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A Fitness Profile: Differences in VO2 Maximum Fitness Levels in NCAA Division I Female Freshman and Returning Upperclassmen Soccer Field Players

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ABSTRACT

Aerobic fitness for female soccer players at the National Collegiate Athletic Associate (NCAA) Division I level has been under represented. The aim of the present study was to evaluate the VO_2 maximal fitness levels (VO_2Max) at pre-season for incoming Division I collegiate freshman (n = 19) female soccer field players compared to returning players (n = 27). Preseason VO_2 Max measures were collected and compared over two separate seasons. Significant differences were seen between freshman and returning upperclassman players in ml/kg/min and metabolic efficiency (METS) ($p < .05$). There were no significant differences between separate incoming freshman classes'VO_2 maximum tests in ml/kg/min, (p = .72) however there were significant improvements in freshman ml/kg/min following one year of participation at the college level ($p = .01$). A large training Effect Size (ES) was noted in VO_2 Max for freshman (ES = > 1.4) compared over one year. Metabolic efficiency (METS) was significantly improved among returners ($p = .02$). The nearly 15% difference in ml/kg/min and METS indicates that Division I female freshman soccer players do not likely meet maximum levels of oxygen uptake and metabolic aptitude until later in their careers. VO_2 Max testing is a vital metric for NCAA Division I female freshman soccer field players and is critical in monitoring the metabolic properties as it relates to training and preparation for women's soccer.

INTRODUCTION

The increasing popularity and participation of women's soccer warrants a better understanding of fitness components that impact performance and injury prevention. Advanced testing protocols, such as, VO_2 Maximum testing (VO_2 Max) and repeated sprint testing has become a primary barometer of aerobic capacity among female soccer players. VO_2 Max testing has commonly been used to evaluate and develop high-intensity sport specific training protocols designed to target and maximize ventilatory thresholds [1-3]. Elevations in VO_2 Max are desirable to enhance current play capacity of even the highest level players. As a result, many training and injury prevention programs for collegiate female soccer programs have focused on the development and sustainability of ventilatory fitness [2].

Improvements in VO_2 Max have been associated with enhanced match play performance, such as, distance covered, maintained sprint speed, heart rate efficiency and workload recovery rates [1,3-5]. Professional or elite female players are reported to have higher ventilatory thresholds thought to allow for nearly 30% higher levels of sustained match play intensity when compared to lower level players. However, the high correlative properties with VO_2 Max and high intensity running in females reinforces the importance of aerobic capacity at all levels of play [6]. The ability for field players to sustain sprinting distance and intensity at or near lactate threshold is a primary training aim regardless of level. Thus, identifying players with lower aerobic capacities can serve as a key marker in monitoring progress and further development of high level training thresholds and potentially higher levels of match play for female soccer players [7,8].

Recent literature has identified training sessions performed once or twice per-week to be effective in improving VO_2 Max levels in collegiate female soccer players over a single season [2,4,9]. As a result, repeated sprint testing, such as a beep-test have become popular to determine fitness level. However, little is known regarding the ventilatory preparedness and progression of female National Collegiate Athletic Associate (NCAA) Division I true freshman players compared to returning upperclassman soccer field players [1]. Much of the fitness literature regarding soccer has focused on elite males or elite females at the national and international levels. Therefore, the purpose of this investigation was to evaluate the VO_2 Max of incoming freshman players compared to returning players and to evaluate the progression of ventilatory thresholds. We hypothesized NCAA Division I freshman field players would have statistically significant lower maximal ventilatory values at preseason compared to returning players. Further, VO_2 Max values for freshman players would improve after one year of participation at the Division I level.

METHODS

Experimental Approach To The Problem

Our intension was to profile and monitor change in VO_2Max and determine if Division I freshman soccer field players have aerobic capacities similar to returning upperclassmen players. Differences in mean VO_2Max output were compared between returning players and incoming freshman classes over two consecutive pre-seasons; Fall 2015 and 2016. VO_2 Max output was evaluated further in the 2015 freshman class at the start of the 2016 season to note progress over one year. Testing was performed as part of a Division I university women's soccer team pre-season protocol for the Fall NCAA collegiate soccer season. An information session was held two weeks prior to testing where volunteers signed an informed consent and completed an orthopedic physical examination. Prior to testing a familiarization session was used to secure accurate testing protocol and to control for a learning effect. Demographic data of height and weight was collected in a laboratory setting on the same day as a treadmill graded Vo_2Max Bruce Protocol test [2,3].

Subjects

Forty-six NCAA female Division I returning (n = 27, 20.6 yo, 167 cm, 65.8 Kg) and freshman soccer players (n = 19, 18.7yo, 169 cm, 66.4 Kg) volunteered for the study. Players were excluded if they were a goal keeper or had an injury/inability to practice over the past 6 months.

