

Hip Stability May Influence the Development of Greater Trochanteric Pain Syndrome

A Case-Control Study of Consecutive Patients

LCDR Ashton H. Goldman,* MD, MC, USN, ENS Vaughn Land,[†] MC, USN, Matthew H. Adsit,[†] BS, and CDR George C. Balazs,*[‡] MD, MC, USN

Investigation performed at the Naval Medical Center Portsmouth, Portsmouth, Virginia, USA

Background: Greater trochanteric pain syndrome (GTPS) is thought to relate primarily to tendinosis/tendinopathy of the hip abductors. Previous studies have suggested that certain anatomic factors may predispose one to development of the condition.

Hypothesis: It was hypothesized that intrinsic acetabular bony stability of the hip is related to the development of GTPS.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 198 consecutive patients diagnosed with GTPS were compared with 198 consecutive patients without clinical evidence of GTPS. Electronic health records of the included patients were examined; data recorded included patient age, sex, race, and body mass index (BMI). Standing anteroposterior radiographs were evaluated by 2 blinded examiners who measured the Tönnis angle, lateral center-edge angle (LCEA), and acetabular depth/width ratio (ADW) and assessed for the presence of a posterior wall sign. The number of dysplastic measures was recorded for each patient based on published norms. Associations between radiographic and patient variables versus the presence or absence of GTPS were determined. Factors with univariate associations where $P < .20$ were included in a binary logistic regression model to identify independent predictors of the presence of GTPS.

Results: There was no difference between groups in terms of age, BMI, or race. There were significantly more women than men in the GTPS group (71% vs 30%; $P < .001$). Intraclass correlation coefficients were good for the LCEA (0.82) and Tönnis angle (0.82) and poor (0.08) for the ADW. Kappa was moderate for the presence of a posterior wall sign (0.51). An increased Tönnis angle, decreased ADW, and $ADW < 0.25$ were significantly associated with the presence of GTPS. The binary logistic regression model identified an increased Tönnis angle ($P < .010$) and female sex ($P < .001$) as independent risk factors for GTPS.

Conclusion: Based on this preliminary retrospective study, decreased intrinsic acetabular bony stability of the hip may be associated with an increased risk of GTPS.

Keywords: greater trochanteric pain syndrome; GTPS; hip instability; acetabular dysplasia

Greater trochanteric pain syndrome (GTPS) is a heterogeneous group of disorders whose common feature is the presence of pain and tenderness about the lateral thigh and buttock.²¹ Historically described as trochanteric bursitis, the modern understanding is that GTPS may arise from bursitis, tendinosis/tearing of the gluteus medius and/or gluteus minimus, friction syndrome/snapping of the iliotibial band over the greater trochanter (coxa saltans), or some combination of these.²⁶ The reported prevalence of the condition has been estimated at 15% in women and 6.6% in men over the age of 50 years.¹⁹ Diagnosis is primarily clinical, though imaging findings may reveal the presence of tendinosis or

tears of the abductor insertions. Multiple studies have attempted to correlate symptoms with imaging findings.

Understanding who gets GTPS and why remains a challenge. While women and older adults have the highest incidence of disease, the condition is seen across all age groups and patient characteristics. Prior studies have found that most patients with GTPS show evidence of abductor tendinosis and/or reactive iliotibial band changes.^{2,10,17} This has led researchers to seek out a pathoanatomic explanation for observed symptoms and identify specific anatomic differences that place patients at risk for GTPS.

Prior studies have examined the influence of femoral neck-shaft angle, trochanteric offset/pelvic width, acetabular index, acetabular anteversion, and leg-length inequality.^{7,13,20,24} These were based on the proposition that increased offset of the greater trochanter relative to the

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line-of-pull of the abductors predisposes to increased compressive forces across the footprint and central tensile stress shielding, resulting in tendinosis and eventual tearing. While conceptually logical, the results of this line of inquiry have been inconsistent.

