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AEROBIC CAPACITY AND ANTHROPOMETRIC CHARACTERISTICS OF ELITE-RECRUIT FEMALE SOCCER PLAYERS

Thomas Dillern[1], Jørgen Ingebrigtsen[1] & Shaher A. I. Shalfawi[3]

[1]*Department of Sports, University of Nordland, NORWAY.*
[2]*Norwegian Olympic Sport Centre, Department of Physical Training, NORWAY.*

Abstract Knowledge concerning the young talented female soccer player is lacking. Therefore, the aims of the present study were to identify and establish aerobic capacity and anthropometric characteristics in 32 Norwegian elite-recruit female soccer players and to examine possible aerobic capacity and anthropometric differences between playing positions. Measurements consisted of two standard anthropometric variables as well as the anaerobic threshold (AT) and the maximal oxygen consumption (VO_2max). The results show that the keepers' running velocity at AT (7.9 ± 1.1 km/h) was significantly ($p \leq 0.05$) lower than that of the midfielders (10.0 ± 0.6 km/h) or the attackers (9.3 ± 1.1 km/h). No VO_2max measurement differences were observed between playing positions, and the anthropometric differences were limited to keepers having a higher body mass index (BMI, 24.2 ± 0.5 $kg \cdot m^{-2}$) and a lower reciprocal ponderal index (RPI, 41.4 ± 0.6 $cm \cdot kg^{-0.33}$) than either attackers (20.5 ± 2.2 $kg \cdot m^{-2}$; 44.1 ± 1.6 $cm \cdot kg^{-0.33}$) or midfielders (20.7 ± 1.9 $kg \cdot m^{-2}$; 43.6 ± 1.3 $cm \cdot kg^{-0.33}$) ($p \leq 0.05$). Present results indicated similar aerobic capacity in the subject group when compared to previously published findings. However, previous data showed that different playing positions had different physiological demands, but these differences were not reflected in the capacity measures across playing positions presented here. Hence, present findings suggest that the coaching staff should individualize physiological training programs to improve the players' abilities to cope with the specific demands of the various playing positions on an elite female soccer team.

Key words: Talent identification, talent development, maximal oxygen consumption, anaerobic threshold, body mass index, reciprocal ponderal index

INTRODUCTION

Soccer has been mentioned as the most popular sport in the world [25], and research indicates that the demands on elite soccer players have increased in recent years [2]. Thus, soccer player profiles and the developmental process towards becoming an elite performer have both become subjects of decisive interest. Therefore, scientists and practitioners are continuously seeking key factors and characteristics that can identify potentially successful soccer players [13]. Research has revealed that technical, perceptual, psychological, physiological, and anthropometric factors must all be highly developed in order to reach an elite performance level [24]. Furthermore, it is well known that aspects such as growth, maturation, genetics, environment, and training each influence the developmental process towards sports expertise [17, 25]. Isolating and quantifying each of the different factors contributing to total performance in soccer is therefore a crucial yet extremely difficult task [14].

The identification and development of talented soccer players often rely on the empirical observations of coaching staff and scouts; however, previously published research underscores the need for supplementing such intuitive opinions with scientific observation [25]. A scientific perspective is helpful in providing practitioners with some objective measures of an athlete's development through predictable stages [25]. It has also been emphasized that, due to the complexity of both soccer and the talent process in general, the approach to understanding talent development in soccer should be multidisciplinary [14]. Such an approach has already proven itself capable of both identifying talented players and consistently distinguishing between elite and sub-elite players [14]. However, it remains unclear whether a multidisciplinary approach can draw accurate distinctions between players who have already been selected and included in systematic training [17, 25]. Importantly, when evaluating available information regarding talent development in soccer, one must be sure to take into consideration that the majority of published data concern male players. Hence, the relevance of existing knowledge is open to debate, given the present aim of isolating and understanding the developmental process towards becoming an elite female soccer player.

