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Severe Lumbar Disability Is Associated With Decreased Psoas Cross-Sectional Area in Degenerative Spondylolisthesis

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Introduction

There has been increasing interest in examining the relationship of lumbar paraspinal muscle morphometry and outcomes after lumbar spinal surgery, as well as investigating any association between changes in paraspinal muscle density and low back pain (LBP). The multifidus, iliocostalis, and longissimus muscles comprise the posterior paraspinal muscle complex, and provide dynamic stability to the lower lumbar spine. Recent literature examining the posterior lumbar paraspinal muscle cross-sectional surface area (CSA), as measured on magnetic resonance imaging (MRI) or computed tomography (CT), has found some association with decreased paraspinal muscle density and worsening lumbago. Decreased CSA of the multifidus muscle has been shown to independently predict poor outcomes after surgical intervention for lumbar spinal...
stenoantis, while increasing fat infiltration of the erector spinae musculature may contribute to worsened disability and the development of modic changes in the lumbar spine. A progressive decrease in paraspinous CSA and multifidus fat infiltration may occur as part of normal aging, but may also result from underlying structural pathology that can contribute to severe LBP.

However, the relationship of the iliopsoas muscle to the posterior paraspinal muscles, and the effect of variation in psoas CSA to lumbar disability, is also of increasing interest. The anterior psoas muscle works in concert with the posterior structures to maintain posture and stabilize the spine. While psoas CSA has been shown to decrease with age and female sex, and may not correlate with severity of structural alterations on MRI in patients with isthmic spondylolisthesis, the association between changes in psoas CSA and the severity of lumbar disability in patients with degenerative spondylolisthesis has not been extensively explored. We hypothesized that psoas and paraspinal CSA in patients with disabling LBP, as determined by the Oswestry Disability Index (ODI), would be significantly decreased when compared to patients without significant lumbar disability. The purpose of this study, therefore, was to compare the absolute psoas and paraspinous CSA in patients with degenerative lumbar spondylolisthesis and corresponding severe disability to similar patients with only mild or moderate disability.

**Methods**

After institutional review board approval, a retrospective review of outpatient medical records was performed for patients with degenerative lumbar spondylolisthesis undergoing single level posterior lumbar fusion. Inclusion criteria were any patient greater than 18 years of age at our institution diagnosed with degenerative lumbar spondylolisthesis based on the ICD-9 code 721.42, with a preoperative lumbar spine MRI and completed preoperative patient-reported outcome scores. Patients younger than 18 years, those lacking a preoperative lumbar spine MRI or completed preoperative patient-reported outcome scores, or those with a diagnosis other than degenerative lumbar spondylolisthesis were excluded from the study. Patients who had previously undergone lumbar spinal surgery of any type were also excluded. Patients were stratified based on their preoperative ODI, with ODI score ≤40 comprising the mild to moderate (MMD) disability group, and ODI score >40 comprising the severe disability (SD) group. Other health-related questionnaires, including the Short Form 12 Physical (SF-12 P), Short Form 12 Mental (SF-12 M), and back pain VAS scores, were also performed. Demographic data, including age, sex, history of coronary artery disease and/or congestive heart failure, BMI, diabetes mellitus, smoking status and American Society of Anesthesiology (ASA) class was also recorded.

T1-weighted axial MRI images were evaluated independently by 2 blinded reviewers. Using Sectra Liteview Picture Archiving and Communication System (PACS) imaging measurement software (SectraAB, Linköping, Sweden), the CSA of the posterior paraspinal musculature (multifidus, iliocostalis, and longissimus), as well as the anterior psoas CSA, were measured. The measurements were taken through the same axial cut at the midpoint of the L3-4 vertebral disc space (Figure 1). The average of the 2 measurements from each reviewer was then recorded as the CSA for that muscle. A ratio of the psoas CSA to the total posterior paraspinal CSA, as well as a psoas-to-multifidus ratio, were calculated to assess for any relative changes between posterior and anterior muscle CSA.

We used Microsoft Excel and Open Source Epidemiologic Statistics for Public Health (OpenEpi) Version 3.01 and JMP (SAS, Cary, NC, USA) for statistical tests. Student’s t test was used to compare continuous variables between groups. Multivariable logistic regression was performed analyzing the effects of ASA (American society of Anesthesiologists) class, history of heart disease, smoking status, and psoas CSA on lumbar disability. P ≤ .05 was considered statistically significant for all tests.

