Spontaneous major tendon ruptures (MTRs) are rare events. However, the prevalence of MTRs (pectoralis major tendon [PMT], quadriceps tendon [QT], patellar tendon [PT], and Achilles tendon [AT]) has increased in recent decades presumably because of increased recreational sports activity in our society. Pectoralis MTRs are most frequently associated with weight training, specifically bench press, and strenuous athletic activities, most notably football, wrestling, and rugby. Ruptures of the QT and PT are rare events. These injuries are commonly seen in elder patients and are frequently associated with chronic medical illness, use of glucocorticoid medications, or the use of fluoroquinolones. In younger patients, QT and PT ruptures are associated with participation in repetitive jumping and sprinting exercises. Quadriceps ruptures have specifically been reported to occur, often with simultaneous bilateral ruptures, with anabolic steroid use. Achilles tendon ruptures have also been well described in the literature. Risk factors include an increase in physical activity, participation in repetitive jumping and sprinting sports, preceding histologic degeneration of the AT, chronic diseases treated with corticosteroids, use of fluoroquinolone antibiotics, male gender, and possibly blood group O. Despite the knowledge of these tendon injuries, there has not been an inclusive demographic study performed on ruptures of the major tendons to determine the effect of activity, race, age, or gender. The majority of the reports have been case studies or focused on one particular tendon and do not have the scope to determine if race is associated with the risk of rupture. It has been shown recently that...
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black race and participation in basketball increase the risk of AT ruptures. Male gender predominance in tendon ruptures has been shown to be between 4 and 7 times greater than for women in different studies. However, these studies are limited only to AT injuries and do not include the other major tendons. The purpose of the present study is to review the prevalence of MTRs during a 2-year period in a military population to determine if race increases risk for sustaining an MTR and to determine which activity predominates during these injuries. Because it is not possible to quantify the population’s exposure to high-risk behaviors, we have also reviewed the ACL reconstructions during the same period. Anterior cruciate ligament tears occur during participation in similar high-risk activities, and any difference identified between the populations might reveal risk factors for ACL tears or MTRs.

MATERIALS AND METHODS

We conducted a retrospective review of all orthopaedic records at Womack Army Medical Center, Fort Bragg, North Carolina (WAMC), between January 1995 and December 1996. The study population included all eligible active-duty military health care beneficiaries eligible for care at WAMC during this 2-year period. We identified all patients admitted for surgical management of a rupture of the PMT, QT, PT, or AT during this 2-year period. These records were abstracted, and the following covariates were identified: age, race, gender, activity at time of injury, mechanism of injury, history of smoking, steroid use, fluoroquinolone antibiotic use, preceding pain at the injury site, and prior MTR. Race was self-categorized as black, white, and other; age was categorized as 24 years and younger, 25 to 34 years, and 35 years and older.

To assess person time at risk, we queried the Defense Medical Epidemiology Database, which compiles International Classification of Diseases–9 Clinical Modification coding information for every patient encounter occurring in a military treatment facility, in addition to maintaining the total number of soldiers on active duty each year. Using the database, we determined the number of service members on active duty at Ft Bragg and at Pope Air Base during the study time period by race, gender, and age. Race was categorized as black, white, or other. Race was self-reported in the database. One exposure year was defined as 1 year that the service member was in the armed forces. Therefore, for example, a person who was at Ft Bragg during the entire study period contributed 2 exposure years.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Age and Race Distribution of the Population at Risk at Ft Bragg and Major Tendon Ruptures and ACL Tears at Womack Army Medical Center, January 1995 to December 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>Number of exposures among population at risk at Ft Bragg over 2 years</td>
<td>62 559</td>
</tr>
<tr>
<td>Number of exposures among population at risk at Ft Bragg over 2 years</td>
<td>246</td>
</tr>
<tr>
<td>Major tendon rupture age distribution, y</td>
<td>26 674</td>
</tr>
<tr>
<td>Major tendon rupture age distribution, y</td>
<td>24 and younger</td>
</tr>
<tr>
<td>Major tendon rupture age distribution, y</td>
<td>35 and older</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>62 559</td>
</tr>
<tr>
<td>ACL tear age distribution, y</td>
<td>24 and younger</td>
</tr>
<tr>
<td>ACL tear age distribution, y</td>
<td>25-34</td>
</tr>
<tr>
<td>ACL tear age distribution, y</td>
<td>35 and older</td>
</tr>
<tr>
<td>Total</td>
<td>246</td>
</tr>
</tbody>
</table>