In a multidisciplinary approach to talent identification in soccer, measurements of physiological factors should be included. VO_2max in female soccer players has been shown to vary between 48.4 to 55.0 $ml \cdot kg^{-1} \cdot min^{-1}$ [3, 5, 9, 11, 21]. Different results are related to different playing positions on the team, with midfielders scoring the highest and defenders (except for keepers) scoring the lowest. Similar findings have appeared in studies of younger female players [6]. Such positional differences have also been found with anthropometric characteristics in female soccer players. Even if there is a lack of significant findings, available data [9, 12, 20] still indicate a trend in observations that resembles documented findings in male soccer players, where goalkeepers and defenders are determined to be, on average, both heavier and taller than players in other positions.

The lack of knowledge concerning the female soccer player, and especially the young, talented female soccer player, has been previously emphasized elsewhere [25]. In a multifaceted sport such as soccer, it can be difficult to recognize the necessary prerequisites to achieving a given level of expertise. Therefore, it may prove helpful to find some objective reference points in accordance with developmental stages, in order to aid in the detection and development of future elite female soccer players. Hence, the purposes of this study were to identify and establish aerobic capacity and anthropometric characteristics of elite-recruit female soccer players, as well as to examine whether there are systematic differences between players assigned to different playing positions.

MATERIALS AND METHODS

Experimental Approach to the Problem

In order to identify and establish normative physiological and anthropometric data with the current cohort, we conducted tests of maximal oxygen consumption (VO_2max), anaerobic thresholds (AT), body mass, and stature. These data were also used for the investigation of possible systematic differences across playing positions. All measures were conducted 3 weeks into pre-season training at the Department of Sports laboratory at the University of Nordland in Norway.

Participants

Thirty-two young, well-experienced (with a mean participation in organized soccer training of 8 ± 3 years) elite-recruit female soccer players, aged 17.4 ± 2.4 years, volunteered to take part in this study. The group consisted of 11 defenders, 8 midfielders, 10 attackers, and 3 goalkeepers. At the time of the testing, all participants played in the Norwegian 3rd senior division and took part in organized training 8.0 ± 2.0 hours per week, on average. Before taking part in the study, each player was familiarized with the testing protocol. All of the subjects involved in this study, including the club, the participants, and the parents of any participants under 18 years of age, approved the use of the depersonalized data presented here. Further, this study was conducted in accordance with the Helsinki Declaration and was approved by the local ethics committee at the University of Nordland.

Warm-up Protocols

Body weight was measured using an electronic Precision Health Scale, ProFIT/IntelliSCALE model UC-321 (A&D Medical, San Jose, California, USA). Stature was attained using a wall-mounted stadiometer (KaWe Medizintechnik, Asperg, Germany). A lactate pro analyzer, model LT-1710 (ARKRAY, Inc., Kyoto, Japan), was used for the Anaerobic Threshold (AT) measurements. Furthermore, for the oxygen consumption test, we used a SensorMedics model VMAX29 (VIASYS Healthcare Respiratory Technologies, Yorba Linda, California, USA) connected to a PC (Intel dual-core) with the aid of a Vmax Program Manager (IVS-0101-12-7). The treadmill used in this study was a Rodby model RL 3500 (Rodby Innovation AB, Hagby, Sweden). Heart rate was monitored with the help of a Polar pulse transmitter T31 (sampling at 0.2Hz) and a polar pulse clock S610i (Polar Electro OY, Kempele, Finland).

