

# Analysis of Cardiorespiratory Function Capacities in K-College Female Hockey Players

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Received July 25, 2023; Revised September 20, 2023; Accepted October 24, 2023

## Cite This Paper in the Following Citation Styles

(a): [1] Kumju Lee , "Analysis of Cardiorespiratory Function Capacities in K-College Female Hockey Players," *International Journal of Human Movement and Sports Sciences*, Vol. 11, No. 6, pp. 1337 - 1342, 2023. DOI: 10.13189/saj.2023.110618.

(b): Kumju Lee (2023). *Analysis of Cardiorespiratory Function Capacities in K-College Female Hockey Players. International Journal of Human Movement and Sports Sciences*, 11(6), 1337 – 1342. DOI: 10.13189/saj.2023.110618.

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**Abstract** This study aimed to collect and analyze their descriptive statistics and provide important information for developing individual cardiorespiratory function and physical strength training programs for female field hockey players who participated in this study. The research subjects who volunteered to participate in this study were 17 female field hockey players in K-College. The body composition measurement equipment in this study used Inbody 4.0 Space, a body composition analysis device. Maximal oxygen intake, maximal ventilation, maximal heart rate, and anaerobic threshold were selected for cardiorespiratory function tests. KSSI protocol considering Korean elite athletes was used as the GXT method. As for the anthropometric and GXT results, the height was 163.96 cm, the weight was 58.35 kg, the BMI was 22.17 kg/m<sup>2</sup>, and the maximum heart rate was 193.59 HRmax. The VO<sub>2</sub>max was 2894.5 ml/min and 49.58 ml/kg/min, the VO<sub>2</sub>/HR was 14.92 ml/bpm, and the respiratory rate per minute of the pulmonary characteristics was 62.40 f/min, maximum ventilation of 105.15 l/min, VE/VO<sub>2</sub> of 37.58 ml/min. And the anaerobic threshold as a representative variable of cardiorespiratory function was Oxygen intake which was 45.55 ml/kg/min, and then the percentage of maximum oxygen intake was 80.59% VO<sub>2</sub>max, and heart rate at the AT level was 172.29HR, and then the percentage of maximum heart rate was 89.03% HRmax. Compared this study with the previous research results, our field hockey coaches and trainers regularly measure and evaluate field hockey players' general physical strength and professional cardiorespiratory system fitness, and based on these physical fitness levels, practical measures to improve

their physical strength are provided. This study may provide useful information to the coaches to develop their specific and sophisticated training program.

**Keywords** Body Composition, Field Hockey, Cardiorespiratory Function, Anaerobic Threshold (AT)

## 1. Introduction

The field hockey game requires dribbling the ball at high speed on an artificial turf field for 60 minutes in the 4th quarter. Based on strong physical contact and physical strength that intermittently changes speed and direction in defense and attack, power, and speed, it is an aerobic and anaerobic complex sports event, in which agility and accurate techniques are essential [1-3]. Field hockey is a popular sport enjoyed by both men and women in North America, Europe, Australia, etc. 119 countries around the world belong to the International Hockey Federation. It is a popular lifestyle sport [4], but South Korea has about 86 teams and approximately 1,250 registered players. Despite being an unpopular sport, the Korean women's hockey team maintains 12th place in the world rankings [5]. Field hockey is a sport similar to soccer and covers the required energy at a rate of 70% aerobic and 30% anaerobic [6].

Bale et al. [6,7,8,9] reported that the general body type of female hockey players was intermediate between the ectomorphic and endomorphic types, and the body fat percentage was around 25%. Field hockey players are

repetitively training to maintain their skills and physical strength. The oxygen consumption of high-level players is 5-6l per minute, midfielders move 7-9km in one game, and they consume considerable energy and have excellent cardiorespiratory fitness, so their high-level function is required [10].

On the other hand, relatively many studies have been reported on soccer events similar to ice hockey or field hockey events. Still, it is difficult to find research results targeting female field hockey players, and in particular, studies on respiratory circulation function are even more lacking. Therefore, based on the results of a previous study [6], which required low body fat percentage, muscle power, muscular endurance, agility, aerobic capacity, and flexibility as determinants of the performance of female field hockey players at the national team level among these factors and data related to respiratory and circulatory functions, this study aims to collect and present descriptive statistics. Moreover, it aims to provide important information for developing individual cardiorespiratory function and physical strength training programs for female field hockey players who participated in this study.

## 2. Materials and Methods

### 2.1. Participants

The research subjects volunteered to participate in this study were 17 female field hockey players in K-College who fully understood the purpose and intention of this

study and voluntarily expressed their intention to participate. All of them signed an experimental consent form indicating that they would voluntarily participate in the professional physical fitness measurement of respiratory and circulatory function in this study. The players who expressed their intention to participate were in good medical condition and had excellent performance. At the same time, it was decided to present the measurement results of the respiratory circulation function to them and to help prescribe an individual respiratory circulation system and physical training program. The physical and physiological characteristics of these study subjects are shown in Table 1.

