A Musculoskeletal Profile of Elite Female Soccer Players

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Abstract The purpose of this study is to identify lower-extremity (LE) musculoskeletal characteristics of elite female soccer players and to determine whether differences between dominant and nondominant extremities exist with respect to strength, flexibility, and range of motion. Physical data were collected from 26 female professional soccer players. Core control, hip and knee passive range of motion (PROM), LE flexibility, hip abductor strength, and dynamic functional alignment were assessed for each LE. Of 26 subjects, 21 scored 2/5 or less on core control. Mean hip internal rotation and external rotation were $33^\circ (\pm 8^\circ)$ and $25^\circ (\pm 6.7^\circ)$, respectively. All subjects had shortened two-joint hip flexors with an average knee flexion angle of $50^\circ (\pm 11^\circ)$ and increased femoral anteversion. Forty one of 48 dominant limbs and 42 of 48 nondominant limbs demon-

strated deviations from neutral alignment during step down or single-leg squat. Of 25 subjects, 15 demonstrated a stiff-knee landing and/or takeoff. All subjects demonstrated limitations in hip external rotation PROM and hip flexor length. There was no difference between dominant and nondominant LEs in all variables including hip abductor strength. Additional research is needed to determine if there is a correlation between the musculoskeletal characteristics, LE biomechanics, and potential risk for injury.

Level of evidence: IV

Keywords core · alignment · flexibility · range of motion · sports injury · strength

Introduction

The success of the US Women's National Soccer Team at the 1996 Olympic Games and the 1999 World Cup provided the impetus for the formation of a women's professional soccer league (Women's United Soccer Association) in the US in 2001. It has been recognized that collegiate and high school female soccer athletes are at a greater risk for tearing the anterior cruciate ligament (ACL) as compared to their male counterparts. Numerous papers have established that women cut and land with their knees in valgus, placing their knees at risk for injury [1–4]. Descriptive data exist for physical characteristics of elite male soccer players [5–7]; however, there is no published information regarding the musculoskeletal characteristics of elite female soccer players.

The purpose of this study is to develop a musculoskeletal profile of professional female soccer players. We hypothesized that elite female soccer players have increased femoral anteversion, asymmetrical hip range of motion (ROM), tight two-joint hip flexors, inadequate core control, and deviations in dynamic alignment that may increase risk for noncontact ACL injuries compared to normal. These measures were selected based on movement patterns required in soccer including kicking, running, planting,

Study protocol was approved by the Institutional Review Board at the Hospital for Special Surgery, New York, NY, USA.

Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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and pivoting, injury patterns or pain described to us by soccer athletes in our clinical practice, and our desire to investigate the relationship between the two. We also hypothesized that differences exist between dominant and nondominant extremities. In this population, leg dominance is defined by preferred kicking leg. Dominance can be identified on the basis of strength, balance, or skill. We predicted that the dominant leg would have greater ROM and/or flexibility because it is the skill leg and that the nondominant leg, because it is the foundation leg, would be stronger, less flexible, and less mobile.

Methods

Lower-extremity passive range of motion (PROM), flexibility, hip abductor strength, dynamic functional alignment, and core control in a group of elite female soccer athletes were prospectively evaluated as part of a preseason physical evaluation of subjects recruited from one Women's United Soccer Association soccer team as part of preseason physicals during training camp. Informed consent was obtained during an informational session designed to educate the athletes who had been drafted or recruited to try out for the team. The purpose of the study and the testing procedures were explained and consent for participation was obtained. Subjects were included if they were drafted or recruited to try out for the team. Athletes were excluded from the study if they declined to participate or if they were injured and not cleared by the medical staff. Twenty-six athletes participated in the study. Age ranged from 21 to 32 years with a mean age of 25. The mean number of years playing soccer was 18 (range 11 to 25). The study protocol (Institutional Review Board #: 22021) was approved by the Institutional Review Board of the Hospital for Special Surgery. Below is a detailed description of the measures used.