What has not been examined is whether bony hip stability influences the development of GTPS. Multiple radiographic parameters have been associated with acetabular dysplasia and hip instability, including the lateral center-edge angle (LCEA), anterior center-edge angle, Tönnis angle, hip extrusion index, and acetabular depth/width ratio (ADW). The gluteus medius and minimus serve 2 functions: (1) the initiation of hip abduction and (2) stabilization of the pelvis during motion and gait. However, the hip abductors may also play a role in stabilization of the femoroacetabular joint. Hip abductor tension not only stabilizes the pelvis relative to the femur in the frontal plane but also produces strong compressive forces across the femoroacetabular articulation, with forces equivalent to 2.5 to 3 times greater than body weight.¹⁴ This compressive force is inherent to the hip joint, and abductor deficiency is a known cause of dislocation after total hip arthroplasty.¹¹ It is possible that, with decreased bony constraint of the femoroacetabular joint, there would be a corresponding increase in stress on the hip abductors as the body seeks to maintain a reduced hip joint. This could potentially result in overuse and subsequent tendinosis of the gluteus medius and minimus.

The purpose of this study was to explore the relationship between acetabular dysplasia and clinical signs of GTPS. We retrospectively compared patient characteristics and radiographic measures of acetabular dysplasia in consecutive cohorts of patients with and without GTPS. We hypothesized that GTPS would be associated with radiographic measures of acetabular dysplasia on standing anteroposterior (AP) radiographs.

METHODS

Sample Size Estimate

No prior studies were available on which to base our sample size estimate. However, the reported rate of radiographic hip dysplasia in the general population is reported to be between 1.7% and 20% depending on the measurement used.⁵ Based on our hypothesis, we assumed a priori that the rate of at least 1 positive dysplastic sign in patients

without a diagnosis of GTPS would be 5% (25th percentile of the reported range), and the rate of at least 1 dysplastic parameter in patients with a diagnosis of GTPS would be 15% (75th percentile of the reported range). Based on this assumption, when setting the alpha to .05 and power to 80%, we required 141 patients per group to detect this difference (Version 3.1.9.6; G*Power for Mac OS X).⁶ Given the uncertainty inherent in our assumed proportions, we elected to increase the sample size by approximately 50% to 200 patients per group.

Patient Identification

After institutional review board approval, we sought to identify a total of 400 patients. Patients were included if they were between the ages of 18 and 40 years with an available standing AP radiograph and they had been evaluated for a chief complain of hip pain. We purposefully excluded older patients to avoid the confounding effects of hip osteoarthritis on radiographic measurements. Patients were excluded from analysis if they had evidence of a prior pelvis fracture, a history of ipsilateral hip surgery of any kind, or Tönnis grade 2 or higher osteoarthritis on radiographs. All patients were TRICARE beneficiaries (active duty military personnel, retirees, and their dependents). All were evaluated and treated in the same geographic catchment area (Hampton Roads area, Virginia) by physicians/surgeons employed with the Military Health System.

The Military Data Repository was queried for all patients between the ages of 18 and 40 years diagnosed in our catchment area with GTPS (International Classification of Diseases, Tenth Revision, code M70.60, M70.61, M70.62, M72.65, M76.00, M76.01, or M76.02) by any health care provider. We identified 200 patients with an available standing AP pelvis radiograph, in reverse chronological order based on date of diagnosis, from September 30, 2018. This comprised our study group. Two patients were subsequently excluded for advanced radiographic osteoarthritis on radiographs, leaving a study group total of 198 patients.

We then searched records from our sports medicine clinic for all patients between the ages of 18 and 40 years, with an available standing AP pelvis radiograph, who were seen for the chief complaint of hip pain. We only included control patients who had documentation of no lateral hip pain, no tenderness about the greater trochanter, no pain with resisted hip abduction, and no diagnosis of GTPS. Here as

†Address correspondence to CDR George C. Balazs, MD, MC, USN, 620 John Paul Jones Circle, Portsmouth, VA 23708, USA (email: gcbalazs@gmail.com).

*Bone and Joint Sports Medicine Institute, Naval Medical Center Portsmouth, Portsmouth, Virginia, USA.

†Eastern Virginia Medical School, Norfolk, Virginia, USA.

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well, 200 patients were identified, in reverse chronological order based on date of radiographs, from September 30, 2018. This comprised our control group. Two patients were subsequently excluded, 1 for advanced radiographic osteoarthritis and the other for a history of prior periacetabular osteotomy.