Testing Setup

All measures of body mass and stature were conducted while the participants were wearing minimal clothing. The results were rounded to the nearest 0.1 kg and 0.05 cm for weight and stature, respectively. Body mass index (BMI) and reciprocal ponderal index (RPI) were later calculated according to a protocol outlined by Nevill et al [13]. To establish aerobic capacity, all players underwent treadmill tests of AT and maximal oxygen consumption (VO_2max). The test-protocol, designed to measure AT, consisted of 5-7 increases in speed of 1 km/h every fifth minute. Before each speed elevation, blood lactate was taken by a finger stick and analyzed. A lactate level of 4.0 $mmol/L^{-1}$ (OBLA), as first introduced by Sjödin & Jacobs [18], was used to define AT. In this study, AT is documented as the velocity level at anaerobic threshold (vAT) and as a percentage of maximum heart rate at anaerobic threshold (%HRAT). After the AT test, the participants were instructed to take a 10 minute recovery break before undergoing the VO_2max test. This test was conducted using a continuous incremental protocol with load increases every 30 s and with a total duration of 5-6 minutes. VO_2max is defined here as the average of the two highest oxygen values, and the exact criteria used to determine VO_2max involved capturing the moment when a plateau in oxygen consumption was observed with still increasing speed [19]. VO_2max results are expressed as the oxygen uptake in millilitres per minute per kilogram of bodyweight (VO_2max /$ml \cdot kg^{-1} \cdot min^{-1}$/) and as the velocity at VO_2max (vVO_2max).

STATISTICAL ANALYSIS

The resulting data for all the examined groups were analysed with a histogram plot, and the normality of distribution was tested using Shapiro-Wilk's test. Levene's test was utilised to examine the equality of variances across the groups. Then, descriptive statistics were calculated and reported as mean ± standard deviations of the mean (SD), for each playing position group and for each anthropometric and physiological variable. If the data followed a normal distribution, the differences in the anthropometric characteristics between the groups were compared using a one-way ANOVA, followed by a Tukey post hoc test. If the data were not found to follow normality, the non-parametric Kruskal-Wallis test was used, followed by the Mann-Whitney test. The level of significance was set at $P \leq 0.05$ for all the statistical analyses. If differences were detected, a Tukey post hoc test was assessed to determine which playing positions were expressing these differences. All of the statistical analyses were carried out using SPSS 17.0 for Windows (SPSS Inc., Chicago).

RESULTS

In exploring the data, vVO_2max and %HRAT were found not to be normally distributed within the groups ($P \leq 0.05$). All of the other variables in this study were normally distributed. The Levene's test did not show any statistically significant differences across all of the groups' variances. Consequently, the differences in the anthropometric characteristics were also examined using the Kruskal-Wallis test for vVO_2max and %HRAT, and a one-way ANOVA was applied for VO_2max, vAT, BMI, RPI, body weight, and stature.

Table 1. The mean (±SD) results of VO_2max, vVO_2max, vAT, % HR AT, BMI, RPI, Body weight and Stature for all groups, and comparison between groups.

Variable	Defenders		Midfielders		Attackers		Keepers		Between Groups differ.
	mean ± SD	95% CI	mean ± SD	95% CI	mean ± SD	95% CI	mean ± SD	95% CI	P-Value
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	52.1±3.6	49.7-54.5	53.8±5.5	49.2-58.4	53.0±5.0	49.4-56.6	48.7±4.6	37.2-60.2	0.431
vVO_2max (km/h)	13.8±1.0	13.1-14.5	14.4±0.6	13.8-14.9	14.0±1.0	13.2-14.7	12.8±1.0	10.2-15.4	0.105
vAT (km/h)	9.2±0.9	8.5-9.8	10.0±0.6	9.5-10.4	9.3±1.1	8.5-10.1	7.9±1.1	5.2-10.7	0.032*
% HR AT (bpm)	85.2±7.3	80.3-90.1	89.3±5.0	85.1-93.4	86.5-5.2	82.8-90.3	87.3±5.3	74.3-100.4	0.516
BMI ($kg \cdot m^{-2}$)	22.1±1.7	20.9-23.3	20.7±1.9	19.1-22.3	20.5±2.2	19.0-22.1	24.2±0.5	23.0-25.3	0.020*
RPI ($cm \cdot kg^{-0.33}$)	42.9±1.3	42.1-43.8	43.6±1.3	42.5-44.7	44.1±1.6	43.0-45.2	41.4±0.6	40.0-42.8	0.026*
Body weight (kg)	61.5±4.9	58.2-64.7	56.0±6.3	50.7-61.3	58.0±7.0	53.0-63.0	65.6±5.1	52.9-78.3	0.076
Stature (cm)	167.8±0.0	164.1-169.6	164.4±0.1	160.0-168.8	168.0±0.1	163.8-172.2	164.7±0.1	149.5-179.8	0.473