PROM was measured with a standard goniometer using techniques described by Norkin and White [8]. The tested motions were chosen to ensure that the flexibility measurements accurately reflected muscle length as opposed to limitations in joint ROM. Knee flexion PROM was measured in supine and PROM hip internal and external rotations were measured in prone with the hip in neutral and the knee flexed 90°. For hip rotation, one physical therapist stabilized the subject's pelvis and hip with one hand and positioned the subject's lower extremity with the other hand, while the second physical therapist measured the motion.

Craig's test or trochanteric prominent angle test was performed to measure femoral anteversion or the angle the femoral neck makes with the femoral condyles [9, 10]. One physical therapist rotated the hip and palpated the position at which the greater trochanter was most prominently lateral. The second physical therapist measured, with a goniometer, the angle of hip internal rotation at which this occurred.

Flexibility of the hamstrings, hip flexors, quadriceps, and gastrocnemius was measured utilizing a standard goniometer. Flexibility is defined as the length and elasticity of the structures that cross a joint. The procedures for all measurements, with the exception of flexibility of the

anterior hip structures, were described by Kendall and McCreary [11]. Hip flexor and rectus femoris lengths were measured utilizing the Thomas test and the prone knee flexion angle, respectively. Hamstring length was measured utilizing the straight leg raise (SLR). Flexibility of the anterior hip structures was measured using a modification of the prone figure-of-four position described by McConnell [12]. McConnell measures the distance from the anterior superior iliac spine to the table when the hip being tested is abducted and externally rotated while the knee of that leg is flexed. The test was modified by examining the subject in supine to help control the rotation of the lumbar spine and pelvis which occurs during testing in prone thus altering the results. In supine, the distance from the lateral joint line of the knee to the table was measured in centimeters when the knee is flexed to the level of the contralateral tibial tubercle and the hip is externally rotated. The test may be considered a combination of Patrick's test ("Faber") [13] and the prone figure-of-four tests (Fig. 1).

The strength of the hip abductors was assessed with the Nicholas Manual Muscle Tester© (Lafayette Instruments, Lafayette, IN, USA) as described by Kendall and McCreary [11]. This dynamometer has been reported to have excellent interrater reliability for testing hip abduction isometric strength [14]. The subject's lower extremity was positioned in abduction, slight extension, and external rotation in order to isolate the gluteus medius. As one examiner stabilized the pelvis to offset the tendency to roll, tilt, and/or hike/drop, the other examiner held the muscle tester against the leg proximal to the lateral malleolus. The maximal force needed to maintain this position against the examiner's pressure was recorded, as the subject abducted their hip against the device for 2 s. All subjects were given the same instructions. No verbal encouragement was given during the testing so as not to affect the subjects' performance. Three trials were performed in alternating fashion on each limb and the mean value was used for analysis.

Fig. 1 Supine figure-of-four test is used to measure flexibility of the anterior hip structures. The distance from the lateral joint line of the knee to the table is measured in centimeters when the knee is flexed to the level of the contralateral tibial tubercle and the hip is externally rotated

Torque measurements were calculated by converting the output measured with the muscle tester from kilograms to newtons and multiplying that by the subject's leg length in meters.

Core control was defined as the ability of the lower abdominal muscles to stabilize the spine during movements of the lower extremities and was evaluated utilizing a Pressure Biofeedback Stabilizer© (Chattanooga Group Inc., Hixson, TN, USA) placed under the spine at the S2 level (Fig. 2) to detect movement of the lumbopelvic region. With the subject in a hook-lying position, the Stabilizer© was inflated to 40 mmHg; this pressure has been found clinically to be appropriate to fill the space between the naturally existing lumbar curve and the testing surface [15]. Each subject was given the same verbal cues by the same examiner, *"Contract your abdominal muscles by pulling your belly button toward your spine."* This causes the pressure in the Stabilizer© to rise slightly and is recorded as the start position. The athlete was instructed to maintain this throughout by holding the contraction of her abdominal muscles, avoiding distention of her abdomen, and keeping her back flat. From the hook-lying position, for level 1, the subject actively flexes one hip to greater than 90°, then flexes the second hip to the same level. A change in the pressure level of less than 10 mmHg (either up or down) from the starting position demonstrates core control and was recorded as successful completion of a level. The subsequent level was then attempted. With each successive level, the legs are moving further away from the spine, making it increasingly difficult for the abdominals to stabilize the spine. During successful completion of level 5, the subject lifts both feet to flex her hips to 90° and then extends her hips and knees and lowers both lower extremities to the supporting surface. This grading system is based on the lower abdominal muscle exercise progression of Sahrman [10] with a minor modification of level 0.5 (Table 1). If the subject was unable to complete level 1, she was asked to perform a single-leg heel slide with the

