ARC Journal of Research in Sports Medicine
Volume 4, Issue 1, 2019, PP 17-24
www.arcjournals.org

Physiological Fitness Profile of NCAA Division I Female Field Hockey Players

Valerie Georgia Smith, Roop Chand Jayaraman*

School of Health Sciences, Exercise and Health Sciences Division, Central Michigan University, Health Professions Building 2244, Mount Pleasant, MI 48859, U.S.A

Corresponding Author:** ***Roop Chand Jayaraman, *School of Health Sciences, Exercise and Health Sciences Division, Central Michigan University, Health Professions Building 2244, Mount Pleasant, MI 48859, U.S.A,* ***Email:*** *r.jayaraman@cmich.edu*

Abstract: *Field hockey, one of the world's oldest competitive sports, requires high levels of muscular strength and endurance. Despite its worldwide popularity, little is known about the physiological fitness profile of collegiate female field hockey player. The purpose of our study was to measure the physiological fitness and lipid profiles of collegiate female field hockey athletes. Fifteen female members of an NCAA Division I Field Hockey team (age 19.9 ± 1.1 years, height 161.4 ± 7.0 cm, mass 61.1±10.9 Kg) completed the following assessments, body composition (hydrostatic weighing) to evaluate percent body fat (%BF), body mass index (BMI), and incremental treadmill (modified Bruce Protocol) to assess maximal oxygen uptake (VO2max), and isokinetic strength (CYBEX Norm Dynamometer) to measure knee extensor and flexor muscle group peak torque production. Fasting blood samples were also collected and analyzed at our local clinic by licensed clinical staff. Study participants tested at a higher fitness level than previously reported in literature, relative VO2max: 55.77 ± 4.70 ml/kg/min (mean ± SD), absolute VO_2max: 3.38 ± 0.50 L/min, %BF: 22.39 ± 0.05, BMI: 23.67 ± 3.08, right H:Q (75 ± 21%), left H:Q (77 ± 18.5%) and peak torque: 69.83 ± 18.88 ft/lbs. Fasting glucose (91.33 mg/dl ± 2.39), triglycerides (82.27 mg/dL± 8.17), total cholesterol (176.13 mg/dl ± 10.09), low-density lipoprotein cholesterol (98.13 mg/dL± 9.22), high-density lipoprotein cholesterol (61.6 mg/dL± 3.57) were all within recommended range outlined in the Adult Treatment Panel (ATP III).Collegiate female field hockey athletes scored high in muscular strength and aerobic capacity. In addition, their blood lipid profiles and serum glucose concentration were well within the recommended range for age and gender.*

Keywords: *Field Hockey, Aerobic Capacity, Lipid Profile, Body Fat Percentage, BMI and Isokinetic Testing*

1. Introduction

The game of field hockey has a long history and is thought to have evolved from prehistoric times. Through the years the game has adapted the balls and sticks used, playing surfaces, as well as training and physiological demands expected of the athletes (19). Field Hockey is one of the most competitive and high-intensity team sports currently played (19). Intermittent sports, such as Field Hockey, require very high levels of muscular strength, endurance, cardiovascular fitness and an overall high degree of physical fitness (8). When examining women's Field Hockey, experts have determined that about 20% of the game is played in what is considered a high-intensity state such as sprinting (average of 5 seconds) with the other 80% spent in a low-intensity state such as jogging or walking (average of 18 seconds) (8). Based on these estimates, it can be assumed that athletes within the sport of field hockey rely on both aerobic and anaerobic energy systems. However, due to the large number of players on the field (11 players per team) and the limited roster size, current field hockey training tends to predominately address the aerobic energy system.

The best indicator of an individual's maximum aerobic capacity is maximal oxygen up take (VO_2max) (19). In the sport of Field Hockey, considered to be a high intensity sport, having a high level of aerobic fitness is believed to enhance the recovery time (17). Field Hockey players participate in repeated bouts of maximal exercise especially in game situations and is positively related to various metabolic indicators of aerobic fitness (2). Knowing a player's maximum aerobic capacity and giving an athlete a target goal or range will improve their on the field performance. But when examining current research, the only parameters that were found was in a review done by Reilly and Borrie which gave the range of a group of elite Field Hockey players; an estimated range VO_2 should range between 45 to 59 ml/kg/min (19). No other parameters have been set for Field Hockey athletes and they should therefore be further examined.