* = $p \leq 0.05$

Differences in vAT, BMI, and RPI were observed between groups (Table 1). Furthermore, a suspected difference was also observed in body weight. Investigation of the data reveals that there was a statistically significant difference between midfielders and keepers ($P \leq 0.05$) in both vAT and BMI (Figure 1 & 2), as well as between keepers and attackers ($P \leq 0.05$) in BMI and RPI (Figure 2 & 3). The suspected differences in body weight were found to be absent and hence judged to be false.

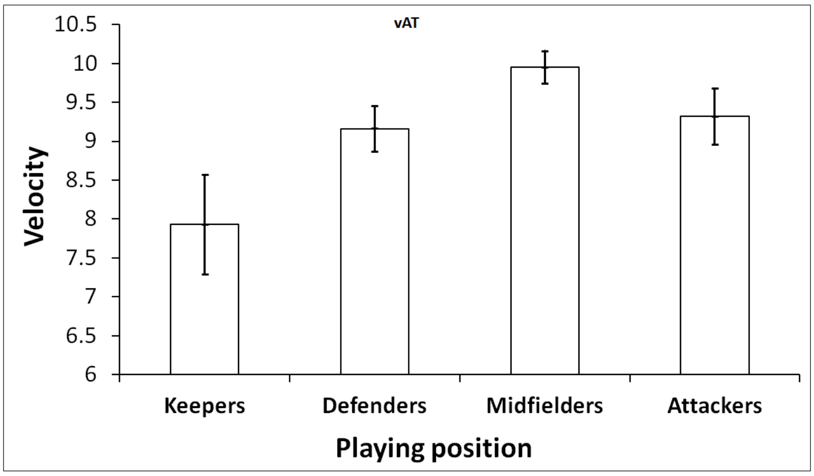

Figure 1. Mean and standard error of the mean (SEM) of the players velocity at anaerobic threshold

