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Selected Static Anatomic Measures Predict Overuse Injuries in Female Recruits

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ABSTRACT This prospective study determined whether selected anatomic measures identified women at increased risk of patellofemoral pain syndrome (PFPS) and shin splints (SS). Ten anatomic measures were performed on 748 women before basic training at the Marine Corps Recruit Depot (MCRD), Parris Island, South Carolina. Recruits were then followed throughout basic training for occurrence of injuries. Logistic regression modeling indicated that a left hip internal rotation range of motion (ROM) ≤25° and ≥46°, a right Q angle ≥20°, and left knee hyperextension ROM ≥6° were positively associated with PFPS. Whereas left dorsiflexion ROM ≥21° was associated with SS, right Q angle ≥20° was inversely associated with SS. These findings suggest that multiple anatomic measures can be used to identify women entering MCRD basic training at risk for PFPS and SS injuries.

INTRODUCTION

Musculoskeletal injuries classified as overuse syndromes are a serious problem for women participating in competitive and recreational running. They are especially important for female recruits during military training. Prospective studies of military populations at different entry-level programs have consistently reported higher injury rates among women than men.[1–3] In particular, the incidence of patellofemoral pain syndrome (PFPS) and shin splint (SS) injuries have been commonly reported among women undergoing various entry-level military training programs.[1,3–5] The impact of these overuse syndrome injuries can be substantial because they frequently result in lost training time, medical expenses, and decreased operational readiness.

Most studies that have examined risk factors for injury among female recruits have focused almost exclusively on stress fractures, likely due to their associated disability and increased risk of attrition.[6–9] However, the risk of non-stress-fracture-related lower extremity overuse injuries during basic training has been shown to be greater than that of stress fractures.[7] Several modifiable and nonmodifiable factors have been associated with non-stress fracture lower extremity overuse injuries, including low aerobic or physical fitness,[2,3] lack of prior conditioning,[4] low self-rated physical fitness,[7] limited leg strength,[4] older or younger age,[9,10] taller or shorter height,[3] increased or decreased body weight,[4,10,11] and menstrual irregularities.[9] Previous studies have suggested that structural/alignment irregularities are associated with overuse injuries.[12,13] However, information in the literature is sparse with respect to the relationship between structural/alignment irregularities and increased risk of non-stress-fracture overuse injuries in female recruits.

Identifying and understanding risk factors for overuse injuries is essential if they are to be prevented or minimized. The purpose of the present study was to examine the association of selected anatomic measures with two common types of overuse injuries among female Marine Corps recruits: PFPS and SS. We initially expected that hip and knee measurements would be predictive of PFPS injuries, and ankle/foot measurements would be associated with SS injuries. We then investigated whether any hip, knee, or ankle/foot measure would be associated with PFPS or SS.

MATERIALS AND METHODS

A total of 748 female Marine Corps recruits, who arrived at the Parris Island Marine Corps Recruit Depot (MCRD) from March 1995 to September 1996, volunteered to participate in a pretraining study of exercise, health, and nutritional habits. All participants received the Privacy Act statement and signed an informed consent form in compliance with all applicable federal regulations governing the protection of human subjects in research and approved by the institutional review board of the Naval Health Research Center, San Diego, CA. All study participants were free of symptoms from injury at the time of the measurements.

Overuse Injuries

We followed the recruits throughout basic training at MCRD for occurrence of lower extremity musculoskeletal overuse-related

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injuries. All injuries were diagnosed by a sports medicine physician and the orthopedic *International Classification of Diseases*, 9th Revision, clinical modification (ICD-9-CM) code for PFPS (719.46) and SS (844.9) recorded in the recruit's medical record.[14]

Descriptive Measurements

At the beginning of the anthropometry session, staff recorded the recruits' age and race/ethnicity. Weight and height were measured with a standard, calibrated physician's beam scale and stadiometer, respectively. Body mass index (BMI) was calculated from weight (kilograms) and height (meters) as weight/height^2.

Anatomic Measurements

Before basic training, subjects were taken to a medical clinic bay that was set up with three measuring stations. Two individuals—one anthropometrist and one medical corpsman—staffed each station. Each station took specific measurements for each subject. One station staffer would always mark and take the measurement while the other staffer assisted and recorded the measurements. Each anatomic measurement was taken in complete sequence twice and then averaged.