*One black male sustained bilateral patellar tendon ruptures. There were 51 total injured people and 52 total injuries.

One exposure was defined as 1 year that the service member was in the armed forces. Therefore, for example, a person who was at Ft Bragg during the entire study period contributed 2 exposure years.
records; however, the data available for ACL patients did not include smoking, medication, or steroid use history.

We conducted overall summary statistics for each injury type to determine the proportion of injuries by gender, activity at time of injury, age, and race. We used multivariate Poisson regression to estimate the rate of each type of MTR per 1000 person-years, controlling for gender and age, and for ligament injury, controlling for gender. We computed rate ratios and 95% confidence intervals (CIs) using whites as the referent category. Data were analyzed using SAS, version 8.1 (SAS Institute, Cary, NC, 1999).

RESULTS

Tendon Ruptures

We identified 52 MTRs and 325 ACL tears among 93,224 service member exposures during the study period (Table 1). All tendon ruptures and ACL tears at WAMC occurred among active-duty patients during this time period. Among the 52 injuries, there were 29 AT ruptures (56%), 12 PT ruptures (23%), 7 PMT ruptures (14%), and 4 QT ruptures (8%) (Table 2). One patient, a black male, sustained a bilateral PT rupture playing basketball. Among the 51 patients, only 1 (2%) of the injuries occurred in a female patient. Forty-one of the injuries (79%) occurred among black soldiers, 8 (15%) occurred among white soldiers, and 3 (6%) occurred among Latino soldiers. Approximately 8% of the injuries occurred in subjects 24 years and younger, whereas 55% occurred in those 25 to 34 years, and 37% occurred in those 35 years and older. Among the 51 patients, 20% reported smoking, 100% denied the use of anabolic steroids or fluoroquinolone antibiotics, and 100% reported no prior pain at the site of injury. Eleven patients experienced prior tendon ruptures, and all of these patients were black; 9 sustained AT ruptures, 1 sustained a PT rupture, and 1 sustained a PMT rupture.

The majority (92%) of tendon ruptures occurred during participation in a sport or physical activity that involves plyometric movements (Table 2). The most common activity causing

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**TABLE 2**

Number of Injuries by Activity Type and Race Among All Muscle Tendon Ruptures (N = 52) at Womack Army Medical Center, January 1995 to December 1996

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Black</th>
<th>Other^a</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
</tr>
<tr>
<td>Achilles tendon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>5 (71.4)</td>
<td>16 (76.2)</td>
<td>1 (50.0)</td>
<td>22 (75.9)</td>
</tr>
<tr>
<td>Bench press</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct blow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fall</td>
<td>0</td>
<td>1 (4.8)</td>
<td>0</td>
<td>1 (3.4)</td>
</tr>
<tr>
<td>Other^b</td>
<td>2 (28.6)</td>
<td>4 (19)</td>
<td>1 (50.0)</td>
<td>6 (20.7)</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>21</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>Patellar tendon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>0</td>
<td>9 (75.0)</td>
<td>0</td>
<td>9 (75.0)</td>
</tr>
<tr>
<td>Bench press</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct blow</td>
<td>0</td>
<td>1 (8.3)</td>
<td>0</td>
<td>1 (8.3)</td>
</tr>
<tr>
<td>Fall</td>
<td>0</td>
<td>2 (16.7)</td>
<td>0</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>Football</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other^b</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
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<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Pectoralis major tendon</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Basketball</td>
<td>1 (100.0)</td>
<td>3 (60.0)</td>
<td>1 (100.0)</td>
<td>5 (71.4)</td>
</tr>
<tr>
<td>Bench press</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct blow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fall</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Football</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other^b</td>
<td>0</td>
<td>2 (30.0)</td>
<td>0</td>
<td>2 (28.6)</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Quadriceps tendon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>0</td>
<td>1 (25.0)</td>
<td>0</td>
<td>1 (25.0)</td>
</tr>
<tr>
<td>Bench press</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct blow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fall</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Football</td>
<td>0</td>
<td>1 (25.0)</td>
<td>0</td>
<td>1 (25.0)</td>
</tr>
<tr>
<td>Other^b</td>
<td>0</td>
<td>2 (50.0)</td>
<td>0</td>
<td>2 (50.0)</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