### 2.2. Measurement of Physique and Body Composition

The physique and body composition measurement equipment in this study used Inbody 4.0 Space, a body composition analysis device [15]. Measured variables included body composition components such as height, weight, muscle mass, body mass index (BMI), and body fat percentage (%fat). When measuring body composition, coffee and alcohol were restricted along with sufficient sleep to minimize measurement error. As shown in Table 1, the subjects of this study first measured their height, entered their gender and age, wiped their hands and soles clean with an alcohol towel, held the handrails with both hands, and lifted both armpits to a height of 45 degrees. It was measured according to the manual of the InBody analyzer (InBody 770, Biospace) in a front-facing posture [15].

**Table 1.** Anthropometric Characteristics in female field hockey players (n=17)

Item	Ages (yrs)	Height (cm)	Weight (kg)	BMI (kg/m <sup>2</sup> )	HRmax (beats/min)	RER (VCO <sub>2</sub> /VO <sub>2</sub> )
Mean	20.69	163.96	58.35	21.72	193.59±6.05	1.16
± S.D.	±0.75	±4.92	±4.99	±1.82		±0.05

### 2.3. Cardio-Respiratory Function Test (GXT)

In this study, maximal oxygen intake, maximal ventilation, maximal heart rate, and anaerobic threshold were selected for cardiorespiratory function tests in female field hockey players. The purpose of measurement was to evaluate and measure aerobic cardiopulmonary exercise capacity. Aerobic cardiorespiratory capacity includes cardiovascular endurance, aerobic capacity, aerobic power, circulo-respiratory endurance, and cardio-respiratory endurance, and these words are used synonymously with other terms [11]. Traditionally, measuring maximal oxygen intake is known as the best cardiorespiratory fitness measurement method used to indicate cardiorespiratory capacity for success during the first half and second half of an endurance sports event of more than 3 minutes. One of the most popular treadmill protocols is the Bruce protocol, known as the earliest standard treadmill test [11]. However, in this study, KSSI (in South Korea) was used as the Graded Exercise Test (GXT) method, considering that the research subject was an elite athlete at the Korean national team level. In GXT of this measurement of the maximum oxygen intake, the determinant criterion for determining that it has been reached is (1) when the change in oxygen intake shows a plateau as the exercise load increases, (2) when the respiratory exchange rate (RER) is higher than 1.05 to 1.15, and (3) lactate in the blood. When the concentration is 8 to 10 mM/L or higher, (4) the heart rate is within 10 to 12 beats of the maximum heart rate predicted based on age ( $220 - \text{age}$ ), and (5) the subjective exercise intensity (RPE; Borg Scale) was 17 or higher [11, 13, 14]. When graded exercise load test, the subjects rested for 30 minutes before the GXT, and then the resting heart rate was checked using the Polar System, and the breathing gas was checked. An automatic respiratory gas analysis

system (Quark series, COSMED Srl, Italy) was used as a variable device [15].

### 2.4. Data Analysis

In this study, the measurement data obtained from GXT were exercise durations, maximum oxygen intake ( $\text{VO}_2\text{max}$ ), respiratory rate (Rfmax), maximum ventilation ( $\text{VE}_{\text{max}}$ ), carbon dioxide emissions ( $\text{VCO}_2$ ), oxygen intake per heart rate ( $\text{VO}_2/\text{HR}$ ), oxygen equivalent ( $\text{VE}/\text{VO}_2$ ), respiratory rate (R; RER; RQ), anaerobic threshold (AT), and maximum heart rate ( $\text{HR}_{\text{max}}$ ), that is, these respiratory circulatory variables were selected. The respiratory gas variables selected and collected in this way were analyzed and evaluated by calculating the average (M) and standard deviation (SD) of all participating athletes by using the SPSS/PC 13.0 statistical data program for Window and applying descriptive statistics techniques.

## 3. Results

In this study, respiratory gas variables related to cardiorespiratory function were measured using the Bruce protocol [11] as a GXT method in 17 female elite field hockey players.