Field Hockey is a sport where the athletes must be able to accelerate quickly to move across the field efficiently and excess body fat (%BF) may hinder their ability to accelerate. Densitometry is one of the most frequently use laboratory method used to measure percent body fat (27). This method will help determine the body density using Archimedes' Principle which is based off of 4 measurements: mass, air mass when immersed at residual lung volume, water density and residual lung volume (27). Withers et. al stated that in Newtons Second Law (a=F/M) that an increase in fat mass (FM) without a concomitant amount of force exerted by the muscles will then decrease one's acceleration (27). An athlete who has extra FM will have to expend extra energy in both horizontal and vertical displacement (27). When excess energy is expended, early onset of fatigue is most likely which in turn will likely increase the risk of injury and affect player performance. Therefore the %BF is an important component of an elite performer's physiological profile (27).

At the collegiate level, physiological factors play a large part in a team's win and loss record with, body weight and body composition as important factors (24,26). Over a college athletes' career, it is important to monitor performance, training, and dieting regimens and an accurate way to do this is by quantifying body composition (24,13). An easy, inexpensive and very fast way to do this is by obtaining Body Mass Index (BMI (kg x m^{-2})). More recently, there have been debates about whether body weight itself or BMI is accurate in the athletic population (24,16,14,17). In a study conducted by Ode et al., it was concluded that BMI should be used cautiously when classifying fatness in college athletes and non-athletes (16). Within an athletic population it is important to know the difference between fat mass (FM) and fat-free mass (FFM) and BMI does not discriminate between FM and FFM. Field Hockey players vary in height and weight and according to the research, BMI may not be a valid measure for this specific population of athlete.

Field hockey being an old sport, has undergone changes from game rules to the equipment and the surface that the game is played on in order to make the game faster, more entertaining, and safer (20). Rishira et. al conducted a study examining the rate, the profile, and severity of injuries associated with the sport. The results of this study showed that out of every 1,000 Field Hockey players, 70 of them were at a significantly greater risk of injury during the second half of a game or practice due to fatigue, leading to belief that fatigue plays a great role on why athletes get injured.

Injury prevention is a goal of strength and conditioning coaches, sport coaches, and athletes. A way to measure one's predisposition to anterior cruciate ligament (ACL) injury is by measuring the difference in hamstrings to quadriceps ratios (H:Q) (11). This ratio has been used to examine the similarity between hamstrings and quadriceps moment-velocity patterns and to assess knee functional ability and muscle balance (21,6,13,10). Baratta et. al found that athletes who did not regularly exercise their hamstrings had a significant decrease in hamstrings activation in comparison to athletes who regularly exercised/trained their hamstrings (8,14). Quadriceps that are over developed in comparison to hamstring often results in decreased hamstrings co-activation, thereby increasing the risk for non-contact ACL injury (8,4). Measuring and monitoring Field Hockey athletes H:Q ratio's will allow coaches' to implement different training protocols to reduce the risk of non-contact ACL injury.

There is considerable amount of evidence that indicates that physical activity exerts beneficial effects on several global measures of cardiovascular health, specifically, lipid profile. A study conducted by Lippi etal. examined the effect of vigorous aerobic training protocols on blood lipid profiles (9). A blood lipid comparison was done between a healthy male control group, professional cross-country skiers, and professional cyclists. Lippi and others found that total cholesterol (TC), high-density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides, TC:LDL ratio and atherogenic index of plasma were significantly lower in both sets of professional athletes compared to healthy controls (9). From these results, it is reasonable to concluded that vigorous aerobic training leads to improvements in blood lipid profile. Research has yet to examine aerobic sports like field hockey to see if the same concept can be applied to field sports. With the assumption that the field hockey players are mainly aerobic athletes, it can be assumed that they should have blood lipid profiles similar to the professional athletes reported in Lippi et al.