Procedures

All testing was performed in a controlled lab setting. VO_2 Max testing to determine aerobic capacity was performed using a Bruce incremental stage of difficulty protocol on a motorized treadmill. A calibrated Parvo Medics True One metabolic analyzer (Parvo Medics, Inc.) was used to measure aerobic capacity where respiratory gases and heart rate (Polar Electro) were recorded in 15 second intervals. Each subject performed a 10 minute warm up and voluntary stretching prior to testing. Stage one of the test was initiated with an 11 Kilometers per hour (kph) pace at a 0% grade for 2 minutes. Preceding stages of progression had a 2% grade increase every 2 minutes until a 6% grade was reached. Subsequent 1% grade increases were made until termination of the test. Perceived exertion numbers were recorded at the beginning of each stage. Testing was terminated voluntarily by the athlete for any reason or if the testing personnel observed risk of harm to the athlete, such as, a stagnant or decrease

VO_2 Max values and/or heart rate despite increases in stage intensity. Testing was performed by blinded evaluators to the category of the athletes; two certified athletic trainers/exercise physiologists and a physician with a combined 60 years of experience.

Statistical Analysis

The independent variables were the freshman class 2015, freshman class 2016 and the returning upperclassman players represented by sophomores, juniors and senior level college athletes. Each freshman class represented true first year college athletes in women soccer. The dependent variables were VO_2Maximal Oxygen Exchange in Liters per minute (L/min), milliliters per kilogram per minute (ml/kg/min), and the metabolic equivalent of task (METS).Data was assessed for normality using a Mann-Whitney U test. An independent sample student t-test was used to assess differences in VO_2 Max values between freshman and returning players. An additional independent sample student t-test was used to analyze the base line differences between freshman classes 2015 and 2016. A paired sample t-test was used to assess pre- to post-test statistical significant differences in the dependent variables in freshman 2015 class after one year of playing and training at the NCAA Division I level. A priori significance level was set at $p \leq .05$. A power analysis with a 95% confidence interval was performed to assess the treatment effect of the one year of playing and training at the NCAA Division I level for the freshman 2015 class [10]. ES was derived using a Cohn's *d* calculation; respectively the freshman 2015 means from pre- to post- were subtracted to represent a true control group and divided by a pooled standard deviation to determine the effect of each intervention [10]. Results were interpreted as small (0 – 0.39), medium (0.40 – 0.69) or large (≥ 0.70) [11]. All data analysis was performed on SPSS 22 software (IBM Corp, Armonk, NY, USA).

RESULTS

It was hypothesized NCAA Division I female freshman soccer field players would have statistically significant lower VO_2 Max ml/kg/min values at preseason compared to returning players. The results in Table 1 and Table 2 express the statistically significant lowerVO_2 Max and higher metabolic equivalent values ($p < .05$) recorded for the 2015 and 2016 freshman players, respectively when compared to returning players. Table 4 illustrates freshman 2015 and 2016 had similar values for all dependent variables prior to the start of the respective seasons. There was a large treatment effect (.85-1.8) and statistically significant increase in all dependent variables *($p = .01$)* for the 2015 freshman class following one year of playing/training at the NCAA Division I level as reported in Table 3. The 2016 freshman class was not analyzed for a treatment effect due to time constraints of the study. There was no statistical change in average height or weight for the freshman classes and the returning players.

Table 1: 2015Meanand Standard Deviation Height, Weight and VO_2 Maximal Performance: Incoming Freshman Comparison to Returning Players.

					VO2_Maximal Oxygen Exchange		
Class	**N**	**Age**	**Ht_cm**	**Wt_Kg**	**L/min**	**ml/kg/min**	**METS**
Freshman	8	18.7	169	66.4	2.78 ± .33	43.01 ± 6.7	12.11 ± 1.76
Returners	14	20.6	167	65.8	3.13 ± .26	48.72 ± 3.7	13.95 ± .80
Team Totals	22	19.5	168	66.1	2.93 ± .29	45.39 ± 5.2	12.39 ± 1.35
Percent Difference					13%	13%	16%
Significance					*.001	*.001	*.01

N = Number of players
Ht = Height in centimeters at time of testing
Wt = Weight in kilograms at time of testing
L/min = Liters of oxygen expressed on average per minute
ml/kg/min = milliliters of oxygen expressed per kilogram of body weight per minute
METS = metabolic equivalent of task for energy to sustain activity
Percent Difference = Difference between scores, divided by low score, multiplied by one-hundred
*Significance = Statistical difference $p \leq .05$ with a two-tailed Independent Student T-Test

Table 2: 2016 Mean Height, Weight and VO_2 Maximal Performance: Incoming Freshman Comparison to Returning Players.