Data Collection

All identified patient medical records were examined for patient age at time of diagnosis, sex, race, and body mass index (BMI); and for the study group, affected laterality.

Standing AP pelvis radiographs were independently evaluated by 2 fellowship-trained orthopaedic surgeons (1 sports medicine [G.C.B.], 1 hip and knee reconstruction [A.H.G.]) who were blinded to patient characteristics and group assignment. Using published techniques, each surgeon measured the Tönnis angle,²² LCEA,³ and ADW.⁴ Each surgeon also determined whether the hip center of rotation was lateralized relative to the posterior wall (positive posterior wall sign).¹⁸ Intraclass correlation coefficients (ICCs) and interobserver agreement (kappa statistic) were calculated for interobserver reliability of measurements; no intraobserver reliability was assessed. The final measurement of Tönnis angle, LCEA, and ADW was the average of the 2 observers' measurements. The final posterior wall sign was based on consensus after a joint review by the 2 observers.

The Tönnis angle, LCEA, and ADW were further subdivided into dysplastic versus nondysplastic, based on published norms.^{4,15,23,25} The total number of positive dysplastic radiographic parameters was counted for each patient.

Statistical Analysis

Shapiro-Wilk testing found that most continuous variables were not normally distributed, with the exception of Tönnis angle measurements in the study group ($P = .22$) and LCEA in the control group ($P = .11$). Consequently, nonparametric statistics were employed for univariate analysis. Data were summarized as counts, medians, ranges, interquartile ranges, and 95% CIs. Univariate statistics were utilized to determine significant associations between the presence of GTPS and the various patient characteristics and radiographic parameters using chi-square analysis, Fisher exact test, and the Mann-Whitney U test as appropriate. Factors with a P value $< .20$ on univariate testing were included in a logistic regression model to identify independent predictors of the presence of GTPS.

RESULTS

Patient characteristics are summarized in Table 1. There was no difference between groups in terms of age, BMI, race, or laterality. There was a significant difference in the sex distribution of the 2 groups, with significantly more female patients in the GTPS group versus the non-GTPS group (71% vs 30%; $P < .001$).

TABLE 1
Patient Characteristics Between Groups^a

	GTPS (n = 198)	No GTPS (n = 198)	<i>P</i>
Median age [IQR]	29 [12]	28 [12]	.434
Median BMI [IQR]	26.1 [6.1]	26.4 [4.8]	.743
Sex			<.001
Male	58 (29)	138 (70)	
Female	140 (71)	60 (30)	
Race			.28
White	111 (56)	117 (59)	
Non-White	42 (21)	30 (15)	
Unknown	45 (23)	51 (26)	
Laterality			.223
Right	106 (54)	119 (60)	
Left	92 (46)	79 (40)	

^aData are presented as number of patients (%) unless otherwise indicated. BMI, body mass index; GTPS, greater trochanteric pain syndrome; IQR, interquartile range.

TABLE 2
Comparison of Acetabular Parameters Between Groups^a

	GTPS	No GTPS	<i>P</i>
Tönnis angle, deg	5.5 [6.5]	4.0 [5.0]	.001
LCEA, deg	30.0 [7.5]	30.0 [8.0]	.3
Acetabular depth/width ratio	0.290 [0.05]	0.300 [0.04]	.01

^aData are presented as median [IQR]. GTPS, greater trochanteric pain syndrome; LCEA, lateral center-edge angle.

ICCs for the LCEA (0.82) and Tönnis angle (0.82) were good. The ICC for the ADW was poor (0.08). The kappa statistic for the presence of a posterior wall sign was moderate (0.51).

Results of the univariate analysis are summarized in Tables 2 and 3. There was a significant difference between groups for the Tönnis angle, ADW, and ADW < 0.25 (indicating dysplasia).

Eight factors met criteria for inclusion in the logistic regression model: sex ($P < .001$); Tönnis angle ($P = .001$); ADW ($P = .03$); Tönnis angle $> 10^\circ$ ($P = .13$); the presence of posterior wall sign ($P = .18$); LCEA $< 25^\circ$ ($P = .15$); the presence of ≥ 3 radiographic dysplastic parameters ($P = .08$); and the presence of 4 radiographic dysplastic parameters ($P = .06$). The Nagelkerke R^2 for the model was 0.24, and Hosmer-Lemeshow testing indicated that the model was significant ($P = .801$).