**Results**

A total of 101 patients met our inclusion criteria, with an average age of 60.0 years. Three patients had minimal disability (ODI <20), 34 patients had moderate disability (ODI 21-40), 48 had severe disability (ODI 41-60), and 16 had crippling and/or exaggerated pain (ODI >60). Using an ODI of 40 as a threshold to group patients as either mild/moderate or severe, there were 37 patients (36.6%) in the SD group and 64 (63.4%) in the MMD group. Average age was 59.1 and 61.6 years in the SD and MMD groups, respectively (P = .377). Average body mass index (BMI) was 30.6 and 31.5 kg/m², respectively (P = .474).
Table 1. Summary of Patient Demographics.

|                        | Mild/Moderate Disability | Severe Disability | P     |
|------------------------|--------------------------|-------------------|-------|
| n (% male)             | 37 (48.6)                | 64 (45.3)         | .746  |
| Mean BMI (kg/m²)       | 31.5                     | 30.6              | .474  |
| Mean age, years        | 61.6                     | 59.1              | .377  |
| Smokers (%)            | 16.2                     | 34.4              | .05*  |
| ASA class              | 1.75                     | 2.03              | .005* |
| DM (%)                 | 16.2                     | 10.9              | .445  |
| CAD/CHF (%)            | 2.7                      | 26.6              | .003* |
| Mean VAS back pain     | 5.8                      | 7.8               | .01*  |
| Mean SF-12 Physical    | 33.5                     | 27.9              | .002* |
| Mean SF-12 Mental      | 51.2                     | 46.8              | .066  |

Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; DM, diabetes mellitus; CAD, coronary artery disease; CHF, congestive heart failure; VAS, visual analogue scale.

There were no differences in the ratio of male and female patients between groups (45.3% male and 48.6% male in the SD and MMD groups, respectively, P = .746). A higher percentage of patients in the SD group reported active tobacco smoking (34.4% vs 16.2%, P = .05). Patients in the SD group had a significantly higher average ASA classification (2.03 vs 1.75, P = .005) and a significantly higher percentage had a history of heart disease (26.6% vs 2.7%, P = .003). The SD group patients also had higher average VAS back pain scores, as well as lower average SF-12P scores. This data is summarized in Table 1.

The average time between lumbar spine MRI and initial outpatient evaluation was 3.6 months. For the posterior paraspinal musculature, average iliocostalis CSA was 1093.5 mm² in the SD group versus 1192.2 mm² in the MMD group, which was not statistically significantly different (P = .168). The measured longissimus CSA was 685.8 versus 764.8 mm² in the SD and the MMD groups, respectively, which was also not significantly different (P = .329). The multifidus CSA was 499.1 versus 526.0 mm² for the SD and MMD groups, respectively, again not significantly different (P = .125). Psoas muscle CSA was significantly decreased in the SD group compared to the MMD group (1010.1 vs 1178.6 mm², P = .041). The overall posterior paraspinal muscle CSA was also not significantly different between groups, and while the ratio of psoas CSA to overall posterior paraspinal CSA was lower in the SD group, it did not reach statistical significance. When analyzing patients based on ODI subgroup (<20, 21-40, 41-60, >60), 1-way analysis of variance did not demonstrate any significant differences in average psoas CSA (P > .05). We also compared patients in the moderate (ODI = 21-40) and severe (ODI = 41-60) disability groups while excluding outliers in the extreme ODI groups. We found average psoas CSA remained significantly decreased in the severe ODI group when compared with the moderate disability group (1193.49 vs 992.71 mm², respectively, P = .028). Univariate contingency analysis of the distribution of psoas CSA demonstrated that the upper quartile (psoas CSA >1349.0 mm²) was protective against severe disability (likelihood ratio = 0.272, P = .006).

A multivariable logistic regression model was then employed and found that active smoking was independently associated with severe disability (odds ratio = 12.9, range = 1.19-140.2, P = .035), while psoas size above the upper quartile threshold value was significantly protective against severe disability (odds ratio = 0.13, range = 0.03-0.66, P = .013). ASA class and history of heart disease were not associated with lumbar disability (P > .05). This data is summarized in Tables 2 and 3. A scatterplot of psoas CSA versus ODI score is represented in Figure 2.

Discussion

We found that in patients with degenerative lumbar spondylolisthesis and LBP leading to severe disability, as determined by preoperative ODI, the CSA of the iliopectamus muscle on MRI was significantly decreased by almost 200 mm² when compared with similar patients with mild or moderate disability. In addition, psoas CSA in the upper quartile range was strongly and independently protective against severe disability. While we did find that smoking status was also independently associated with severe lumbar disability, which corroborates the results of a previously published meta-analysis, there were no significant differences in CSA in any of the posterior paraspinal musculature between groups. To our knowledge, this is the first

Table 2. Muscle Cross-Sectional Area Measurement Results and Univariate Analysis.

|                      | Mild/Moderate Disability | Severe Disability | P-value |
|----------------------|--------------------------|-------------------|---------|
| Psoas CSA (mm²)      | 1178.6                   | 1010.1            | .041*   |
| Iliocostalis CSA (mm²)| 1192.2                   | 1093.5            | .168    |
| Longissimus CSA (mm²)| 764.8                    | 685.8             | .329    |
| Multifidus CSA (mm²) | 526.0                    | 499.1             | .125    |
| Total posterior paraspinous muscle CSA (mm²) | 2456.8 | 2278.4 | .168 |
| Psoas-posterior paraspinous muscle CSA ratio | 0.485 | 0.441 | .087 |

Abbreviation: CSA, cross-sectional area.

