (bpm)
SW01	19.0	goalie	170.2	71.3	51.0	185.0
SW02	20.0	center/midfield	182.6	81.0	50.6	197.0
SW03	19.0	forward	173.3	63.3	57.5	189.0
SW04	19.0	goal keeper	175.1	61.4	47.5	183.0
SW05	21.0	midfield	165.6	57.1	57.8	187.0
SW06	20.0	defender	162.0	55.3	51.8	190.0
SW07	18.0	midfield	170.2	65.9	43.6	197.0
SW08	18.0	defender	164.1	59.0	48.1	182.0
averages	19.3		170.4	64.3	51.0	188.8
range	18-21		162.0-182.6	55.3-81.0	43.6-57.8	182.0-197.0

Table 4. Subject characteristics for male athletes

subject number	Age (yrs)	Position	Height (cm)	Weight (kg)	VO2max (ml/kg/min)	Max HR (bpm)
SM1	19.0	forward	195.5	86.9	62.9	196.0
SM2	19.0	Not recorded	177.2	74.1	63.3	200.0
SM3	19.0	midfield	174.6	58.8	59.0	196.0
SM4	19.0	goal keeper	181.4	83.3	62.4	200.0
SM5	20.0	goal keeper	182.8	80.1	60.6	205.0
SM6	20.0	midfield	175.0	72.7	61.6	194.0
SM7	19.0	midfield/defender	181.6	74.5	63.5	191.0
SM8	20.0	midfield	171.1	63.8	61.2	208.0
SM9	20.0	midfield/forward	177.3	76.7	49.9	197.0
SM10	23.0	forward	178.4	76.9	63.9	204.0

averages	19.8	179.5	74.8	60.8	199.1
range	19-23	171.1-195.5	58.8-86.9	49.9-63.9	191.0-208.0

Discussion:

The initial purpose of this study was to compare the VO2 max of cross country and soccer athletes in the interest of looking at differences between two endurance sports; however, we were met with the complications of team training schedules, coach cooperation, general recruitment and scheduling of the athletes. Despite best efforts and repeated correspondence, in the end, cooperation and data collection was only successful with the men’s and women’s soccer teams and 2 male track athletes. Because of this, the purpose of the study had to be re-evaluated and revised. Accordingly, the bulk of the following discussion will center around the data collected and review of literature specific to soccer in the hopes that that data that was collected can contribute in some way to the general body of knowledge available on this topic.

As stated in the review of the literature, the studies we found that recorded VO2max values were not done for that specific purpose. One of the contributions of this study is the opportunity to consolidate this data to report averages for male and female soccer players of collegiate age and level of competition. The compiled men’s VO2max results (excluding Kemi, Lasby) averaged 61.09 mL/kg*min (n= 328). After adding the data from the UNM men’s team the average was 61.08 mL/kg*min (n=338). For female soccer players, the compiled VO2max data from the literature review averaged 49.95 mL/kg*min (n=49). After adding the data from the UNM women’s soccer team the average was 50.10 mL/kg*min (n=57). VO2 max in soccer players has been correlated with increased work on the field during a match; therefore we believe that these normative data can be used as a bench mark for training and improvement in the physical fitness aspect of the game.

Evaluation of our data in isolation reveals a few points of interest. First of all, as mentioned, during the initial phase of our study the VO2 max of two male cross country runners was obtained. Their max results were approximately 20 ml/kg*min higher than that of the men’s soccer team. In looking at the VO2 max of the men soccer players as compared to the women soccer players, not surprisingly, the average VO2 for the UNM

male soccer players was approximately 10 ml/kg*min higher than the women's soccer players. Finally, in looking at VO2 max in relationship to position, the unexpected results were the performance of the goal keepers. The goal keepers of both teams did not have the lowest VO2 max and the men's goal keepers had a VO2 max that was either near the average or above the VO2 max average (62.4, 60.6 ml/kg*min). The women's goal keepers had VO2 max at 47.5 and 51.0 ml/kg*min. In contrast, both men's and women's teams had a single midfielder that recorded a max value significantly below the average and that could be excluded from the data analysis as outliers. This result was not anticipated, and the cause is unknown.

Looking specifically at the age range most closely resembling the age range specified in our data, the normative values of VO2 max for men (age 20-29) is 44.2 mL/kg*min and women (age 20-29) is 37.8 mL/kg*min.³ Other normative values available had many errors including not clarifying the level of competition, not specifying age ranges, and lacking values for women.^{4,5}

In evaluating the usefulness of the data that we collected it is important to remember that there are numerous factors that affect the measurement of VO2max. For example when looking at the data collected from the UNM athletes specifically, there are important factors that may have influenced our results. These include motivation of the athlete, the time of their last practice or game, hydration status of the athlete, their general health (i.e. only recently cleared to play after an injury), and time of the year of the testing (pre-during, or post-season). We tried to minimize some of these factors by giving detailed instructions to the athletes; however, compliance with instructions cannot be verified other than by athlete's word. Additionally, we gave verbal encouragement to the athletes during the treadmill testing to try to elicit a true VO2max. Of note, the data from the men's team was all collected on a single day at the end of spring training. The women's data was collected throughout the year including off-season, during season and during the spring season. In looking at the literature, very few of the studies specified at what point in the season the data was obtained. Interestingly, two of the women's studies looked at both pre- and post-season VO2 max values for the same athletes.^{16, 18} The study done by Clark et al. demonstrated a large increase in the VO2 max from pre to post season (from an average of 42.2 mL/kg*min pre-season to 50.0 mL/kg*min post-season)

which we would expect due to structured and rigorous training schedule required in team training. However, in the study done by Miller et al. (2007) the authors reported a decrease in average VO₂ max from pre to post season (49.24 to 44.87 mL/kg*min), something we would not of suspected. These data illustrate the extent of variability that is possible between groups of athletes possibly due to factors such as different training techniques, game and practice schedules, overtraining, dietary issues, and athlete motivation.

Given the many factors that can potentially impact the results of a VO₂ max test, it is possible that a more appropriate means of evaluating norms would be to look at ranges rather than averages. This data would be more difficult to collect as the majority of previously published studies report only the averages with the standard deviation and not individual data. Looking at ranges, even ranges within specific teams potentially provide additional useful information. For example, comparing the VO₂ max range of a national championship soccer team to that of a team that did not go to the NCAA tournament may provide useful guidance in training.

It has been shown that VO₂max values of athletes are correlated with work rate on the soccer field during games. Also, with effective training, the VO₂max of players can improve. This paper provides a compilation of the current literature on college-aged soccer players, along with data collected from Division 1 male and female soccer teams. We hope that these data that include updated average values for VO₂ max of college-aged soccer players, can help coaches, trainers and athletes develop training methods and standards of fitness to improve the performance of a team as a whole.²⁶⁻²⁸ Maximal oxygen consumption (VO₂max) data for collegiate athletes as a whole continues to be sparse. Further studies collecting more data from collegiate soccer teams to increase the n size for normative chart development is needed. Additionally studies collecting and compiling data from other endurance collegiate sports are warranted. Ideally, further studies with many more subjects need to address some of the confounding variables found in this type of research such as when in the season testing is conducted.

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