opposite limb supported on the surface (level 0.5). Testing of these subjects led to the described modification, as all subjects who were not able to perform level 1 were in fact able to perform the heel slide maneuver. The Stabilizer© assesses if movement of the spine occurs during lower-extremity movements. For example, arching or extension of the lumbar spine (anterior pelvic tilt) is reflected in a decrease in pressure from the baseline. This test examines the ability of the trunk muscles to hold the lumbopelvic region in a steady position which determines successful completion of a level.

Dynamic functional alignment of the hip, knee, and ankle were observed as the subject performed a single-leg squat, performed a forward step down from an 8-in. platform, and landed a jump from a 12-in. platform. Subjects performed three trials on each leg in alternating fashion. A grid was placed on the wall behind the subjects to help identify obliquity. The subjects were graded independently by the same two physical therapists. The presence or absence of deviation from neutral at the hip, knee, and/or foot during each task was noted, as well as the quality or control of movement (Figs. 3, 4, and 5). If the subject experienced pain, the task was not graded and thus marked as "not assessed," as the presence of pain can cause deviation. A deviation was recorded only if both therapists agreed. Observations focused on deviations in the frontal, sagittal, and transverse planes. The hip was observed for movement into adduction or abduction, internal or external rotation, or pelvic obliquity (rise of the ipsilateral hip). The knee was observed for movement into varus or valgus and for quality of quadriceps control. Poor control was confirmed by nonfluid movement, a hard landing, or a "wobble"/"shake" of the knee with the dynamic task. The foot and ankle were observed for increased pronation or supination or early heel rise.

PROM, flexibility, strength, and functional alignment values were compared using dominant and nondominant legs

Fig. 2 **a** The Stabilizer© is placed under the spine to detect if movement of the lumbar spine occurs during lower-extremity movements. The subject watches the reading on the gauge from the outset of the test. **b** The Pressure Biofeedback Stabilizer© consists of a combined gauge/inflation bulb and registers pressure changes via a connected pressure cell

Table 1 Sahrman lower abdominal exercise progression

Level Sahrman Exercise	
0	Unable to complete exercise
0.5	Slide one foot to extend the hip and knee
1.0 1A	Flex hip to $>90^\circ$ and lift the other foot
1.5 1B	Flex hip to 90° and lift the other foot
2 2	Flex hip to 90° , lift and slide other foot to extend hip and knee
3 3	Flex hip to 90° , lift foot, and extend leg without touching supporting surface
4 4	Slide both feet along supporting surface into extension and return to flexion
5 5	Lift both feet off the supporting surface, flex the hips to 90° , extend the knees and hips, and lower both lower extremities to the supporting surface

of the 26 subjects. One player reported equal dominance of both legs; therefore, in this case, each leg was recorded as dominant. Thus, there are 27 dominant and 25 nondominant legs.

To ensure consistent and accurate measurements, each parameter was evaluated by the same examiner utilizing the same methods. All tests were performed in a single day, in the same order, and by the same therapist for all subjects.

We used frequency distributions, mean values, and standard deviations to describe the musculoskeletal profile of professional female soccer players. To compare dominant legs to the norm, we used the *t* test when comparing continuous variables and chi-squared when comparing categorical variables. To compare the measures of the dominant and nondominant sides, paired *t* tests were used. Differences between groups were considered significant if the *p* value was less than 0.05.

Results

Physical testing of the players demonstrated a mean weight of 62.5 ± 7.2 kg (range 54.5–83.6 kg) and a mean height of 166.9 ± 6.7 cm (range 157.5–185.4 cm).