*Indicates a statistically significant difference (P ≤ .05).

Table 3. Multivariate Analysis Results.

| Variable               | Odds Ratio*                          | Range      | P     |
|------------------------|--------------------------------------|------------|-------|
| ASA class              | 5.28                                 | 0.189-147.7| >.05  |
| CAD/CHF                | >200                                 | 0 to >1000 | >.05  |
| Psoas CSA (>75%ile)    | 0.13                                 | 0.03-0.66  | .013* |
| Smoking status         | 12.9                                 | 1.19-140.2 | .035* |

Abbreviations: ASA, American Society of Anesthesiologists; CAD, coronary artery disease; CHF, congestive heart failure; CSA, cross-sectional area.

*Odds ratios are presented as the independent likelihood of having severe lumbar disability, based on Oswestry Disability Index (ODI) score >40.

*Indicates a statistically significant difference (P ≤ .05).
Wan et al\textsuperscript{10} reported significant ipsilateral atrophy of the para-
found that patients with multifidus CSA <8.5 cm\textsuperscript{2} undergoing
of the posterior paraspinal muscles and the relationship
group of preoperative patients.

corresponding to the severity of lumbar disability in a select
trend in decreasing psoas CSA with increasing ODI is noted, but there
area (CSA) versus Oswestry Disability Index (ODI) score. A general
Figure 2.

Recent literature has focused on changes in size and density
of the posterior paraspinal muscles and the relationship between LBP, disability, and surgical outcomes.\textsuperscript{3,4,9,10} In the
present study, we were unable to show any significant differences in CSA of posterior paraspinal musculature between
patients with severe or mild/moderate lumbar disability. In
their study of LBP patients with spinal stenosis, Zotti et al\textsuperscript{3} found that patients with multifidus CSA <8.5 cm\textsuperscript{2} undergoing
posterior lumbar decompression and had significantly worse
health related outcomes scores at 1 and 2 years. Selective atrophy
of the multifidus muscle has also been found in patients with
isthmic spondylolisthesis.\textsuperscript{7} However, our inability to show
any significant association between posterior paraspinal CSA and lumbar disability corroborates the results of a recent sys-
tematic review, which concluded that currently published evi-
dence is conflicting and no relationship has been definitively established.\textsuperscript{11} In a retrospective chart analysis of 178 patients,
Wan et al\textsuperscript{10} reported significant ipsilateral atrophy of the para-
spinal muscles in patients with acute and chronic LBP, includ-
ing the psoas, but that significant associated fatty degeneration occurred synchronously with the loss of CSA. In support of
their findings, there is increasing evidence that such fatty
degeneration is related to paraspinal dysfunction and poten-
tially to structural changes within the spinal column. A recent
cross-sectional study of patients with severe LBP and ambula-
tory dysfunction found that lipomatous infiltration of the para-
spinal musculature was significantly associated with type II
Modic changes and chronic LBP.\textsuperscript{5} Thus, it may be reasonable
to posit that it is the quality of the paraspinal musculature,
rather than the absolute or relative cross-sectional size of indi-
vidual components alone, that is more relevant as a predictor of
lumbar dysfunction.

Particular interest in changes in the CSA of the iliopsoas has
also recently developed, as some previous studies have shown a
relationship between LBP and CSA.\textsuperscript{2,6,11-15} One study of
patients with unilateral LBP found a significant decrease in
ipsilateral multifidus and psoas CSA, which also positively
correlated with the severity of self-reported pain and radiculo-
pathic symptoms\textsuperscript{2}; these findings were confirmed by a later study in unilateral LBP patients.\textsuperscript{16} Arbanas et al\textsuperscript{10} compared a
cohort of patients with LBP to normal controls and found an
increase in the relative psoas CSA in patients with chronic pain;
however, they also found that the relative psoas CSA signifi-
cantly decreased in patients with degenerative structural
to the lumbar spine. The authors argue that these
changes are likely related to decreased activation of the psoas
secondary to chronic pain, and acknowledge that by normal-
izing psoas CSA to intervertebral disc CSA, rather than using
an absolute psoas CSA, these differences may be explained.\textsuperscript{6}
Psoas size and mass have also been shown to predict poor
surgical outcomes in patients undergoing spine surgery. Zakaria et al\textsuperscript{13} showed that for both male and female patients
undergoing lumbar surgery, a psoas CSA in the lowest tertile
was independently predictive of having a postoperative com-
plication, while decreases in the posterior paraspinals were not.
Similarly, Bokshan et al\textsuperscript{14} found that patients in the lowest third
of measured psoas CSA were at a 3-fold increased risk of post-
operative complications after thoracolumbar surgery and had a
significantly lower cumulative survival. In fact, some studies
have suggested that psoas CSA may function as a surrogate
measurement for overall sarcopenia and health status,\textsuperscript{14,17}
though this assumption has not necessarily borne out in recent
spine literature.\textsuperscript{18} While these studies have found associations
between decreased psoas CSA and poor surgical outcomes,
which were not explored in the present study, to our knowledge
this is the first study to show a relationship between psoas CSA and severity of lumbar symptoms and disability in patients
meeting operative criteria for degenerative spondylolisthesis.