The following selected measures were obtained in the standing position:

Pelvic Width

Arms of a large sliding caliper with a Vernier scale were placed at the widest point (iliac tubercle) on the right and left sides of the subject's pelvis.[15] The width of the pelvis girdle was recorded to the nearest 0.1 cm.

Knee Alignment

Subjects were asked to stand with knees locked and feet shoulder-width apart. Subjects then moved one leg toward the other until their ankle or knee came together.[15] Using a triangle caliper, the distance between the subject's knees (femoral condyles [valgus]) or ankles (medial malleoli [varus]) was measured to the nearest 0.1 cm.

Navicular Height and Foot Length

With subjects braced against a table or wall, subjects were asked to take weight off and bend their left leg at the knee, and then extend their left leg backward slightly, thus keeping weight balanced and evenly distributed on right foot with the knee locked.[15] For navicular height, the vertical distance between the floor and the lower edge of the navicular tubercle of the subject's right foot (previously marked) was measured to the nearest 0.1 cm with a metric ruler. For foot length, the distance from the tuber calcanei (heel edge) to the first metatarsophalangeal joint on the floor along the medial edge of the foot was measured to the nearest 0.1 cm. The process was repeated for the left foot.

The following measures were obtained in the supine position:

Absolute Leg Length

Absolute leg length was a combination of the subject's upper and lower leg length. For upper (femoral) and lower leg (tibial) lengths,[15,16] a cloth measure was tautly extended from the anterior superior iliac spine (ASIS) to medial knee joint space and then medial knee joint space to medial malleolus, respectively. Both lengths were recorded to the nearest 0.1 cm.

Q Angle

A mark was made on the center of the subject's patella.[15] The ASIS and tibial tuberosity were then located and marked. The fulcrum of a standard 360° goniometer was placed in the center of the patella and arms were directed at the ASIS and tibial tuberosity. The angle obtained was recorded to the nearest degree.

Knee Extension

With the subject's toes pointing toward the ceiling, one examiner held the subject's heel about 8 inches off the table and then instructed the subject to relax her thigh muscles. Another examiner then placed the fulcrum of a goniometer in the center of the lateral space of the knee with one arm pointing toward the greater trochanter and the other arm at the lateral malleolus. The angle obtained was recorded to the nearest degree.[15]

Ankle Dorsiflexion

The subject was asked to point (dorsiflex) her foot maximally with the knee in an extended position. The examiner then placed the axis of a goniometer on the lateral malleolus with the stationary arm parallel to the fibula. The movable arm was then aligned parallel to the lateral midline of the fifth metatarsal.[15] The angle obtained was recorded to the nearest degree.

The following measurements were obtained in the prone position:

Internal Hip Rotation

The subject's right knee was flexed to a 90° position and perpendicular to the transverse line across the ASIS of the pelvis, midway between external and internal rotation. The axis of the goniometer was placed over the central patella of the right leg, with the stationary arm of the goniometer parallel to the axis of the tibia and perpendicular to the floor and exam table. The movable goniometer arm was lined up along the midline of the tibia, and the ankle was moved inward until taut. The angle between the stationary arm and movable arm was recorded to the nearest degree.[15]

Hindfoot Eversion

With the subject's legs in an extended position and feet off the exam table, the axis of the goniometer was placed on the mark of the upper heel at the insertion of the Achilles tendon. The stationary and movable arms of the goniometer were aligned parallel to the axis of the tibia and long axis of the midheel, respectively. The subject's right heel was then turned inward with subtalar movement only. The angle between the stationary (midline of lower leg) and the movable arms of the goniometer (midline of the calcaneus) was measured to the nearest degree.[15]

Ober's Test

To measure iliotibial band (ITB) tightness, the subject was placed at the right edge of the exam table in the left side-lying position, and the left knee in a slightly flexed position. The subject's right extended leg was lifted at the ankle toward the ceiling maximally, pulled back toward the examiner, and then the leg was allowed to slowly lower toward the table while stabilizing the pelvis at a right angle to the table. If the leg settled above horizontal (intermediate) it was recorded as a positive (tight ITB) test.[16]