Despite field hockey's worldwide popularity, little is known about the parameters of players conditioning levels. Physiological profiles may become of increasing importance because they are predictive of on-field performance and injury risk. With an understanding of the physical demands players and coaches will then have the ability to determine appropriate in and off-season training. It is also important for the athletes to know their true fitness status so that they can adjust training for better overall performance. Therefore, the purpose of this study is to measure the physiological fitness and lipid profiles of collegiate female Field Hockey athletes. Considering the competitive success of these athletes and the physical demands placed on them by the sport, we expect that female Field Hockey players will have relatively high levels of physical fitness.

2. METHODS

Fifteen members of a Women's Division I Field Hockey team were recruited for this investigation. All participation was voluntary, collection was during the off-season and researchers had approval from University Department of Athletics, the Head Women's Field Hockey Coach and the Strength and Conditioning Coach. In addition, the University Institutional Review Board (IRB) approved all procedures prior to data collection.

For one week during their offseason each athlete preformed one test a day until all tests were completed. During this week there was no practice scheduled. On the first day, subjects were provided an overview of the study after written informed consents were obtained. Each test was proceeded by verbal instructions, demonstration, and a short specific warm-up period. Athletes at this time also had the opportunity to ask questions about the tests they would be performing. Subjects returned to the laboratory that same week on 3 different days and one additional day for a blood draw at our local clinic. Each day the subjects came in to perform one of 3 tests either the graded exercise test (VO_2max), Hydrostatic Weighing, or Isokinetic Testing that were conducted in University's Exercise Physiology Laboratory.

2.1. Graded Exercise Test

A graded exercise test was used to determine each athlete's VO_2max on a PARVO Medics integrated metabolic measurement system. A Modified Bruce Protocol was used consisting of a 3 minute warm up at 3mph and 0% grade. Each subsequent stage was 1 minute long starting at 3mph and 5% grade for stage one and increasing by 0.5mph each stage until volitional exhaustion. During the graded exercise test a 12-lead electrocardiogram was monitored and recorded, blood pressure was recorded electronically, and the oxygen and carbon dioxide contents of the expired air were analyzed.

2.2. Isokinetic Testing

Isokinetic testing was conducted using a CTBEX Norm Dynamometer System to determine hamstrings to quadriceps strength ratios. Before testing each athlete had a five-minute warm up on a Monarch bike and then performed 6 practice repetitions at 120^0 s^{-1} with concentric flexion and extension movements. The starting position was 90^0 of knee flexion and end point was 0^0 knee extension. A 25 second rest was given for any adjustments and questions then athletes performed 5 maximal effort repetitions.

2.3. Hydrostatic Weighing

Body composition was measured and determined using hydrostatic weighing. Athletes wore a bathing suit and were asked to fully submerge themselves in the pool. Once in the pool they were asked to perform a maximal exhalation while under water so that only residual volume was left in their lungs. After all air was exhaled they were asked to remain submerged for 5 seconds. This was repeated for 3 trails for each athlete and the highest submerged body weight was accepted and used for data analysis.

2.4. Blood Lipid Profile

Fasting blood samples were taken to analyze and determine each athlete's blood lipid panel. Samples were collected in a clinical setting at our local clinic by certified staff. Serum markers analyzed were as follows; HDL, LDL, TC, Triglycerides and fasting Glucose. These measures were then compared to healthy values from the Adult Treatment Panel Three, more commonly known as ATP III.

Data analysis was performed using Microsoft Excel, means ± standard deviations were reported for all the descriptive data and for the following variables, VO_2max, absolute VO_2, BMI, and percent body fat, isokinetic testing as well as blood serum markers. The mean ± standard deviation was also reported for all descriptive data.

3. Results

The purpose of this study was to measure the physiological fitness and lipid profiles of collegiate female field hockey athletes. Fifteen field hockey players participated in the study and underwent a series of fitness assessments. Measurements of muscular strength and endurance, body composition, and aerobic fitness were obtained as well as blood serum markers of health.

Fifteen members of a NCAA Division I Women's Field Hockey team (age 19.9 ± 1.1 years, height 161.4 ± 7.0 cm, mass 61.1±10.9 Kg) participated in this investigation with their demographic information shown in Table 1.