Total hip PROM (internal plus external rotation) was 58° for dominant legs and 56° for nondominant legs (Table 2). External rotation (ER) was 25° and 24° for dominant and nondominant legs. Internal rotation (IR) was 33° and 32° , respectively. There was no statistically significant difference between dominant and nondominant legs for internal ($p=0.445$) or external rotation ($p=0.660$). All subjects presented with increased femoral anteversion as measured by Craig's test. Increased femoral anteversion is present when the angle of hip internal rotation is greater than 15° [13]. There was no statistically significant

Fig. 3 **a** During testing of dynamic functional alignment, the subject performs a (L) single-leg squat without deviation from neutral. **b** Deviation from neutral alignment at the hip and knee is observed during the (R) right single leg squat

Fig. 4 **a** During testing of dynamic functional alignment, a forward step down with her (R) right leg is performed without deviation from neutral alignment. **b** In this subject, a forward step down with her (R) right leg reveals deviation from neutral alignment with pelvic obliquity

difference in Craig's test between dominant and nondominant legs.

All subjects demonstrated shortening of their two-joint hip flexors as evidenced by decreased knee flexion angle as

compared to normal values during the Thomas test (Table 3). Significant deviations were observed in the Thomas test position (Fig. 6). These deviations are indicative of muscle imbalance about the hip and knee. In dominant legs, 25/27

Fig. 5 **a** This subject demonstrates neutral alignment of hips, knees, and ankles and adequate flexion of the hips and knees while landing from a jump off a 12-in. platform. **b** During this attempt, the subject lands from a jump with (R) right knee valgus

Table 2 Passive range of motion

	Dominant		Nondominant		Normal values ^a
	Mean±SD	Range	Mean±SD	Range	
Knee flexion (°)	147.0±3.6	138–152	148.0±4.0	136–152	135
Ankle dorsiflexion (°)	20.0±3.1	14–25	20.0±3.1	13–26	20
Femoral anteversion (°)	23.0±5.1	15–32	22.0±4.1	16–30	15 ^b
Hip external rotation ROM (°)	25.0±6.7	11–38	24.0±5.9	8–38	45
Hip internal rotation ROM (°)	33±8	16–47	32.0±7.4	20–46	45

^a American Academy of Orthopedic Surgeons [16]^b Magee [13]

hips were abducted. Of these 25 hips, 12 were in femoral internal rotation (four had concomitant tibial ER); five were in femoral external rotation (one had concomitant hip flexion), and eight were in neutral femoral rotation (one had hip flexion; one had lateral deviation of the patella, and one had tibial ER). Two of the 27 dominant hips were in neutral abduction (one had femoral internal rotation; one had neutral femoral rotation but presented with lateral patella deviation). When the femur was passively moved into a neutral position 13/25 abducted hips showed a compensatory lateral position of the patella and 12/25 showed compensatory tibial external rotation.

In nondominant legs, 25/25 hips were abducted. Of these 25 hips, ten were in femoral internal rotation (three had concomitant tibial ER); six were in femoral external rotation (two had concomitant tibial ER), and nine were in neutral femoral rotation (one had concomitant lateral deviation of the patella). When the femur was passively moved into a neutral position, 15 demonstrated a compensatory lateral patellar position and ten showed compensatory external rotation of the tibia.

There was no difference in knee flexion angle with the Thomas test between dominant and nondominant legs (p value=0.25).

Mean abductor torques (Table 4) demonstrated no difference between dominant and nondominant legs (p =0.288).

Of 26 subjects, 13 were graded as level 1.5 on testing for core control (Table 5). With successful completion of this level, the subject is able to control the movement of the spine while actively flexing one hip to 90°, then her second hip to the same level from a hook-lying position. Four

athletes graded less than 1.5. Another four of the remaining nine athletes scored a level 2, with only one athlete achieving level 5.