The model determined that female sex (odds ratio, 5.4; 95% CI, 3.6-8.5; $P < .001$) and higher Tönnis angle ($P < .01$) were independent predictors of GTPS within the study cohort.

DISCUSSION

The most important finding of this study was that, within our study population, an increased Tönnis angle predicted

TABLE 3
Proportion of Patients With Dysplastic Parameters
Between Groups^a

	GTPS (n = 198)	No GTPS (n = 198)	P
Tönnis angle, deg			.133
≤0	173 (87)	183 (92)	
>10	25 (13)	15 (8)	
Posterior wall			.18
Normal	161 (81)	149 (75)	
Deficient	37 (19)	49 (25)	
LCEA, deg			.151
≥25	156 (79)	168 (85)	
<25	42 (21)	30 (15)	
Acetabular depth/width ratio			.03
≥0.25	177 (89)	189 (95)	
<0.25	21 (11)	9 (5)	
≥1 dysplastic parameters			>.99
Yes	71 (36)	71 (36)	
No	127 (64)	127 (64)	
≥2 dysplastic parameters			.32
Yes	33 (17)	25 (13)	
No	165 (83)	173 (87)	
≥3 dysplastic parameters			.08
Yes	16 (8)	7 (4)	
No	182 (92)	191 (96)	
4 dysplastic parameters			.06
Yes	5 (3)	0 (0)	
No	193 (97)	198 (100)	

^aData are presented as number of patients (%). GTPS, greater trochanteric pain syndrome; LCEA, lateral center-edge angle.

the presence of GTPS. The Tönnis angle is a measure of the weightbearing surface of the acetabulum, and higher angles indicate decreased coverage of the femoral head. This finding supported our hypothesis that decreased acetabular constraint of the femoral head within the femoroacetabular articulation may result in increased load on the hip abductors, resulting in GTPS. Univariate analysis also found a significant association between decreased ADW and the presence of GTPS, but this was not significant when adjusting for other factors. Female sex was an independent predictor of the presence of GTPS, with a 5.4 times increased risk in women compared with men. This is consistent with prior incidence studies, which have reported odds ratios between 2.4 and 5.03.^{1,8}

The observed increased incidence and prevalence of GTPS in women led to the hypothesis that the generally wider pelvises in women result in increased compression loading of the abductor tendons.⁸ This spawned several studies seeking to correlate radiographic findings with the presence of GTPS.^{7,13}

Fearon et al⁷ examined differences in the femoral neck-shaft angle, acetabular index, pelvic width, distance between the trochanters, and hip circumference (adiposity) in 220 women, concluding that a neck-shaft angle lower than 134° and increased adiposity were risk factors. A closer examination of their analysis, however, raises some doubts about the strength of these associations. An

association between decreased neck-shaft angle was only found in patients who had undergone abductor tendon reconstruction, not in patients with GTPS who did not require surgical intervention. The association with adiposity was not present with standard analysis of variance testing, but only appeared with canonical discriminant analysis. This suggests that the association between a varus neck and GTPS may only be operative in more advanced disease. Their analysis was also limited by their division of their patient population into 4 different groups, with 2 subsets of patients with GTPS (“standard” GTPS and those requiring operative intervention) and 2 control groups (patients with hip osteoarthritis and asymptomatic controls).

In contrast, Moulton et al¹³ found no association between femoral neck-shaft angle and the presence of abductor tendinosis on magnetic resonance imaging (MRI) in 203 patients. They did find an association between increased acetabular anteversion and radiographic evidence of abductor tendinosis, but this finding was substantially limited by their lack of clinical data showing symptomatic disease. As has been noted in multiple previous studies, there is very poor concordance between MRI findings and clinical symptoms. Many, if not most, patients with gluteal tendinosis on MRI are asymptomatic.

Viradia et al²⁴ measured the difference in width between the greater trochanters and the iliac wings in 202 patients and found a significant association with clinical GTPS. However, the overall difference was small (2 mm), and they did not consider potential confounding variables. This association may simply reflect the generally wider hips seen in women coupled with increased prevalence of GTPS in women.