Data Analysis

Descriptive and univariate statistics were used to describe the population and compare outcome groups. The following continuous variables were categorized on the basis of reported clinical normal/abnormal ranges: leg-length difference (≤0.50 cm [normal]/>0.50–1.0 cm/>1.0–1.5 cm/>1.5 cm),[17] internal femoral rotation range of motion (ROM ≤25°/26–45° [normal]/≥46°),[16] Q angle (<20° [normal]/≥20°),[17] knee hyperextension ROM (≤5°[normal]/≥6°),[18] ankle dorsiflexion ROM (≤10°/11–20° [normal]/≥21°),[16,19] and hindfoot eversion ROM (0–1°/2–10° [normal]/≥11°).[19] The Ober's test was classified as positive or negative (normal).[16] Knee alignment was categorized as varus, valgus, varus/valgus, and neutral (normal).[16] For the following two measurements that did not have reported clinical normal/abnormal values, we used the top and bottom 20% quintiles to define abnormal.[12,13] Pelvic width/femur length ratio was calculated as pelvic width divided by femur length and categorized as ≤0.26 (narrow)/0.27–0.30 (normal)/≥0.31 (wide). Arch index was calculated as arch height divided by foot length and categorized as ≤0.149 (low)/0.150–0.216 (normal)/≥0.217 (high).

Initially, unadjusted logistic regression models were used to calculate odds ratios and 95% confidence intervals separately for PFPS and SS injuries, comparing the proportion of recruits in a high-risk group with the proportion of recruits in a baseline or referent (low risk) group for each anatomic measure. The normal range was used as the reference (low risk) category. Multivariate logistic regression was then fit for PFPS and SS injuries, separately, adjusting for age, height, weight, and anatomic measures found significant in the univariate analyses, to determine a final adjusted risk model. Statistical significance was defined as a 95% confidence interval exclusive of 1. SPSS version 15.0 statistical software was used for all analyses (SPSS, Inc., Chicago, IL).

RESULTS

Study Population

Mean ± SD age of the sample was 19 (2.0) years (range 17–31 years) and 90% were younger than 22 years. Approximately 64% of subjects identified themselves as Caucasian, 18% black, 12% Hispanic, and 7% other. Mean ± SD height, weight, and BMI were 163.4 (6.6) cm, 58.4 (6.7) kg, and 21.9 (1.8), respectively. Over 90% (93.3%) of the subjects were in the normal BMI range (Centers for Disease Control guidelines: 18.5–24.9 kg/m^2).

Lower Extremity Overuse Injuries

During the 13 weeks of Marine Corps basic training, of the 748 subjects, 7.5% (n = 56) were diagnosed with PFPS and 7.2% (n = 54) with SS. Of these, 6 of the recruits incurred both a PFPS and SS injury. For these recruits, we only used the injury that occurred first in our analyses. Thus a total of initial 53 PFPS and 51 SS injuries were used in the risk analyses.

Hip Measures and Injury

Recruits with a left hip (femoral) internal rotation ROM ≤25° or ≥46° were more than four and two times as likely to incur a PFPS injury, respectively, than recruits with a left hip (femoral) internal ROM 26°–45° (≤25°: OR = 4.7; 95% CI: 2.2–10.2; ≥46°: OR = 2.3; 95% CI: 1.2–4.4) (Table I). Recruits with a narrow pelvic width/femur length ratio (≤0.26) were twice as likely to incur an SS injury as were recruits with a pelvic width/femur length ratio of 0.27–0.30 (OR = 2.0; 95% CI: 1.1–3.9).

TABLE I. Unadjusted Odds Ratios of Patellofemoral Pain Syndrome and Shin Splint Injuries by Selected Hip Anatomic Measures Among Female Marine Corps Recruits (n = 748)