					VO_2_Maximal Oxygen Exchange		
Class	**N**	**Age**	**Ht_cm**	**Wt_Kg**	**L/min**	**ml/kg/min**	**METS**
Freshman	11	18.5	169	64.6	2.83 ± .44	44.14 ± 6.1	12.75 ± 1.9
Returners	19	20	166	66.5	3.18 ± .19	48.63 ± 2.8	13.89 ± .6 .6.6
Team Totals	30	19	167	65.1	2.93 ± .28	46.39 ± 4.6	13.25 ± .9
Percent Difference					11 %	11 %	9 %
Significance					*.03	*.03	*.02

N = Number of players
Ht = Height in centimeters at time of testing
Wt = Weight in kilograms at time of testing
L/min = Liters of oxygen expressed on average per minute
ml/kg/min = milliliters of oxygen expressed per kilogram of body weight per minute
METS = metabolic equivalent of task for energy to sustain activity
Percent Difference = Difference between scores, divided by low score, multiplied by one-hundred
*Significance = Statistical difference $p \leq .05$ with a two-tailed Independent Student T-Test

Table 3: Percent Change in VO_2 Maximal Performance, Metabolic Equivalent Values, and Effect Size for Freshman Class 2015 after One Year of Participation.

VO2_Maximal Oxygen Exchange				
Percentile Difference for Class	**N**	**L/min**	**ml/kg/min**	**METS**
Pre-Freshman 2015	8	2.78 ± .33	43.01 ± 6.7	12.11 ± 1.7
Post-Freshman 2015	8	*3.06 ± .26	*47.48 ± 3.7	*13.74 ± .80
Percent Change	8	10 %	10 %	13 %
Significance	8	*.04	*.04	*.05
ES-Freshman 2015	8	.85	.85	1.8
ES-Returners	**11	.38	.38	.62

N = Number of players
Pre-Freshman 2015indicates initial VO_2 Max data for the freshman class of 2015
Post- Freshman2015indicates 1 year follow-up VO_2 Max data for the freshman class of 2015
L/min = Liters of oxygen expressed on average per minute
ml/kg/min = milliliters of oxygen expressed per kilogram of body weight per minute
METS = metabolic equivalent of energy to sustain activity
ES-Freshman = Effect Size for Freshman Class 2015 following one year of play
ES-Returners = Effect Size for returning players following one year of play
**8 of the 19 returning players were from the freshman 2015 class thus the Effect Size was calculated for the 11 remaining returning players
Percent Change = Difference between scores divided by the low score multiplied by one-hundred
*Significance = Statistical difference $p \leq .05$ with a two-tailed Paired T-Test

Table 4: Mean VO_2 Maximal Performance Values for Incoming Freshman Comparison of 2015 and 2016 Freshman Classes.

Class	N	Age	Ht_cm	Wt_Kg	VO2_Maximal Oxygen Exchange		
					L/min	ml/kg/min	METS
Freshman	8	18.7	169	66.4	2.78	43.01	12.11
Returners	11	18.5	169	64.6	2.83	44.14	12.75
Team Totals	19	18.6	169	65.5	2.8	43.6	12.4
Significant Difference $p < .05$					*.001	*.001	*.01

DISCUSSION

The comparable differences between incoming NCAA Division I female freshman soccer field players and returning players seem reasonable. Higher levels of soccer performance, such as professional or international levels arereported to have greater levels of aerobic power [1]. On average Division I NCAA female soccer players have respectable VO_2 Max outputs but higher levels of variance; 40-55 ml/kg/min compared to professional elite female players having higher values with less variance; 49-58 ml/kg/min [1]. The more refined oxidative and metabolic capacities seen in the elite players results in an increased ability to sustained high-intensity levels of match play running by nearly 30% more when compared to lower and moderate international level players [1]. Our data is similarif we consider NCAA Division I returning players to be higher level players compared to incoming freshman. The returning players consistently had statistically higher VO_2 Max values with less variability(48.7 + 3.7, 48.6 + 2.8 range = 46-55 ml/kg/min, $p = .03$) when compared to both freshman classes(43.01 + 6.7, 44.1 + 6.1, range = 36-52 ml/kg/min, $p = .03$). The higher VO_2 Max was also accompanied with higher metabolic efficiency as indicted by the advanced level of METS for the returning players. In this case, METS serve as a good gage in estimating energy expenditure equivalent per a given task, such as ventilatory thresholds at a maximum level. Here the values indicate the returning players to be more efficient metabolically when compared to the freshman players. For example, mathematically METS can be used to calculate caloric cost in kilocalorie per minute = ((METS x 3.5 x kg of body wt)/200)). Therefore, the freshman 2015 VO_2 Max values can be expressed as approximately 14.08 kcal/min ((12.11x3.5x66.44)/200)); when compared to returning players expressing approximately 15.72 kcal/min ((13.65x3.5x65.85)/200)) [12]. These values do not necessarily indicate skill level however higher oxygen uptake are associated with higher levels of work expressed in the form of sprinting activity during match play which has been linked with higher levels of soccer [1,13]. Thus, similar to professional levels of female soccer fitness aptitude, a fitness dichotomy exist between incoming female freshman and returning players at the NCAA Division I level.