Table1. *Physical characteristics of NCAA Division I female field hockey players*

Age (yr)	18-21
Height (cm)	161 ± 7
Weight (kg)	61.1 ± 10.9

Values are expressed as mean ± SD, n = 15.

Athletes were asked to complete each of the following assessments to maximal effort or to the best of their ability. The results (mean ± SD) of the fitness tests are presented in Table 2.

Table2. *Physical fitness and isokinetic measures of NCAA Division I female field hockey players*

VO_2 Max	55.77 ± 4.70 mlO_2/kg/min
Absolute VO_2	3.38 ± 0.50 LO_2/min
BMI	23.67 ± 3.08
% Body Fat	22.39 ± 0.05%
Rt: Hamstring/Quadriceps	75 ± 21%
Lft: Hamstring/Quadriceps	77 ± 18.5%
Mean Peak Torque (ft/lb)	69.83 ± 18.88 ft/lb

Values are expressed as mean ± SD, n = 15.

Test analysis were as follows; graded exercise test (maximal aerobic capacity) VO_2max; (55.77 ± 4.70 mlO_2/kg/min), absolute VO_2max; (3.38 ± 0.50 L/min), isokinetic testing (CYBEX) right H:Q; (75 ± 21%), left H:Q; (77 ± 18.5%), peak torque (69.83 ± 18.88 ft/lb), body composition (hydrostatic weighing) %BF; (22.39 ± 0.05), BMI; (23.67 ± 3.08).

Figure 1, depicts the right and left hamstrings to quadriceps (H:Q) strength ratio of female field hockey players in relationship to other female athletes participating in NCAA Division I sports. The comparison data were gathered from the Exercise Science literature.

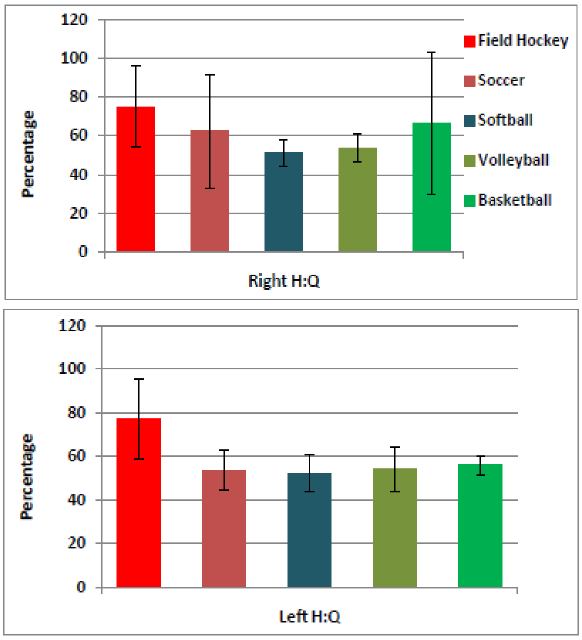

Figure1. *Right and left hamstrings to quadriceps (H:Q) strength ratio comparison of female field hockey players to other female athletes participating in NCAA Division I sports. Presented as mean ± SD*

Table3. *Blood serum lipid profile of female field hockey players at the NCAA Division I level*

Marker	**Field Hockey (mg/dL)**	**Optimal Values (mg/dL)**
HDL Cholesterol	61.6 ± 13.8	≥60
LDL Cholesterol	98.1 ± 35.7	<100
Total Cholesterol	176.1 ± 39.1	<200
Triglycerides	82.3 ± 31.6	≤150
Fasting Glucose	91.3 ± 9.3	≤110

Values are expressed as mean ± SD, n = 15.