		PFPS		Shin Splints	
Hip Measures	N	(%)	OR 95% CI	(%)	OR 95% CI
Ober's Test					
R Negative	502	7.2	1.0	6.2	1.0
R Positive	246	6.9	1.0 (0.5–1.8)	8.1	1.4 (0.8–2.4)
L Negative	496	7.1	1.0	6.0	1.0
L Positive	252	7.1	1.0 (0.5–1.8)	8.3	1.4 (0.8–2.5)
Leg Length Difference					
≤0.5 cm	401	7.2	1.0	7.0	1.0
>0.5–1.0 cm	199	6.9	1.0 (0.5–1.9)	6.9	1.0 (0.5–1.9)
>1.0–1.5 cm	98	5.3	0.7 (0.3–1.9)	7.4	1.1 (0.5–2.5)
>1.5 cm	50	10.0	1.4 (0.5–3.9)	4.0	0.6 (0.1–2.4)
Femoral Internal Rotation					
R ≤ 25°	41	12.2	2.1 (0.8–5.7)	4.9	0.7 (0.2–3.2)
R 26–45°	449	6.2	1.0	6.5	1.0
R ≥ 46°	258	7.8	1.3 (0.7–2.3)	7.8	1.2 (0.7–2.2)
L ≤ 25°	68	17.6	4.7 (2.2–10.2)	2.9	0.4 (0.1–1.8)
L 26–45°	460	4.3	1.0	6.7	1.0
L ≥ 46°	220	9.5	2.3 (1.2–4.4)	8.2	1.2 (0.7–2.3)
Pelvic Width/Femur Length Ratio[a]					
Narrow (≤0.26)	150	8.0	1.2 (0.6–2.3)	10.7	2.0 (1.1–3.9)
Normal (0.27–0.30)	448	6.9	1.0	5.6	1.0
Wide (≥0.31)	150	6.7	1.0 (0.5–2.0)	6.7	1.2 (0.6–2.6)

OR, odds ratio; CI, confidence interval; PFPS, patellofemoral pain syndrome; R, right limb; L, left limb.

[a]Pelvic width/femur length ratio: narrow and wide categories based on top and bottom quintiles.

Knee Measures and Injury

Recruits with a right or left Q angle ≥20° were over and nearly two times more likely to incur a PFPS injury, respectively, than recruits with a right or left Q angle <20° (right: OR = 2.3; 95% CI: 1.3–4.0; left: OR = 1.9; 95% CI: 1.1–3.3) (Table II). However, recruits with a right Q angle ≥20° were less likely to incur an SS injury than were recruits with a right Q angle <20° (OR = 0.4; 95% CI: 0.2–0.9). Recruits with a left knee hyperextension ROM ≥6° were twice as likely to incur a PFPS injury than recruits with a left knee hyperextension ROM ≤5° (OR = 2.0; 95% CI: 1.1–3.5).

Ankle/Foot Measures and Injury

Only recruits with a right or left dorsiflexion ROM ≥21° were over two and three times more likely to incur an SS injury than recruits with a right or left dorsiflexion ROM 11–20°, respectively (right: OR = 2.6; 95% CI: 1.1–6.0; left: OR = 3.4; 95% CI: 1.4–8.4) (Table III).

Multivariate Logistic Analyses

In our final models for PFPS and SS, our exposures were the anatomic factors that were associated with risk of injury in our unadjusted analyses. We also controlled for age, height, and weight in our final models since they have been associated with injury in previous studies. For PFPS, left hip (femoral) internal rotation ROM ≤25° or ≥46° (≤25°: OR = 4.6; 95% CI: 2.1–10.2; ≥46°: OR = 2.2; 95% CI: 1.1–4.2), a right Q angle ≥20° (OR = 2.5; 95% CI: 1.4–4.6), and left knee hyperextension ROM ≥6° were associated with risk of injury (OR = 2.1; 95% CI: 1.2–3.7) (Table IV). Although a left dorsiflexion ROM ≥21° was associated with SS injury (OR = 3.7; 95% CI: 1.4–9.6), a right Q angle ≥20° was associated with a 60% decreased risk of SS injury (OR = 0.4; 95% CI: 0.2–0.8).

TABLE II. Unadjusted Odds Ratios of Patellofemoral Pain Syndrome and Shin Splint Injuries by Selected Knee Anatomic Measures Among Female Marine Corps Recruits (n = 748)

		PFPS		Shin Splints	
Knee Measures	N	(%)	OR 95% CI	(%)	OR 95% CI
Knee alignment					
Neutral	81	3.7	1.0	9.9	1.0
Varus	147	8.2	2.3 (0.6–8.4)	8.8	0.9 (0.4–2.2)
Valgus	399	7.0	2.0 (0.6–6.6)	5.3	0.5 (0.2–1.2)
1 Valgus/1 Varus	121	8.3	2.3 (0.6–8.8)	7.4	0.7 (0.3–2.0)
Q Angle					
R < 20°	466	4.9	1.0	8.6	1.0
R ≥ 20°	282	10.6	2.3 (1.3–4.0)	3.9	0.4 (0.2–0.9)
L < 20°	459	5.4	1.0	7.0	1.0
L ≥ 20°	289	9.7	1.9 (1.1–3.3)	6.6	0.9 (0.5–1.7)
Knee Extension (hyper)					
R ≤ 5°	542	6.8	1.0	6.1	1.0
R ≥ 6°	206	7.8	1.2 (0.6–2.1)	8.7	1.5 (0.8–2.7)
L ≤ 5°	518	5.6	1.0	6.4	1.0
L ≥ 6°	230	10.4	2.0 (1.1–3.5)	7.8	1.3 (0.7–2.3)

OR, odds ratio; CI, confidence interval; PFPS, patellofemoral pain syndrome; R, right limb; L, left limb.