The data of the respiratory and circulatory variables measured in this way were analyzed and evaluated by dividing the data into 1) **Cardiorespiratory system indicators**, 2) **Indices of Pulmonary ventilation**, and 3) **Functional indices of cardiorespiratory system** at the anaerobic threshold. The results are shown below. As shown in Table 2 below, the **cardiovascular system** of elite female field hockey players was as follows:

Table 2. Cardiorespiratory system indicators in female field hockey players (n=17)

Item	Exercise durations (min)	$\text{VO}_2\text{max}$ (ml/min)	$\text{VO}_2\text{max}$ (ml/kg/min)	$\text{VO}_2/\text{HR}$ (ml/bpm)	$\text{VCO}_2\text{max}$ (ml/min)
Mean	14.20	2894.5	49.58	14.92	3303.8
$\pm\text{S.D}$	$\pm 1.18$	$\pm 398.4$	$\pm 5.11$	$\pm 1.21$	$\pm 491.3$

During GXT, the exercise duration was 14.20 min, the maximum oxygen intake ( $\text{VO}_2\text{max}$ ) was 2894.5 ml/min and 49.58 ml/kg/min, the oxygen intake per heart rate ( $\text{VO}_2/\text{HR}$ ) was 14.92 ml/bpm, and the maximum carbon dioxide emission was 3330.8 ml/min.

As shown in Table 3, the pulmonary ventilation of elite female field hockey players was measured as respiratory rate per minute of 62.40 f/min, maximum ventilation of 105.15 l/min, ventilation per oxygen intake ( $\text{VE}/\text{VO}_2$ ) of 37.58 ml/min, and respiratory exchange rate (RER) of 1.16.

**Table 3.** Indices of Pulmonary ventilation in female field hockey players (n=17)

Item	Rf (b/min)	VE <sub>max</sub> (l/min)	VE/O <sub>2</sub> (ml/min)	RER (RQ)
Mean	62.40	105.15	37.58	1.16
±S.D	±6.38	±15.44	±2.01	±0.05

As shown in Table 4, the anaerobic threshold (AT), a representative variable of cardiorespiratory system in elite female field hockey players.

Oxygen intake ( $\text{VO}_2$ ) of AT level was 45.55 ml/kg/min, the percentage of maximum oxygen intake was 80.59%  $\text{VO}_2\text{max}$ , and the heart rate at the AT level was 172.29HR, the percentage of maximum heart rate was 89.03% HR.

**Table 4.** Funtional indices of cardiorespiratory system at AT in female field hockey(n=17)

Item	$\text{VO}_2\text{max}$ (ml/kg/min)	$\text{VO}_2\text{max}$ (%)	Heart rate (AT)	HR <sub>max</sub> (%)
Mean	45.55	80.59	172.29	89.03
±S.D	±6.50	±8.33	±9.58	±4.58

## 4. Discussion

This study measured respiratory and circulatory variables using the KISS protocol [12] as a GXT method in 17 female field hockey players. Among the respiratory and circulatory system variables measured in this way, cardiovascular system and lung function-related variables were discussed by comparing and analyzing the results of previous studies of similar female field hockey subjects. Looking at the physical and anthropometric results of the female field hockey players participating in this study, the height was 163.96 cm, the weight was 58.35 kg, the BMI was 22.17 kg/m<sup>2</sup>, and the maximum heart rate was 193.59 HR<sub>max</sub>. When these results are compared with previous studies on female field hockey players, the age of the Spanish semiprofessional female player was 20.0 years old, the weight was 60.7kg, the height was 167.0cm, and the player experience was 11.0 years old [16]. The age of the Indian Junior female hockey player was 18.2 years old, the height was 158.3 cm, the weight was 48.6 kg, the BMI was 19.5, and the body fat percentage was 17.3% fat [17]. The average age of the Italian field hockey team female