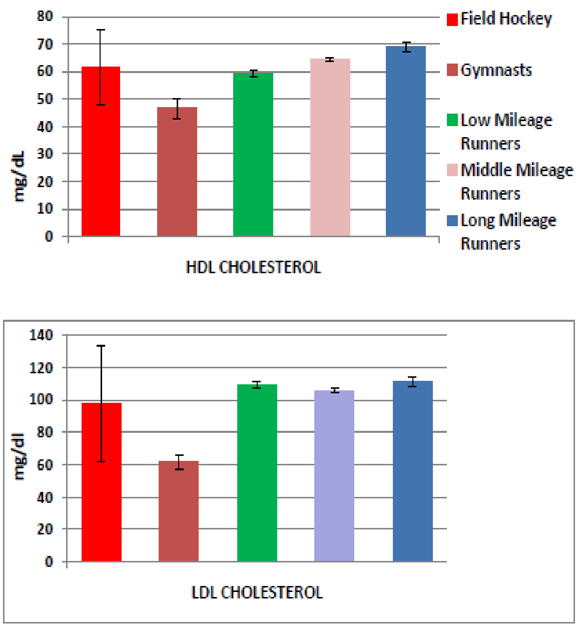

Figure2. *Lipid profile comparison of female field hockey players to other female athletes participating in NCAA Division I sports. Field Hockey & Gymnast data reported as ±SD. Runner data reported as ±SE*

Table 3 lists the blood serum markers (mean ± SD). Blood serum marker were as follows; fasting blood glucose (91.33 mg/dl ± 2.39), triglycerides (82.27 mg/dL± 8.17), total cholesterol (176.13 mg/dL± 10.09), low-density lipoprotein cholesterol (98.13 mg/dL± 9.22), high-density lipoprotein cholesterol (61.6 mg/dL±3.57).

Figure 2 shows serum lipid comparison of female field hockey players to other female athletes participating in NCAA Division I sports. All comparative data were extracted from the Exercise Science literature.

4. Discussion

Based on the review of literature this is the first study to document off-season physiological fitness profile of NCAA Division I female field hockey athletes. As hypothesized, our study results suggest that the physiological characteristics of elite Field hockey players places them in the very physically fit category compared to guidelines reported in the literature for various female athletes.

Since the sport of field hockey places a greater demand on the aerobic energy system it is important when measuring maximal aerobic capacity that VO_2max protocol is in line with the demands of the sport. Some believe that indoor laboratory treadmill tests are inaccurate for field athlete. As a result, through the years there have been several field tests that have been developed to evaluate physical performance of players who play field sports such as Field hockey and Soccer (8,5,7,15,25). Koen and Visscher developed two field tests to examine both aerobic and anaerobic energy systems (8). The first test developed was the Interval Shuttle Sprint Test (ISST) and the Interval Shuttle Run Test (ISRT), each of which were designed to examine each energy system in a game like situation versus using laboratory equipment (8). Koen, wanted to compare athletes ISST and ISRT performance to lab Wingate and VO_2max testing. Results confirmed that relative VO_2max contributed significantly to the number of 20m runs of the ISRT, with a percentage of shared variance of 54% (8). These results may indicate that using laboratory equipment to measure athlete's aerobic capacities are as effective as field measures despite the athletes being field athletes.

Previous research examining field hockey players mostly analyzed each athlete's interval sprint ability and interval run ability (8,2). Physiologically, field hockey is much like soccer and is best described as a repeated-sprint sport, requiring high levels of aerobic capacity. Reilly and Borriw measured VO_2max from the top female field hockey players worldwide from the college level to the Olympic level (19). VO_2max results of these athletes ranged from 42.9 – 59.3 $mlO_2/kg/min$. Maksaud et al. found that the USA collegiate field hockey players on average were had the lowest VO_2max, 42.9 $mlO_2/kg/min$ (11). Ready and der Merwe reported that the year leading up to the Los Angeles Olympics Canadian National Olympic female field hockey team had the highest VO2max, 59.3 mlO2/kg/min. One important note concerning these studies was that the Maksaud etal. study was published in 1976 and the Ready and der Merwe study was published in 1986 (11,18). The most recent data was produced by Lemmink and Visscher, where 21 women field hockey players of the second highest skill level in The Netherlands had a mean VO_2max of 48.7 ±4.6 ml/kg/min (8). NCAA Division I players that were tested in this study reported a mean VO_2max of 55.8 ± 4.7 ml/kg/min placing them well above the USA college team that Maksaud examined in 1976 and closer to the Canadian Olympic team (11,18).