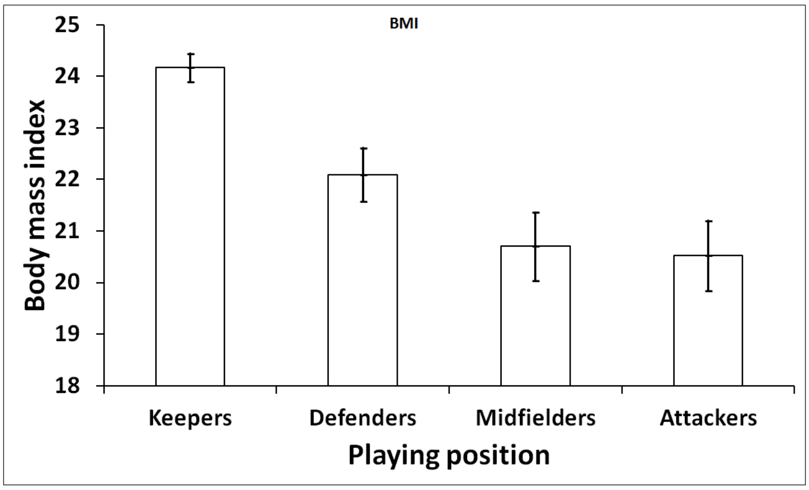

Figure 2. Mean and standard error of the mean (SEM) of the players BMI

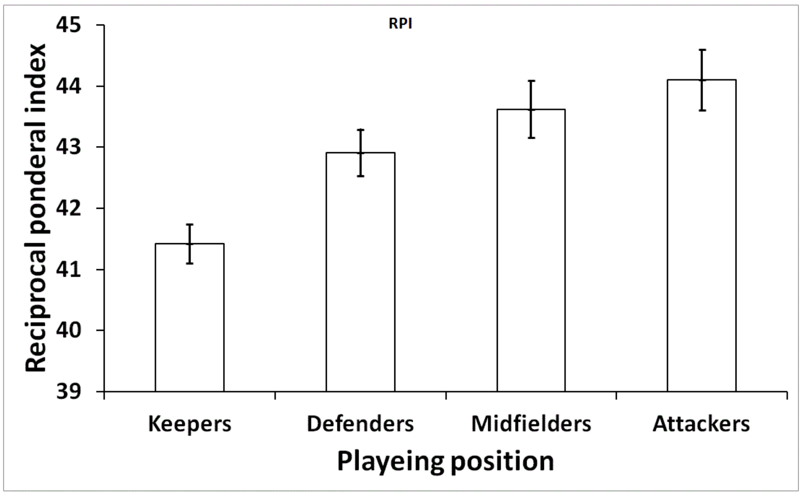

Figure 3. Mean and standard error of the mean (SEM) of the players RPI

DISCUSSION

The main aim of this study was to identify and establish aerobic capacity and anthropometric characteristics of elite-recruit female soccer players. Further, the second aim was to examine if there were any systematic differences between players assigned to different playing positions.

AEROBIC CAPACITY AND ANTHROPOMETRIC CHARACTERISTICS

Aerobic capacity has been identified as one of the key factors leading to high performance results in soccer [25]. The elite-recruit female players in this study achieved levels of oxygen consumption between 48.7 and 53.8 $ml \cdot kg^{-1} \cdot min^{-1}$. Compared to previously published data within female soccer studies, the present results were lower than what had been reported among elite female players [8, 9] and among Danish female national players [11]. However, the present VO_2max results were somewhat higher than those reported within studies of English [4] and Australian [21] female national players, as well as both Canadian female university players [15] and Italian Division 1 female players [5]. It should be noted, however, that our study consisted of younger players; yet, previous research shows only minor differences between adult versus younger soccer players in VO_2max, when this measure is expressed relative to the player's body mass [1].

Research shows that soccer players' aerobic capacity is competition-level dependent. Thus, measurements of maximal oxygen consumption could be a criterion for detecting a successful future player or team [19]. In a study by Jankovic et al [10], two groups of soccer players, aged 15–17, were compared. One of the groups was found to be successful at a later stage in development while the other was not. The results indicate that measures of fitness, such as VO_2max, positively predict the group that will become successful based on better performance levels.

The results in running speed at VO_2max (13.75 km/h) and AT (9.1 km/h), within the participants in this study, were slightly lower than previously published data onelite female soccer players [9]. Moreover, based on our review of the existing literature, these measures had only been reported once previously within female soccer studies even though they were elsewhere considered as important determinants of endurance capacity [7].

A link between anthropometric characteristics and performance in soccer has been proven to exist, and therefore, it is plausible to utilise such characteristics to direct the process of identifying talented players [25]. The present study produced mean values for the group as a whole of 21.87 $kg \cdot m^{-2}$, 43 $cm \cdot kg^{-0.33}$, 60.27 kg, and 166.22 cm for BMI, RPI, body weight, and stature, respectively (Table 1). The current participants were therefore highly comparable to elite Norwegian female soccer players [9], female university players [15], and both Danish [11] and English [4] female national team players. However, while they had a slightly lower mean body mass and stature than the Danish players, the present players appeared heavier than both Spanish female first division [12] and Australian female national soccer players [21].