An association between acetabular undercoverage and GTPS, to the best of our knowledge, has not been previously explored. The hip abductors not only are important initiators of motion and pelvic stabilization with gait, but they also may provide dynamic stabilization of the femoral head within the acetabulum. Nonoperative treatment of hip dysplasia and microinstability focuses on improving dynamic stabilization of the hip. Tendinopathies are thought to arise from overload in many cases, so the increased work of the hip abductors in the setting of hip microinstability and borderline or frank hip dysplasia could potentially result in clinically symptomatic GTPS.

Evaluating hip stability, however, remains challenging.⁹ Unlike the shoulder and knee, clinicians can rarely detect instability in the hip with physical examination maneuvers. Even frankly dysplastic hips are challenging to subluxate with manual force alone. The diagnosis of more subtle instability, as has been hypothesized for hip microinstability, relies on a combined assessment of patient-reported symptoms, physical examination findings, and radiographic measures. No single test, or even combination of tests, is definitive for the diagnosis.

We identified increased Tönnis angle as a risk factor for GTPS, even after adjusting for patient sex and other radiographic parameters. This suggests that our hypothesis of a relationship between hip stability and GTPS may be true. However, these data should be interpreted very cautiously,

especially given that our regression model parameters suggest that the included factors account for less than half of the observed variance in the data set. We consider our results only a first step in defining whether this association exists.

There are several important limitations to our findings that must be acknowledged. First, while our cohorts were identified consecutively, the fact that all of them were evaluated for various hip conditions does introduce an unspecified degree of selection bias. Second, we did not collect information on final diagnosis other than GTPS. Previous authors have suggested potential relationships between femoroacetabular impingement and osteoarthritis with GTPS.^{16,19} While our inclusion of only patients aged 18 to 40 years and exclusion of advanced osteoarthritis likely controlled for degenerative changes to an extent, we were not able to control for potential confounding with FAI. Third, we did not match patients based on sex. This is a potential source of bias, in that the skewed sex distribution may also skew the distribution of the radiographic parameters between groups. We chose to account for this statistically by utilizing our regression model. While this is statistically correct, and we stand by these results, it does not provide the same level of robust controlling that explicit matching provides. Fourth, the diagnosis of GTPS in our study cohort was made by a variety of physicians from both primary care and specialty practices. While the condition is well defined from a clinical standpoint and relatively easy to diagnose, it is possible that some of these patients were misdiagnosed, introducing error into our analysis. Fifth, our analysis is limited by varying definitions of what constitutes normal radiographic parameters in the hip. This particularly influenced the cutoffs for “normal” versus “dysplastic” parameters when we converted our measurements to categorical variables. We attempted to mitigate this by also including these measurements as continuous variables. Sixth, by excluding patients over 40 years of age, we eliminated the traditional category of patients discussed in the literature. This was purposeful, as we believe the confounding effect of mild degenerative changes is likely significant. However, this could potentially limit the applicability of our findings to older patients.

Finally, it remains unclear why only the Tönnis angle was associated with GTPS, whereas other parameters were not. This may be an issue with statistical power. However, a recent study by McQuivey et al¹² found an association between increased Tönnis angle and failure of hip arthroscopy in patients with borderline hip dysplasia. Interestingly, they found no association between failure rates and lower LCEA, lower anterior center-edge angle, extrusion index, or ADW. It may be that the Tönnis angle carries an outsized importance in determining instability, compared with other traditional measures of potential hip instability.

In spite of these limitations, we believe that our data are suggestive of a real association between decreased acetabular coverage and the presence of GTPS. Future studies could consider performing prospective comparative studies of GTPS findings in patients with and patients without borderline or frank acetabular dysplasia, or retrospective

case-control studies with larger patient populations that would permit matching based on sex.

CONCLUSION

Women had a 5.4 times increased likelihood of GTPS compared with men. An increased Tönnis angle appeared to be an independent risk factor for GTPS when controlling for patient age, BMI, and sex. This may indicate that decreased bony hip stability predisposes patients to GTPS via overuse of the hip abductors during dynamic stabilization of the femoroacetabular articulation.

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