Not only do our NCAA Division I athletes place well against other field hockey athletes but according to the American College of Sports Medicine (ACSM) they rank in the 90th percentile among females at their age (1). In comparison to other females VO_2max data, including those who are sedentary and those who participate in the following physical activities; cross-country skiing, running, swimming, speed skating, and fencing the athletes in the current research performed closest to swimmers and speed skaters (12). We believe that our athletes placed well above other college field hockey players because the sport has changed significantly over the last few decades and more emphasis has been placed on training year around. However, more research should be done on the aerobic capacity of female hockey players to reflect the current aerobic fitness levels of today's field hockey players.

Aerobically fit field hockey athletes should maintain a lean body mass and decrease the amount of fat mass (FM) to eliminate any unnecessary energy expenditure (27). If energy expenditure is kept to a minimum then fatigue is less likely to set in and performance level will be able to stay at a high level (27). According to ACSM, it is recommended for women under the age of 34 years old to have anywhere from 20 – 35%BF (1). With the athletic population, the ACSM %BF recommendation is 12 – 22%BF (1). After obtaining hydrostatic weighing measures for each subject a mean %BF was found to be 22.39 ± 0.05%. This measurement places the participants in the upper half of female athlete recommendation (1). Even with the placement on the high end of the category, these females still fell in the very lean category among females their age (1). Important to note that %BF may differ in-season due to training, and overall daily energy expenditure.

BMI is a measurement that does not distinguish the difference between the FM and FFM an individual has. It is most commonly used to identify a person's risk for cardiovascular disease, hypertension, and mortality rate. Field hockey athletes vary in height and weight but as shown in Table 1 the athlete's average height was 167cm and weight was around 67kg. Ode et. al argued that BMI does not consider shapes or leg length that differ from the norms and with the smaller athletes in our study, it was not surprising that the average BMI was 23 (16). Classifications set by ACSM places our athletes at the higher end of the normal category which includes a BMI range between 18.5 and 24.9 (1). Torstveit and Borgen concluded that BMI was not a valid measure for assessing or monitoring body composition in female athletes (24). Due to the large amount of muscular strength field hockey requires, it is highly probable that field hockey players muscle mass contributed to their body weight; which in turn may have contributed to the higher BMI. With an increase in muscle mass and a decrease in fat mass, the all-around performance of an athlete should improve (24).

Rishira et. al did a comparative study on the rate of injury in female field hockey athletes and ice hockey athletes (20). They concluded that field hockey athletes were at greater risk of injury and were more likely to be injured in the latter stages of games and practices (20). Over half of the injuries that were sustained by field hockey players were non-contact and they were most vulnerable to muscle strains and lower back, ankle/foot, and knee injuries (20). With these non-contact injuries, the playing fields was often blamed for the higher non-contact injury rates. Field hockey is played on a water-based surface that is supposed to assist in lessening the friction between footwear and the playing surface (20,23). In most cases the wetting of the field is done by field personal but if not adequately watered at the beginning of the game/practice session, then increased footwear friction caused by a "dry spot" can occur increasing the risk of knee and ankle injuries (20,23).

An assessment that is used to measure an athlete's predisposition to knee injuries is isokinetic testing. Evaluation of the quadriceps and hamstrings muscle strength that provides the magnitude or torque generated involves determining hamstrings to quadriceps (H:Q) strength ratio (21). With the knowledge that female field hockey athletes are at a higher risk for knee injuries, it will be helpful to know if strength imbalances exist (20). On average it would be ideal for an athlete to have a H:Q ratio between 50% and 80% (21,22). After the testing from our athletes, we found that they fell on the higher end of this range at 75 ± 21% for the right leg and 77 ± 18.5% for the left leg. These results placed them well within the acceptable range and not at an increased risk for knee injuries. When the H:Q ratio moves closer to 100%, the hamstrings have an increased functional capacity providing more stability to the knee joint and may reduce the risk of anterolateral subluxation of the tibia (11,22).