Of all subjects tested, only four subjects were able to perform a dynamic functional task (single-leg squat, forward step down, landing from a jump) without deviation. Not all players were assessed for all three dynamic functional alignment tasks. Twenty-four of 27 and 24/25 of the dominant and nondominant limbs were tested for single-leg squat and forward step down, respectively. In addition, one subject presented with no deviations during the 8-in. step down and single-leg squat on her dominant and nondominant legs (Table 6). During the dominant single-leg squat ($n=24$), 20 subjects demonstrated deviation in the hip, 21 in the knee, and 11 in the foot. The nondominant single-leg squat ($n=24$) revealed 19 subjects with deviations in the hip, 20 with deviations in the knee, and eight in the foot. During the step down using the dominant leg, 20 had deviations in the hip, 17 in the knee, and seven in the foot. The step down with the nondominant leg revealed 22 with deviations in the hip, 14 in the knee, and four in the foot. One subject did not perform the jumping task. Out of 25 subjects who performed the task of landing from a 12-in. platform, 15 demonstrated a stiff-knee landing and/or takeoff. A “stiff knee” is defined here as having minimal (<30°) hip and knee flexion.

Discussion

There are limited published data available that focus on the musculoskeletal attributes of female professional soccer

Table 3 Flexibility

	Dominant		Nondominant		Normal values ^a
	Mean±SD	Range	Mean±SD	Range	
Hip flexor length (°)	50±11	31–74	51±10	35–74	80
Prone knee flexion (°)	127.0±4.7	117–137	128.0±5.2	117–137	135
Hamstring length (°)	77.0±6.1	65–90	73.0±7.3	50–86	80
Gastrocnemius length (°)	9±3	5–17	9.8±3.4	5–18	10
Figure four (cm)	12.0±3.1	7.0–18.5	12.50±2.87	4.0–17.5	n/a

^a Kendall and McCreary [11]

Fig. 6 **a** The deviations of the dominant leg from the neutral position is outlined in this flow diagram. **b** The deviations of the nondominant leg from the neutral position is outlined in this flow diagram

players. Our profile has begun to identify the presence of musculoskeletal characteristics in these athletes that may be associated with injury risk.

Normal ranges of hip internal and external rotation have been reported as 45° and 45°, respectively [16]. Active hip rotation (AROM) in healthy female subjects with a mean age of 21.8 years was recorded as 38° for internal rotation and 46° for external rotation with a mean total hip rotation

Table 5 Core control

Level	N=26 subjects
<1	2
1	2
1.5	13
2	4
3	3
4	1
5	1
Mean level±SD	1.9±1

of 83° [17]. In our subjects, the mean PROM of hip internal rotation/external rotation was 33°/25° for dominant legs and 32°/24° for nondominant legs with a mean total hip rotation of 58° and 56°, respectively. Normal values for internal rotation were present in eight of 27 dominant hips and seven of 25 nondominant hips. No subjects demonstrated normal values for hip external rotation in either hip. Although our subjects on average were limited in both internal and external hip rotation, external rotation was more limited than internal rotation. In our study, the total hip ROM was similar side to side but very different when compared to the total hip range of motion in the group of Simoneau et al. [17]. In general, PROM should be greater than AROM; however, we observed lower measurements for PROM. This contrast highlights the significant limitation in hip rotation range of motion in this population.

Femoral neck anteversion (FNA) is greatest at birth—the average FNA angle is 31° in the newborn. During postnatal development, a reduction of the FNA angle usually occurs during growth. The average FNA angle is 26° by 5 years of age, 21° by 9 years of age, and 15° by 16 years of age. The FNA angle, therefore, diminishes about 1.5° a year until about 15 years of age where in the adult it averages about 15° [18]. All subjects in this study demonstrated increased femoral anteversion in at least one limb. What causes this increase in femoral neck anteversion? Lack of femoral regression, heredity, torsional forces applied perpendicularly by passive muscle tension or active muscle contraction to the epiphyseal plate of the femur, and/or behavioral factors have been suggested. Bony as well as soft tissue adaptations in response to many years of playing soccer may be responsible for this increased FNA in our subjects. This may be comparable to the adaptive changes of humeral head retroversion in throwing athletes observed over time [19–21].