^aAll injuries among "other" race occurred in Latino soldiers.

^b"Other" includes hand-to-hand combat, push-ups, racquetball, running, softball, and being struck from behind.
Tendon Ruptures and ACL Tears in US Army

Vol. 35, No. 8, 2007

Race is often a risk factor for disease in many areas of medicine. Particularly, there are race differences in kidney disease, hypertension, diabetes, breast cancer, and osteoporosis. The notion of race as a risk factor in tendon ruptures is not novel, as Davis et al reported that black race and participation in basketball were predominant risk factors for AT ruptures. In addition, white European American female basketball players in the Women’s National Basketball Association (WNBA) were recently found to have an 11 times greater rate of ACL tears than did black female athletes. In our population, 7 black female soldiers sustained ACL tears, whereas 26 white female soldiers experienced ACL tears. The race incidence (2.2% injury in 5.1% of the population) in black women was less than the white women (8% injury in 5.9% of the population), but this does not approach the 11 times greater risk experienced in the WNBA. It has previously been reported that tendon ruptures predominate in men. The prevalence of female gender in the tendon rupture population was strikingly different, with only 1 female soldier experiencing an MTR. This woman was a 42-year-old smoker who sustained a PT rupture as a result of a fall. Despite the rigorous physical standards and daily physical activity of this US military population, the prevalence of female soldiers with ACL tears was not higher, and the prevalence of MTRs was significantly lower. Currently, there is much interest in determining why the female ACL tear rate is increased. Information from ongoing studies may reveal insight into why there is a distinct difference in MTR prevalence as well. Currently, the cause of this difference is not known.

Tendons actively participate in the transmission of force generated by muscles to achieve motion. Specifically, the tendons of locomotion (quadriceps, patellar, and Achilles) are elastic; the stored energy in the tendon is used to facilitate movement. High forces created by eccentric muscle activation are usually responsible for tendon failure.
Activities that maximize eccentric loading, such as repetitive jumping and sprinting exercises for the lower extremities (bench press for the pectoralis), potentiate the risk for tendon rupture. Specifically, those activities in which the eccentric load is maximized and then followed by a forceful concentric contraction (plyometric activities) place the highest tensile forces across the tendon. Participation in sports activity accounted for the majority of the ruptures in our study, with basketball participation accounting for most of the lower extremity injuries. In this study, all ACL tears occurred as a result of sports participation, with race incidence proportion ratios that were similar to the overall population (rate ratio was 0.64 [95% CI, 0.48-0.85] between blacks and whites) yet significantly different than the race incidence ratio of the MTR population (rate ratio was 13.7 [95% CI, 3.8-45.4] between blacks and whites). Furthermore, although basketball accounted for 62% of the tendon ruptures, of the patients who sustained a tendon rupture as a result of an activity other than basketball, 75% (15/20) were black soldiers despite only composing 24% of the entire population. These findings suggest that risk factors for tendon ruptures include black race and potentially plyometric activities. It is not possible to quantify the race ratio of exposure to high-risk activities, but because all ACL tears occurred during sports participation, this may serve as a proxy for activity. Because ACL tears did not predominate in black soldiers, we assume that black soldiers are not the only soldiers exposed to high-risk activities.