Insight to VO_2 Max data and training specificity among NCAA Division I female freshman soccer players is limited. Our data suggests female freshman soccer players may need to rely more on skill in their initial year rather than fitness. However, higher ventilatory thresholds in freshman players may serve as an advantage when playing against other freshman or even higher skilled players with lower ventilatory thresholds [13,14]. Elite female players have been reported to cover 5.3 + 2.0% of total distance at sprint speeds during match play. These levels are consistent with higher metabolic efficiency and VO_2 Max values. Thus, it seems reasonable to use VO_2 Max data to assist in understanding ones potential as a player and guiding the development of high intensity and sprint thresholds for NCAA Division I female soccer field players [14].

High correlation between fatigue and VO_2 Max performance in previous reports suggests higher ventilatory thresholds at any level of soccer can assist in improving some aspects of match play related to running speed, distance and possibly reduce the risk of injuries commonly occurring at the end of a half, match or practice [1,5]. Sprint bouts have been reported to reduce on average 20-40% at the end of a half and at the end of a match. Thus, fitness levels measured as a VO_2 Max data is a critical metrics and can be used to enhance training progressions and play strategies. Repeat spring testing and training have also been used in this manner to track player performance. It has been suggested that lower levels of VO_2 Max performance is likely a result of less intense training protocols and inconsistent match intensities [1, 2, 5]. Thus, it appears freshmen are not receiving adequate training sequences of intensity and/or match competition prior to playing at the Division I collegiate level. Efforts to counter balance these deficits in freshman players may serve to improve the sustainable efforts of freshman players, thus reducing fatigue and potential injury rates.

An increase in VO_2 Max is commonly a result of lactate threshold training with repeated bouts of high intensity sprints near 85% maximum efforts to heart rate and VO_2 Max values [1,2]. Favero et al demonstrated improvements in a VO_2 Max (50.89 to 53.11ml/kg/min) in 16 Division I collegiate female soccer players following a one-day per-week in season aerobic interval training program over an entire 16 week season. While these findings support our data there remains some inconsistencies between studies. The improvements reported by Favero et al were not stratified by academic year (freshman, sophomore, junior, senior). The current study indicates simply playing the collegiate soccer and general strength and conditioning modalities at a higher level of performance improves work outputs as measured by VO_2 Max and METS in younger players. Improvements in the

freshman players could potentially be the primary reason for overall team average improvement. Therefore, it is likely the improvement in the team average VO_2 Max was a result of simply playing at a higher level of competition not solely the training intervention [7]. Without a control group or stratification of academic year we can only speculate the improvements listed in the Favero et al study were truly a change in team averages due to the training intervention. Conversely, we did not have a control group other than a historical VO_2 Max comparison of a freshman profiled over two separate years. The lack of a control group and a specific interventionin our study limits the generalizability of the data, however it offers insight to the lack of empirical data available in this content area [2]. The test subjects in the current study were trained with the same sequence of weight room and field preparation. The only differences in work load may be noted during match play which was predominately performed by the returning players. Further, these work load values were not calculated thus challenging the external validity. However, it has been reported when elite female players compete at an international verse domestic level the amount of sprint bouts are more intense. Perhaps possible contributors to the gains noted in our freshman class are similar. The higher levels of expectation, match/practice intensity, speed and skill compared to high school level play warrant high energy expenditure which exponentially results in better VO_2 Max and METS values [15]. Further, match substitution rules are more lenient for high school age players than the college level. These factors combined with player maturity, increased intensity and consistency in the weight room/ resources and play on the pitch seems to provide an adequate stimuli formula for improvement in the younger players. While more data is needed regarding VO_2 Max values inNCAA Division I collegiate female soccer players our data offers novel insight as to the differences that may need to be addressed in female freshman players prior to beginning a collegiate season.

PRACTICAL APPLICATION

To date there is limited empirical data regarding the ventilatory threshold profile of NCAA Division I female freshman soccer players. Our data is novel and suggest that incoming freshman have inferior aerobic capacities when compared to returning NCAA Division I female soccer players. Strength coaches and sports medicine specialists should take into consideration the VO_2 Max and METS values when planning training protocols. Monitoring VO_2 Max testing appear to be helpful inplanning and identifying deficits in ventilatory thresholds among female freshman athletes.

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