POSITIONAL DIFERENCES

No differences in VO_2max measurements were observed between playing positions. A similar lack of positional difference had also been found by Todd et al [20] in female English championship players and by Wells & Reilly [23] in female university players. This equivalent finding could be documenting what has been previously speculated elsewhere, namely, that VO_2max is not a sensitive enough parameter to differentiate between players [20]. Furthermore, the absence of differences in aerobic capacity may be due to a lack of individualization in the training programs of different playing positions [22]. This theory may explain our findings, given that our examination and testing of athletes occurred during the early preseason. Also, even if a fitness variable, such as oxygen consumption, has proven capable of distinguishing between elite and non-elite young soccer players, it remains to be seen whether such fitness variables possess the sensitivity to distinguish between players who have already been selected onto an elite-recruit soccer squad [25]. Regarding running speed at VO_2max and AT, the only apparent differences between playing positions were that keepers ran significantly more slowly than midfielders and attackers at both vVO_2max and vAT (Figure 1).

Concerning the findings of anthropometric characteristics, this analysis revealed a significantly higher BMI among keepers as compared to midfielders and attackers (Figure 2). Also, the RPI was found to be lower among keepers compared to midfielders and attackers (Figure 3). These results could possibly be explained by the findings of Rienzi et al [16]. These authors disclosed a relationship between the match work rate and anthropometric measures in soccer. It is probable that the keepers who participated in this study tended to perform less running than the attackers and the midfielders during both practice and matches and thus had a lower work rate in general.

Clearly, there may be some limitations behind the findings in this study. First, the information about the players' weekly work rate at the time of the testing was not accessible. Such information would probably have made it easier to interpret our findings. Second, the low number of players participating in the study could also call into question the strength of our results. However, when studying elite performers, and especially when conducting laboratory testing, it is not easy to gather large samples. A third, previously acknowledged, limitation may be the timing of the data collection. Three weeks into preseason training is traditionally the period when Norwegian soccer teams prioritize training their members in general attributes rather than specific qualities. Finally, the use of BMI as a measure of body composition among sports performers is also a possible weakness of this study. BMI does not distinguish between fat and fat-free mass; therefore, we cannot know for certain whether a high BMI is the result of abundant adipose tissue or muscle mass.

CONCLUSION AND PRACTICAL APPLICATION

Current results indicate that the subjects, taken from a group of elite-recruit female players, performed comparably well versus elite international female soccer players in terms of their aerobic capacity tests. It also appears that their anthropometric characteristics were comparable as well. Concerning positional differences, we found that the running velocity of keepers was significantly lower than that of midfielders and attackers, based on both the anaerobic threshold test and the test of maximal oxygen consumption. Furthermore, within the VO_2max measurements, no differences were observed across playing positions, and a higher BMI and lower RPI in keepers compared to attackers and midfielders were the only anthropometric differences found. No other significant differences between playing positions were identified amongst the participants in this study. Previous research had revealed that there were several positional differences amongst soccer players based on physiological and anthropometric variables [2]. Earlier studies had also shown that results of young, talented players often correlated with research findings at the elite level [Pena Reyes, 1994, in /25/]. Nevertheless, a large number of the results in the present study do not accord with these expectations. Some possible limitations behind our findings have been mentioned. However, as the main aim of this study was to establish normative data within a field that is still characterized by paucity of information and knowledge gaps, we conclude that the various limitations will have little impact, and that our data remain a significant addition to the field.

Based on our findings of lacking positional differences in aerobic capacity, it is recommended that coaching staff implement regular testing programs to monitor current players' physical development, given that aerobic capacity is claimed to be one of the most important physiological factors behind soccer performance, and that the physiological demands placed upon elite soccer players have been proven to vary between different playing positions. In constructing a multifactorial assessment of talent development in soccer, objective information based on scientific measurements can be crucial as it increases the comprehension of the individual players' capabilities by the coaching staff. Thus, attention to scientific knowledge and measurements of player performance can enhance the coaches' ability to design optimized training programs for young, talented players, and ultimately will support their ability to master the different positional demands within elite soccer.

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Address for correspondence:

Thomas Dillern
Department of Sports
University of Nordland
8049 Bodø
NORWAY
Phone +47 75517131
E-mail: thomas.dillern@uin.no

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