DISCUSSION

There is sports medicine literature suggesting that the extremes of anatomic variation and malalignment of the lower extremity predispose runners and athletes to musculoskeletal overuse injury due to abnormal mechanical stress.[12] Yet, most studies reporting on risk factors for overuse injuries have not specified clinical or threshold cut points that suggest abnormality or excessive risk. Instead, the "risk" has primarily been evaluated by comparing mean differences between injured and non-injured runners[20–23] or recruits.[9] However, comparing mean values alone may be misleading if injury risk is increased by either abnormally large or abnormally small values.[6,17,24] Furthermore, reporting mean values exclusively does not facilitate interpretation in the clinical setting. Thus, we presented our data by known or suggested clinical thresholds or distribution-based categorizations to compare the risk of injury using varying degrees or levels (e.g., Q angle <20°/≥20°) of the risk factor.

The results of our study indicated that only 4 of the 10 lower extremity anthropometric measures were associated with increased risk for an overuse injury that they were developed to identify. We also found that several anthropometric measures were able to predict the likelihood of multiple injury types.

TABLE III. Unadjusted Odds Ratios of Patellofemoral Pain Syndrome and Shin Splint Injuries by Selected Ankle/Foot Anatomic Measures Among Female Marine Corps Recruits (n = 748)

		PFPS		Shin Splints	
Ankle/Foot Measures	N	(%)	OR 95% CI	(%)	OR 95% CI
Dorsiflexion					
R ≤ 10°	206	5.8	0.7 (0.4–1.4)	6.3	1.1 (0.5–2.0)
R 11–20°	487	8.0	1.0	6.2	1.0
R ≥ 21°	55	3.6	0.4 (0.1–1.9)	14.5	2.6 (1.1–6.0)
L ≤ 10°	257	6.2	0.8 (0.5–1.5)	8.2	1.6 (0.9–3.0)
L 11–20°	446	7.4	1.0	5.2	1.0
L ≥ 21°	45	8.9	1.2 (0.4–3.6)	15.6	3.4 (1.4–8.4)
Hindfoot Eversion					
R 0–1°	68	7.4	1.1 (0.4–2.9)	10.3	1.6 (0.7–3.8)
R 2–10°	446	6.7	1.0	6.7	1.0
R ≥ 11°	234	7.7	1.2 (0.6–2.1)	6.0	0.9 (0.5–1.7)
L 0–1°	78	10.3	1.4 (0.6–3.0)	11.5	2.0 (0.9–4.4)
L 2–10°	489	7.8	1.0	6.1	1.0
L ≥ 11°	181	3.9	0.5 (0.2–1.1)	6.6	1.1 (0.5–2.2)
Arch Index[a]					
R Low (≤0.149)	150	8.0	1.1 (0.6–2.2)	8.0	1.1 (0.6–2.2)
R Normal (0.150–0.216)	446	7.4	1.0	7.2	1.0
R High (≥0.217)	152	5.3	0.7 (0.3–1.5)	4.6	0.6 (0.3–1.5)
L Low (≤0.149)	152	7.2	1.0 (0.5–2.0)	9.2	1.4 (0.7–2.6)
L Normal (0.150–0.216)	446	7.4	1.0	7.0	1.0
L High (≥0.217)	150	6.0	0.8 (0.4–1.7)	4.0	0.6 (0.3–1.4)

OR, odds ratio; CI, confidence interval; PFPS, patellofemoral pain syndrome; R, right limb; L, left limb.

[a]Arch index: high and low categories based on top and bottom quintiles.