There is no clear consensus on the role of the iliopsoas
muscle to the development of lumbar pain or degenerative
disease.\textsuperscript{11} The psoas muscle acts in concert with the posterior
paraspinal muscles to dynamically maintain sagittal alignment
and stabilize the lumbar spine, and various physical therapy
regimens for lumbago typically focus on strengthening and
stretching of the core stabilizers.\textsuperscript{7} As noted previously, some
authors have hypothesized that changes in CSA of the psoas
occur secondary to development of structural degenerative
disease, rather than as a cause of it.\textsuperscript{6} Still others, however,
have suggested that changes in recruitment of fibers from the
primary lumbar stabilizers, because of lifestyle or other fac-
tors, can lead to compromised spinal stability and worsening
pathology.\textsuperscript{2,19} Additionally, age-related changes affecting the
psoas and other paraspinals likely alter function, but the rela-
tionship between these changes and progression of disease is
unclear. In the present study, we did not find any significant

Figure 2. Graphical distribution of iliopsoas cross-sectional surface
area (CSA) versus Oswestry Disability Index (ODI) score. A general
trend in decreasing psoas CSA with increasing ODI is noted, but there
is no strong linear correlation ($R^2 = 0.0058$).
differences in age between the cohorts, despite differences in psoas CSA, limiting the applicability of age as a potential confounding factor.

There are several limitations to this study. The retrospective design can increase the risk for observer and reporting bias. The distribution of paraspinal and iliopectineus CSA in normal, asymptomatic controls is not known or well-studied. Additionally, our study population is limited in size, which places our analysis at risk for type II error. The ODI value of 40 is somewhat arbitrary for use as a cutoff value, though we elected to do so because of the small number of patients in the minimal or crippling/exaggerated symptoms groups. As such, we were unable to show any significant differences in psoas CSA when analyzing by each ODI subgroup, which we believe is likely related to low numbers of patients in the extreme groups. We also lacked potentially valuable data, such as the duration of LBP prior to evaluation, and we did not examine postoperative outcomes. Lumbar spine MRIs were performed at separate locations, which may potentially affect image quality and introduce variability in our CSA measurements. However, the measurement process was conducted by two blinded reviewers on the same imaging software system to minimize the risk of this error. The strengths of the study include utilization of an established method of measuring the CSA of the paraspinous musculature, as well as generally similar demographic data between cohorts. Our study population represents patients with prior advanced imaging who were seeking surgical evaluation for lumbar spondylolisthesis, which likely makes our findings specifically applicable to this population. However, as a purely cross-sectional study, we are unable to make any conclusions with regard to the etiology of psoas atrophy in patients with severe disability, nor can we make any determinations with regard to causal relationships between lumbago and psoas degeneration.

Conclusions

In patients with severe lumbar disability and a diagnosis of degenerative spondylolisthesis, when compared to similar patients with mild or moderate disability, we found significantly decreased absolute CSA of the psoas muscle. In addition, multivariate analysis found that increased psoas CSA was significantly protective against severe lumbar disability. However, we were unable to show any association between posterior lumbar paraspinous CSA and lumbar disability. Future studies prospectively measuring lumbar paraspinous muscle CSA and fatty degeneration in patients with different lumbar diagnoses, or even in normal healthy controls, would be optimal. Additionally, any effects of paraspinous morphology on postoperative outcomes, especially with validated health related outcomes scores, may further elucidate any potential relationships between these measurements and symptoms.

Authors’ Note

This study was performed at the Rothman Institute at Thomas Jefferson University, Philadelphia, PA. Two authors (SCW and PBM) are employees of the United States government. This work was prepared as part of their official duties and as such, there is no copyright to be transferred. The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Navy, Department of Defense, or US Government.

Declaration of Conflicting Interests

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