When comparing the H:Q ratio to the athletes in the Roseneet al. study, our athletes had the best ratio (21). Field hockey is a high-speed activity and balanced muscle activation around the knee will be extremely beneficial. One would expect that field hockey players would have similar numbers when compared to soccer athletes due to the similarity of movements involved in the two sports. However, our results, as shown in Figures 1, show that field hockey players had a greater ratio than the soccer players (21). This could be due to soccer's kicking component increasing quad strength and field hockey athletes are usually in a hunched over position placing extra strain on the hamstrings. Rosene et al. concluded that it would be beneficial to include a preseason evaluation of the H:Q ratio to track injuries to the lower extremities (21).

Serum blood lipids were analyzed and compared to the Adult Treatment Panel Three (ATPII). All serum markers are shown in Table 3 and fell within the normal range. According to the Center for Disease Control and Prevention (CDC) guidelines, a majority of health benefits can be achieved by only walking 2 miles most days of the week (26). Williams conducted a study to examine if increasing the amount of physical activity (i.e. running) would increase HDL cholesterol level in females (26). Williams found a positive correlation between running distance and increased HDL and decreased LDL (26). When our athletes HDL was compared to the HDL levels of those who participated in Williams study, as seen in Figure 3, the field hockey athletes ranked closest to those levels of low mileage runners (26). HDL is not a direct measure of physical fitness but is known to have a positive correlation with fitness levels despite genetic influence (26). Therefore, our female field hockey players are more likely to fall under the aerobically fit category.

5. Practical Application

This study investigated sport-specific physiological characteristics of elite NCAA Division I female field hockey players. Majority of the physiological characteristics in our study have been studied in the past and provided us with baseline data. However, the many changes in the sport of field hockey have occurred over the last few decades suggest that we need to more studies to provide normative data, and possibly off-season training motivation, for athletes competing at the Division I level.

The 4 tests that were performed in this study are reliable and valid measures of maximal aerobic capacity, body composition, muscular strength of hamstrings to quadriceps, and blood serum levels. Our findings were shared with the strength and conditioning coach to develop an in-season and off-season monitoring program. Furthermore, the results from our study can provide coaches with a starting point for identifying individual training areas that need to be emphasized. In most programs each athlete will be given a preseason training program. For athletes who do not stay in the area for the summer, most training is unsupervised and athletes are expected to meet the expectations set for them. During the off-season time, testing of physical fitness levels as a potential to motivate athletes to commit to their off-season training program.

Our study results suggest that female field hockey players have high fitness levels well above the norm for their age and sex. More importantly, our data suggests that field hockey players have a high aerobic capacity compared to other collegiate athletes and are most comparable to low mileage runners. Coaches should expect athletes to come aerobically conditioned. Not only will this increase their ability to perform at a higher level longer, prolong the onset of fatigue and could decrease the risk of injury. Body composition should be monitored throughout in-season and off-season with a goal of maintaining it between 12 and 22%. Body composition is most accurately obtained from %BF rather than BMI in athletes therefore coaches should use %BF while monitoring the athlete's body composition.

Coaches should maintain and enhance hamstring to quadriceps ratios. When creating a strength and conditioning program for these athletes, coaches should focus on muscular strength surrounding the ankle and knee joint which may decrease non-contact injuries to these joints (20). Programs should include neuromuscular training to counter dominant-leg dominance, ligament dominance, and quadriceps dominance (20). Rishira and co-workers research suggest that agility drills, balance exercises, flexibility, plyometrics, proprioception, and strengthening exercises are critical for injury prevention (20). Over all fitness levels of field hockey athletes is very high and blood serum levels all fell within normal ranges further supporting their high levels of fitness. In and off-season samples could be obtained to monitor all levels, but especially HDL levels, which has been positively correlated with high fitness levels. Field Hockey players should therefore undergo in-season and off-season training to maintain aerobic capacity, muscular strength, lean body mass and optimal blood serum levels in order to compete at the highest level in their sport. Entering the season with these high levels of fitness and maintaining it through the season should assist with performance on the field.

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Citation: *Valerie Georgia Smith, Roop Chand Jayaraman. Physiological Fitness Profile of NCAA Division I Female Field Hockey Players. ARC Journal of Research in Sports Medicine. 2019; 4(1):17-24.*

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