TABLE IV. Adjusted Odds Ratios Patellofemoral Pain Syndrome and Shin Splint Injuries by Selected Anatomic Measures Among Female Marine Corps Recruits

	PFPS	Shin Splints
Anatomic Variable	AOR 95% CI[a]	AOR 95% CI[a]
Hip		
Femoral Internal Rotation		
L ≤ 25°	**4.6 (2.1–10.2)**	–
L 26–45°	1.0	–
L ≥ 46°	**2.2 (1.1–4.2)**	–
Pelvic Width/Femur Length Ratio[b]		
Narrow (≤0.26)	–	1.9 (0.9–3.9)
Normal (0.27–0.30)	–	1.0
Wide (≥0.31)	–	1.4 (0.6–3.1)
Knee		
Q Angle		
R < 20°	1.0	1.0
R ≥ 20°	**2.5 (1.4–4.6)**	**0.4 (0.2–0.8)**
Knee Extension		
L ≤ 5°	1.0	–
L ≥ 6°	**2.1 (1.2–3.7)**	–
Ankle/Foot		
Dorsiflexion		
L ≤ 10°	–	1.6 (0.9–3.0)
L 11–20°	–	1.0
L ≥ 21°	–	**3.7 (1.4–9.6)**

AOR, adjusted odds ratio; CI, confidence interval; PFPS, patellofemoral pain syndrome; R, right limb; L, left limb.
[a]Adjusted for age, height, and weight. [b]Pelvic width/femur length ratio: narrow and wide categories based on top and bottom quintiles.

Anatomic Measures and PFPS

Our findings support the theory that PFPS may be influenced by the segmental interactions of the lower extremity.[25] Theoretically, a large Q angle increases the lateral pull on the patella against the lateral femoral condyle, contributing to patellar subluxation and other patellofemoral pain disorders.[25] As suggested by previous reports,[22,25,26] we found that a large Q angle and greater femoral internal rotation and (hyper) knee extension increased the risk for PFPS. To the best of our knowledge, the current study is the first to report the association between Q angle and PFPS in female recruits. Our finding is consistent with a previous study of female high school runners, which found an association between knee pain and a Q angle using a criterion of 20° or more.[26] While others[20,22] have also reported that runners with PFPS had higher Q-angle values than noninjured runners, results were not reported separately for female runners. As there is increasing evidence to suggest that a large Q angle may increase the risk of knee overuse injury, we propose that the Q-angle measurement be included in the pretraining evaluation of female recruits for PFPS.

The Q angle can be influenced by tibial and femoral rotation. It has been theorized that excessive femoral internal rotation may increase the Q angle but also influence patellar alignment and kinematics, thereby creating PFPS.[25] Our finding that recruits with excessive hip (femoral) internal rotation were at increased risk of PFPS, independent of Q angle, supports this theory. However, we also found that those with limited femoral internal rotation were at increased risk of PFPS. As suggested by Powers et al.,[27] limited femoral internal rotation among those with PFPS may be due to compensatory strategies to reduce the Q angle. Because there are limited reports on the association between femoral internal rotation and PFPS, future studies are warranted.

Athletes with genu recurvatum, knee extension greater than 5°, may be more likely to experience anteromedial pain due to compressive forces at the medial tibiofemoral compartment (accentuated if a varus alignment is present).[18] Both our univariate and adjusted models confirmed this finding. Recruits with a left knee hyperextension ≥6° were more likely to incur PFPS than recruits with ≤5°. We are unaware of any previous studies that have examined increased knee extension and PFPS or other lower extremity injury among female recruits or runners. Although Cowan et al.[12] found an association between increased knee extension and all lower extremity overuse injuries combined, no association was reported specifically between knee extension and PFPS.

Anatomic Measures and SS

We found that recruits with right or left excessive (≥21°) dorsiflexion were more likely to have an SS injury. We are unaware of previous studies that have examined the relationship between dorsiflexion and SS injury in military recruits, regardless of gender. Messier et al.[23] found no association between dorsiflexion and SS injuries in adult recreational and competitive runners. However, a comparison between studies is difficult since their findings were not stratified by gender and mean values were compared between injured and noninjured runners.

Pelvic width/femur length ratio and Q angle may be construed as partial measures of hip and knee valgus/varus alignment.[28–30] In our sample, the directions of both measures suggest that recruits with a varus alignment were at greater risk for SS. In our adjusted model, a small Q angle was associated with SS injuries. Furthermore, while a significant association was observed between SS and narrow pelvic width/femur length ratio in our unadjusted estimates, this association was only of borderline significance in the final adjusted model. Similar to PFPS injuries, these hip–knee measures help support the closed-kinetic theory that abnormal segments in one body region may identify those at greater risk for an injury at a different lower extremity region.