All subjects exhibited shortness in their two-joint hip flexors as demonstrated by the resting posture of their legs in the Thomas test position. Muscle shortening may be attributed to the habitual recruitment of hip flexors during soccer skills. Variations, such as abduction of the thigh as the hip extends, lateral deviation of the patella, extension of the knee with hip adduction, internal rotation of the thigh and/or external rotation of the tibia on the femur, indicate shortness of the tensor fascia latae. Shortness in the sartorius is indicated when any combination of three or

Table 4 Gluteus medius strength

	Dominant		Nondominant	
	Mean±SD	Range	Mean±SD	Range
Hip abduction torque (nm)*	135.2±26.3	94.9–182.6	130.2±18.1	102.6–167.7

* $p=0.288$

Table 6 Dynamic functional alignment

	Dominant (<i>n</i> =27)			Nondominant (<i>n</i> =25)		
	Hip	Knee	Foot	Hip	Knee	Foot
Squat						
Deviation	20	21	11	19	20	8
No deviation	4	3	13	5	4	16
Not assessed	3	3	3	1	1	1
Eight-inch step down						
Deviation	20	17	7	22	14	4
No deviation	4	7	17	2	10	20
Not assessed	3	3	3	1	1	1

more of the following are evident: hip abduction, hip flexion, hip external rotation, and knee flexion [11]. Many deviations and combinations of deviations were noted, indicating a high prevalence of muscle imbalances at the hip in these subjects. During the leg cocking phase of the soccer kick, the knee is flexed as the hip extends creating an anterior pelvic tilt in the presence of shortened hip flexors. Clinically, excessive anterior tilt of the pelvis has been associated with increased femoral internal rotation, genu valgus, genu recurvatum, and subtalar pronation [22]—the “position of no return” in ACL injuries described by Ireland [23]. Inadequate length of the hip flexors could create excessive lumbar extension, which could result in low back pain or injury. Repeated hyperextension and rotation are predisposing factors in the etiology of spondylolysis. Several sports, including soccer, are associated with the development of spondylolysis. Playing soccer is also associated with a symmetrical bone stress response [24].

Normal hamstring length permits 80° hip flexion from the straight leg position with the low back and sacrum flat on the table [11]. All players expressed a concern that their hamstrings were tight. Despite their perceived tightness, many of the subjects demonstrated good hamstring length (77° dominant, 73° nondominant) when compared to published norms (80°). It is possible that soccer players require more hamstring length to participate in their sport. If so, the players’ perception of hamstring tightness may be a legitimate concern. A significant association between preseason hamstring muscle tightness (SLR < 90°) and the development of in-season hamstring muscle injury was found in professional male soccer athletes [7]. The results of Witrouw’s study suggest that hamstring muscle flexibility of less than 90° SLR could be considered “tight” because these players had a significantly higher risk for an injury. On average, the dominant leg in the study group presented with greater hamstring length than the nondominant leg. This is significant during a sport-specific activity which requires hamstring length, such as the kicking follow through in soccer. This limitation may place excessive stress on the hamstring muscle leading to injury.

There are no available normative data for assessment of the hip in the figure-of-four position. In our subjects measured in the supine Figure-4 position, there was no statistically significant difference between dominant and nondominant legs.

The scores obtained during dynamic functional alignment were based on observation by two senior physical therapists. The deviations observed during dynamic functional alignment testing may be a factor in the noncontact ACL injuries reported in female soccer players [1, 2, 4]. More than 58% of the severe injuries reported in a prospective study of German National League female soccer players were located at the knee including 11 ACL ruptures [25]. Seven of these injuries were a result of changes in direction. Soccer-specific motions such as planting and pivoting, deceleration, and landing from a jump have all been identified as mechanisms of noncontact ACL injuries [1]. Recent studies have shown gender differences in lower-extremity kinematics and kinetics in athletic tasks [1, 2]. Numerous authors have identified valgus collapse of the knee as the common body position in noncontact ACL injuries [26–28]. Core stability may also be a factor in ACL injury [29]. Several recent studies have demonstrated gender differences in core stability [6, 7, 30] and increased risk of injury related to that difference [30–32].

The deviations observed during dynamic functional alignment combined with ROM limitations of hip rotation and inadequate core control may contribute to noncontact ACL injury by increasing valgus stress at the knee. The athletes may not have the strategies to overcome these forces, putting the knee at risk for injury.

Limits in hip ER or greater hip IR ROM than ER ROM and increased femoral anteversion in all subjects may put the lower extremity in a vulnerable position and place the knee at risk. The combination of hip adduction, internal rotation, and knee valgus during the step down and single-leg squat creates a functional valgus as the knee motion then occurs around an axis which is oblique to the coronal plane [11]. This, as well as a stiff knee, was observed in many of the subjects landing from a jump off the 12-in. platform. During jump testing, deviations were also observed during takeoff.