There is another unique military feature of this population that warrants discussion. Many of these soldiers are on airborne status and regularly participate in parachute exercises. The parachute landing fall is a dynamic fall involving eccentric muscle contraction of the lower extremity locomotion muscle groups designed to minimize injury during the landing. None of the tendon ruptures in this population occurred as a result of this activity. The theory is that the eccentric contraction without maximal contractile force applied, as seen in repetitive jumping or sprinting with plyometric activity, is not a significant enough load to result in tendon ruptures. Similarly, none of the ACL tears in this population occurred as a result of parachuting. Anterior cruciate ligament tears have occurred as a result of military parachute exercises, but these injuries typically occur as a result of getting the leg tangled in the static line that is attached to the aircraft. This frequently results in knee dislocations, which are the predominant mechanism of knee ligament injuries in parachuting, and is distinctly different from the eccentric muscle contraction of the dynamic parachute landing fall.

There are many potential causes for the observations in this tendon rupture population. These can be separated into intrinsic and extrinsic factors. Intrinsic factors include the rate and magnitude of force applied across the tendon and the health of the tendon. The extrinsic factors include high-risk activity exposure, training errors, and environmental factors. The rate and magnitude of force applied across the tendon depend on the forces generated by the adjoining muscle. There are 2 types of muscle fibers, type I (slow twitch) and type II (fast twitch). Many studies have evaluated the potential of a genetic-related difference in the predominant muscle fiber type. Type II (fast-twitch) muscle fibers, specifically Type IIb (fast-twitch glycolytic) fibers, have a larger diameter and generate a more rapid contractile force. A larger muscle fiber that generates higher rates of force across the tendon to the insertion would potentially put the tendon at higher risk for rupture.

There is no clear consensus on whether a racial difference in skeletal muscle fiber type exists.AMA et al evaluated 23 sedentary black Africans and 23 sedentary white Canadians. The whites had a significantly higher percentage of type I fibers and a lower percentage of type II fibers, but the differences were only slightly greater than the sampling error, and the authors acknowledged that the results should be viewed with caution. COETZER et al studied 5 white and 6 black South African distance runners, finding a trend toward a higher percentage of type II fibers in black runners but did not achieve statistical significance. DUEY et al studied 14 US black and 14 US white sedentary college students and found no significant differences between the 2 racial groups for type I, IIa, or IIb fibers. MALINA reviewed 8 studies from 1938 to 1976, evaluating the vertical jump and sprint performance of American black and white children. Seven of the 8 studies revealed better performances in the black children, suggesting a higher percentage of type II fibers. Finally, AMA et al studied maximal knee extension in black and white Americans. They noted that the black subjects demonstrated greater fatigue at 90 seconds, lending support for a higher percentage of type II fibers. In conclusion, current knowledge does not support the theory that a racially-based difference in fiber type exists and cannot explain the racial incidence ratio of MTRs in our population.

Another intrinsic difference could be anthropometric variation. Longer lever arms could result in increased forces across the tendon. It has been suggested that blacks have longer upper and lower extremities relative to height. These morphologic differences could result in higher tensile loads across the tendon, but this was not investigated in this study.

It has previously been shown that blood type O may be associated with tendon ruptures. Unfortunately, in our population, we were unable to determine the blood type of the overall population, the ACL tear population, or the MTR population. Without these data, we cannot comment on the relationship between blood type and MTRs. In a report on a 10-year demographic database with 3.1 million blood donors, GARRATTY et al reported that the highest percentage of blood type O was found in Latino (56.5%), North American Indian (54.6%), and black (50.2%) donors. Our data reveal an increased racial incidence ratio of MTRs in black soldiers. The increased prevalence of blood type O among blacks may be an explanation for the predominance of blacks experiencing MTRs. However, the study also reveals that a high percentage of blood type O is found in Latinos, and this population did not experience an increased incidence of tendon ruptures. Future prospective
studies of tendon ruptures should consider including analysis of blood type to determine if this is an associated risk factor.