players was 28.8 years old, the height was 163.0 cm, the weight was 57.98 kg, the BMI was 21.83, and the body fat percentage was 15.75% fat [18]. The US Olympian was 165.0 cm tall and weighed 15.75% [18]. An American NCAA Division III player was reported to be 19.33 years old, 161.0 cm tall, 64.35 kg in weight, and 21.9% fat in body fat [19]. In terms of physical and anthropometric aspects, when directly or indirectly comparing the subjects of this study with the subjects of previous overseas studies, it is judged that there is no significant superior or inferior item, and only height and weight are slightly lower than Canadian and American players. It is lower, and in terms of body mass index (BMI), it can be evaluated at a similar level to other foreign athletes. The maximum oxygen intake ( $\text{VO}_2\text{max}$ ) of the female field hockey players in this study was 2894.5 ml/min and 49.58 ml/kg/min, and the maximum ventilation (VE<sub>max</sub>) and oxygen intake ( $\text{VE}/\text{VO}_2$ ) were 105.15 l/min & 37.58, respectively. It was evaluated in ml/min. In addition, the anaerobic threshold (AT) level was 80.59%  $\text{VO}_2$  max of maximum oxygen intake and 89.03% HR<sub>max</sub> of maximum heart rate, respectively. According to the results of previous foreign studies conducted on elite female hockey players [20-24], the results of this study were 55.77 (±4.70) in the case of US NCAA Division I female field hockey players. Reported in ml/kg/min [20], the data showed 52.9 (±2.9) ml/kg/min and 40.1(±1.0) ml/kg/min [24] for female hockey players at Nottingham Trent University [21]. Summarizing the results of previous overseas studies mentioned above, this study found a range of about 15 ml/kg/min from the highest level of 55.77(±4.70) ml/kg/min to the lowest level of 40.1(±1.0) ml/kg/min. Comparison and analysis of these preceding studies with female field hockey players are somewhat lower than those of the US NCAA Division and Nottingham Trent teams. According to a recent overseas study, Chilean female field hockey players' maximum oxygen intake before and after the high-intensity interval training (HIIT) program was 37.50 ml/kg/min and 40.20 ml/kg/min, respectively [25]. US NCAA Division 3 players reported that their maximum oxygen intake improved from 45.39 ml/kg/min to 48.22 ml/kg/min for 4 weeks before and after off-season training [19]. According to the ACSM fitness guidelines [26], the aerobic fitness of these US NCAA Division III players was evaluated as equivalent to the "excellent" level. The cardiorespiratory system fitness of female field hockey players in this study was 49.58 ml/kg/min, similar to or slightly higher than the US team's 48.22 ml/kg/min. This standing can be evaluated as an excellent level for female field hockey players. However, NCAA Division I players in the US could be evaluated at a much higher level than the subjects in this study at 55.77 ml/kg/min. In a similar event, the average peak oxygen intake of female ice hockey players in Canada was reported to be 44.62 ml/kg/min [27]. Field hockey players require cardio-respiratory capacity, endurance, and muscular

power because consistent speed and direction change are required during the game [25, 28, 29]. Similarly, other studies have suggested that basketball and hockey players need training programs such as high-intensity interval training (HIIT) to significantly increase  $VO_2$  max [25, 28, 30]. In another latest HIIT program study based on the results of these preceding studies, the body composition (muscle mass, body fat percentage), general physical strength (jumping performance,  $VO_2$ max), and professional fitness (pushing speed, dribbling speed, shooting speed, dribbling speed, shooting speed) of Chilean female field hockey players were considered. As a result of analyzing the effect of accuracy, there were significant improvements in muscle mass, jump performance, maximum oxygen consumption ( $VO_2$ max), dribbling speed, and shooting accuracy, and at the same time, significant improvements in fat mass and pushing speed, which was confirmed to be reduced [25]. As a result of comprehensively comparing and analyzing these previous research results, a useful training method is recommended for female field hockey players in body composition (muscle mass, body fat mass, body mass index, etc.), considering the determinants of field hockey players' performance. There is an urgent need for a customized physical fitness training method that can improve cardiovascular capacity ( $VO_2$  max, AT), speed, and agility. When considering these research results, field hockey coaches and trainers regularly measure and evaluate the general and professional fitness of field hockey players and, based on these fitness levels, provide more effective training methods to improve their fitness (e.g., HIIT program). One will have to put effort into planning and developing these programs.

## 5. Conclusions

Summarizing these research results, the level of anthropometric variables of female field hockey players, indirectly comparing to the anthropometric data of female field hockey players in other countries overseas, is evaluated so that there is no significant significance or inferior item, but height and weight are slightly lower than Canadian and American players. Body Mass Index (BMI) can be evaluated similarly to foreign players. Maximum oxygen consumption is slightly lower than that of the US NCAA Division and Nottingham Trent teams but significantly higher than that of the Swedish and Indian groups when compared and analyzed with foreign field hockey female players. Regarding the level of anaerobic threshold, it is regrettable that there are almost no research results targeting female field hockey players in previous overseas studies. Based on the previous research results, field hockey coaches and trainers regularly measure and evaluate field hockey players' general physical strength and professional cardiorespiratory system fitness, and based on these physical fitness levels, practical measures

to improve their physical strength are provided. Coaches or trainers will have to put effort into planning and developing specific training methods to strengthen respiratory circulation fitness in female field hockey players. Still, as the age of these players increases, they prefer to strengthen the anaerobic threshold rather than the maximum oxygen intake. To improve the functional indicators of the cardiorespiratory system of the athletes participating in this study, it is recommended to use means from athletics such as middle and long distance running, or interval training is recommended such as load - run 400 meters 60-70% of MPK; rest - 400 meters warm-up run, and perform 6 approaches. Perform HIIT program, etc.

Aerobic and anaerobic powers of female hockey players are required differently for each position on the specificity of field hockey. Specific and sophisticated analyses of professional physical strength and performance reflecting each position are recommended in follow-up studies.

## Acknowledgements

The authors gratefully thank all subjects for participating in this study.

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