Lower abdominal testing revealed that 21 subjects scored a grade of 2/5 or less, 13 of which scored a 1.5 (1B). Playing soccer involves running, kicking, and the ability to stand on one leg while extending the contralateral hip to kick a ball. These skills require the ability to stabilize the spine in a manner similar to level 3; however, this testing is done in a supine supported position versus a standing more challenging position. Due to the demands of

their sport, the authors believe that soccer athletes should demonstrate a minimum grade of 3 in testing of their lower abdominals. There can be two possible explanations for the scores. First, the athletes demonstrate dominance in their rectus abdominis, secondary to a training focus on these muscles. This could explain why the rectus abdominis is recruited in an attempt to stabilize the pelvis, rather than the lower abdominals. An alternate explanation relates to the observed tightness in the two-joint hip flexors of all subjects. Shortened muscles are recruited more readily than lengthened (taut and weak) muscles which creates a bias toward recruitment of hip flexors instead of lower abdominals [10, 11].

Leg dominance has also been proposed as a possible contributor to the increased risk of ACL injury in female athletes. Two studies have reported greater strength in the dominant leg of soccer players [33, 34], while others report symmetry between players' dominant and nondominant limbs [35, 36]. Thus, the importance of leg dominance in soccer player performance and injury has not been determined. In this study, no statistically significant difference was found between dominant and nondominant legs.

Limitations of this study include a small sample size which may not necessarily be indicative of all elite female soccer players; however, this sample represented a diverse group of athletes who had been raised and trained in different parts of the US and of the world. They had only one thing in common; with an average of 18 years of experience and a mean age of 25, they had all played soccer for more than half of their lives.

In conclusion, we have begun to develop a musculoskeletal profile of elite female soccer players and in doing so have begun to successfully identify specific physical characteristics common to these athletes. These data can serve as a baseline for future studies to determine: if the musculoskeletal characteristics such as hip rotation PROM, increased femoral anteversion, and shortness of two-joint hip flexors, identified in professional female soccer players, are identifiable in female soccer players of all levels; the point at which these musculoskeletal characteristics become identifiable as we follow players prospectively; if these musculoskeletal characteristics are different than the musculoskeletal characteristics of male soccer athletes; and if these musculoskeletal characteristics are related to injury risk.