In our adjusted models, we found that left ankle dorsiflexion ROM ≥21° was associated with SS. Since there are many parameters of the ankle and foot during running and marching, we are unclear of the exact role that a large dorsiflexion contributed to the increased association with SS. However, we speculate that those with an excessive dorsiflexion might not have adequate foot muscle strength to support the increased ROM dynamic to offset the increased amount of ground reaction forces, or that the increased motion may alter foot biomechanics.

Strengths and Limitations

Several strengths of this study should be noted. First, the prospective design allowed the risk profile of each recruit to be established before injuries occurred, reducing the likelihood of recall or measurement bias.[31] The large sample size provided adequate power to examine multiple potential risk factors (anatomic measures) concurrently. Second, since all injuries were diagnosed by the same sports medicine physician, the misclassification of specific injury type was likely decreased. Third, we measured both limbs of each recruit. Because not all anatomic measures are bilaterally symmetric, this allowed us to identify limbs that were abnormal on either side, a finding that might not have been captured if we had measured only one side.[26,32] Fourth, standard training, geographic and ambient conditions, training surface and equipment, including footwear, controlled for extrinsic variables known to be associated with overuse injuries, allowed a more direct study of intrinsic risk factors. Finally, military populations have access to medical care, which increases accurate reporting and tracking of personnel.

Limitations of our study should be acknowledged. First, some recruits may not have reported their injury for fear of being withheld from training. Second, minor injuries or those with minimal pain, especially near the end of the training program, also might have been missed. Third, we were unable to examine whether a right or left anatomic measure was associated with a right or left injury because information regarding side of injury was not captured. Studies in female runners, basketball players, and those with anterior knee pain have reported mixed findings of the relationship between the side of injured limb and side of abnormal anatomic measure.[17,26,34,35] Thus, we recommend that studies are needed to examine the affect of sidedness and injury in female recruits. Finally, although digitized slides[12] or other dynamic motion analyses may have provided more-sensitive anatomic information, the tests performed in the current study are inexpensive and can be reliably performed with appropriate training.

Recommendations for Future Research

Our findings should be confirmed in other cohorts. As suggested by several studies, we recommend that data be grouped according to measured clinical criterion values so that results are more transferable for clinical interpretation.[6,24,26,33] We also recommend that future studies should focus on preventive interventions and/or orthotics that have been shown to reduce biomechanical imbalances or structural differences might then be indicated to decrease the risk of lower-extremity overuse injuries.[36]

CONCLUSION

This prospective study of female Marine Corps recruits indicated that several static alignment factors were associated with PFPS and SS. If the findings of this study are confirmed by future research, many of these measures can be feasibly implemented during prebasic training screening for recruits or other similar athletic populations.

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14. ABSTRACT

Background/Purpose: Overuse injuries account for substantial time lost or training activities, especially in young women undergoing U.S. Marine Corps basic training. The purpose of this study was to explore static anatomic measures that may identify recruits with anatomic irregularities/malaligment that may place them at increased risk for four common overuse injuries: iliotibial band syndrome (ITBS), patellofemoral pain syndrome (PFPS), shin splints (SS), and plantar fasciitis (PF) during basic training. **Methods**: Data collected included 10 anatomic measures performed on a sample of 748 women prior to basic training at the Marine Corps Recruit Depot (MCRD), Parris Island, in 1995-1996. Recruits were then followed throughout basic training for occurrence of acute and overuse injuries. **Results**: Of the 748 recruits, 7.5% (n=56) were diagnosed with PFPS, 7.2% (n=54) with SS, 3.2% (n=24) with ITBS, and 2.9% (n=22) with PF. We found that left-hip internal rotation range of motion (ROM) $\leq$25° and $\geq$46°, a right Q-angle $\geq$20°, and left-knee hyperextension ROM $\geq$6° were positively associated with PFPS. In addition, a narrow pelvic width/femur ratio and left-ankle dorsiflexion ROM $\geq$21°were associated with SS injury. A right Q-angle $\geq$20° was inversely associated with SS injury. **Conclusions:** Our findings suggest that multiple anatomic tests can be used to identify women entering MCRD basic training at risk for PFPS and SS. Prophylactic or pretraining activities designed to improve or correct malalignment may help reduce training-related overuse injuries.

14. SUBJECT TERMS
malalignment, women, military training, overuse syndrome, prospective cohort

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