The use of fluoroquinolone antibiotics has been previously reported as a risk factor for MTRs. Basic science research suggests that the fluorinated quinolone compounds alter the expression of collagenases and matrix metalloproteinases theorized to cause the tendinopathy and ruptures previously cited. In our population, the use of fluoroquinolone antibiotics was not found in any of our 51 tendon rupture patients. Therefore, no conclusion regarding this risk factor can be made in this study.

The status of tendon health is the final intrinsic factor. It is well accepted that AT ruptures occur at the watershed area, where there is decreased vascularity. It is also well established that decreased activity and age are responsible for collagen degradation, decreased tensile strength, and decreased concentration of metabolic enzymes in the fibroblasts. There is a well-established race-related incidence of hypertension, cardiovascular disease, and peripheral vascular disease with an increased risk in black males. Potentially, this vascular phenomenon, which worsens with age, may be present in other soft tissues, including the major tendons in blacks. If a race-related vascular phenomenon were present in tendons, and compounded the known aging effects in tendons, this could help explain the increased racial incidence ratio of MTRs in this population. Unfortunately, blood pressure data were not available for the overall population, ACL tear population, or the MTR population; therefore, no conclusions regarding this theory could be made from these data. There is a paucity of literature on this topic, so at this time no conclusions can be reasonably made regarding this theory.

The predominant extrinsic factor is the exposure to high-risk activities. It has been well described that an eccentric load placed on a maximally stressed pectoralis muscle causes rupture of the inferior fibers. This same mechanism has also been described in AT ruptures. In our study population, we found this to be true with most of our MTRs. In our study, 93% of the patients experiencing a MTR described sports participation that involved an eccentric load on the affected muscle group at the time of injury. However, there is a paucity of studies that quantify the exposure to high-risk activities. Davis et al noted that basketball was a risk factor for AT ruptures, but they could not quantify the exposure. Similarly, we note that sports participation, especially basketball, was associated with MTRs, but we lack exposure time for these activities. Therefore, we cannot stratify the risk in relation to the activity. One might surmise that race is a proxy for activity in this MTR population. However, the disparity in the race-related incidence rate of MTRs and ACL tears in this study is strikingly different. In addition, Trojan and Collin showed that when they controlled for activity exposure in the WNBA, there was a difference in ACL tear risk in different races, with the white European American players having more than 6 times greater tear rate than did the other ethnic groups combined and 11 times greater than did African American players.

There is a host of other information that relates to the extrinsic factors that we do not have. Generally speaking, older individuals tend to sustain more chronic overuse injuries. In addition, the status of the sporting venue is another variable. Fields or playing courts that have poor ergonomic design with little shock absorption increase the risk of injury. Finally, the quality of the equipment worn (shoes and protective equipment) may alter the injury rate. If there is a race difference in the prevalence of participation in the sporting events, this might be compounded by the environmental and equipment features that increase the risk of injury.

In conclusion, in our population, black race, age, male gender, and sports participation were all significant risk factors for tendon rupture. Although there are many theories as to the cause of the race predominance of tendon ruptures in this population, there are insufficient data to come to sound conclusions. Furthermore, it is unclear why the stated theories for the findings result in an increased incidence of MTRs but not ACL tears. The distinction between the age, sex, and race differences between ACL tears and MTRs in this population is poorly understood.

Future studies are surely warranted. Potential studies include quantifying the activity exposure and obtaining biopsies in the affected tendon and adjoining muscles. The goal would be to identify any modifiable risk factors that could be used to reduce the incidence of tendon ruptures and possibly improve treatment.

REFERENCES