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References

- Chappell JD, Yu B, Kirkendall DT, Garrett WE (2002) A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks. *Am J Sports Med* 30(2):261–267
- Malinzak RA, Colby SM, Kirkendall DT, Yu B, Garrett WE (2001) A comparison of knee joint motions in patterns between men and women in selected athletic maneuvers. *Clin Biomech* 16(5):438–445
- Ford KR, Myer GD, Hewett TE (2003) Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc* 35(10):1745–1750
- Zeller BL, McCroy JL, Kibler WB, Uhl TL (2003) Differences in kinematics and electromyographic activity between men and women during the single-legged squat. *Am J Sports Med* 31:449–456
- Mangine RE, Noyes FR, Mullen MP, Barber SD (1990) A physiological profile of the elite soccer athlete. *J Orthop Sports Phys Ther* 12:147–152
- Rosch D, Hodgson R, Peterson TL, Graf-Baumann T, Junge A, Chomiak J et al (2000) Assessment and evaluation of football performance. *Am J Sports Med* 28:S29–39
- Witvrouw E, Danneels L, Asselman P, D'Have T, Cambier D (2003) Muscle flexibility as a risk factor for developing muscle injuries in male soccer players. *Am J Sports Med* 31:41–46
- Norkin CC, White DJ (1987) Measurement of joint motion: a guide to goniometry. FA Davis, Philadelphia
- Ruwe M, Gage JR, Ozonoff MB, DeLuca PA (1992) Clinical determination of femoral anteversion. A comparison with established techniques. *J Bone Joint Surg Am* 74(6):820–830
- Sahrmann S (2002) Diagnosis and treatment of movement impairment syndromes. Mosby, St. Louis
- Kendall FP, McCreary EK (1993) Muscles: testing and function, 4th edn. Lippincott Williams and Wilkins, Baltimore
- Grelsamer R, McConnell J (1998) The patella: a team approach. Aspen, Gaithersburg, pp 109–118
- Magee DJ (1992) Orthopedic physical assessment. Saunders, Philadelphia, pp 333–371
- Fredericson M, Cookingham CL, Chaudhari AM, Dowdell BC, Ostreicher N, Sahrmann SA (2000) Hip abductor weakness in distance runners with iliotibial band syndrome. *Clin J Sport Med* 10(3):169–175
- Richardson C, Jull G, Hodges P, Hides J (1999) Therapeutic exercise for spinal segmental stabilization in low back pain. Churchill Livingstone, New York
- American Academy of Orthopedic Surgeons (1965) Joint motion: method of measuring and recording. American Academy of Orthopedic Surgeons, Chicago
- Simoneau GG, Hoenig KJ, Lepley JE, Papanek PE (1998) Influence of hip position and gender on active hip internal and external rotation. *J Orthop Sports Phys Ther* 28(3):158–164
- Cibulka MT (2004) Determination and significance of femoral neck anteversion. *Phys Ther* 84(6):550–558
- Crockett HC, Gross LB, Wilk KE et al (2002) Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med* 30(1):20–26
- Osborne DC, Cannon DL, Speer KP (2002) Retroversion of the humerus in the throwing shoulder of college baseball pitchers. *Am J Sports Med* 30(3):347–353
- Reagan KM, Meister K, Horodyski MB, Werner DW, Carruthers C, Wilk KE (2002) Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med* 30(3):354–360
- Hruska R (1998) Pelvic stability influences lower-extremity kinematics. *Biomechanics* 6:23–29
- Ireland ML (1999) Anterior cruciate ligament injury in female athletes: epidemiology. *J Athl Train* 34(2):150–154
- Gregory PL, Batt ME, Kerslake RW (2004) Comparing spondylolysis in cricketers and soccer players. *Br J Sports Med* 38:737–742
- Faude O, Junge A, Kindermann W, Dvorak J (2005) Injuries in female soccer players. A prospective study in the German national league. *Am J Sports Med* 33(11):1694–1700
- Boden BP, Dean GS, Feagin JA, Garrett WE Jr (2000) Mechanisms of anterior cruciate ligament injury. *Orthopedics* 23:573–578
- Olsen OE, Myklebust G, Engebretsen L, Bahr R (2004) Injury mechanisms for anterior cruciate injuries in team handball: a systematic video analysis. *Am J Sports Med* 32:1002–1012
- Teitz CC (2001) Video analysis of ACL injuries. In: Griffin LY (ed) Prevention of noncontact ACL injuries. American Academy of Orthopaedic Surgeons, Rosemont, pp 93–96

29. Wilson JD, Dougherty CP, Ireland ML, Davis IM (2005) Core stability and its relationship to lower extremity function and injury. *J Am Acad Orthop Surg* 13:316–325
30. Leetun DT, Ireland ML, Wilson JD, Ballantyne BT, Davis IM (2004) Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc* 36:926–934
31. Hewett TE, Myer GD, Ford KR et al (2005) Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes. *Am J Sports Med* 33(4):492–501
32. Pollard CD, Sigward SM, Ota S, Langford K, Powers CM (2006) The influence of in-season injury prevention training on lower-extremity kinematics during landing in female soccer players. *Clin J Sport Med* 16(3):223–227
33. Egrun M, Islegen C, Taskiran E (2004) A cross-sectional analysis of sagittal knee laxity and isokinetic muscle strength in soccer players. *Int J Sports Med* 25:594–598
34. McLean BD, Tumilty DM (1993) Left-right asymmetry in two types of soccer kick. *Br J Sports Med* 27(4):260–262
35. Burnie J, Brodie DA (1986) Isokinetic measurement in preadolescent males. *Int J Sports Med* 7:205–209
36. Capranica L, Cama G, Fanton F, Tessitore A, Figura F (1992) Force and power of preferred and non-preferred leg in young soccer players. *J Sports Med Phys Fitness* 32:358–363