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Alteration in the Cross-sectional Area (CSA) Ratio of the Paraspinal Muscles following Vertebral Insufficiency Fractures

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Abstract

Background Vertebral insufficiency fractures in the elderly are associated with increased morbidity and mortality. Early diagnosis is essential to direct patient-specific rehabilitation.

Aims We hypothesize that in patients with vertebral insufficiency fractures, there is atrophy of the psoas and paraspinal muscles with alteration in the cross-sectional area (CSA) of the muscles.

Materials and Methods Magnetic resonance imaging (MRI) studies for 100 consecutive patients, older than 60 years presenting with lower back pain, were included in the study. For each MRI study, the CSA of the psoas and paraspinal muscles (multifidus) at the level of L4/5-disc space was measured to calculate the cross-sectional area ratio (CSAR) by two readers. One reader repeated the measurements after an interval of 2 weeks. We divided the patients (n = 100) into various groups based on the number of vertebral fractures.

Results In total, 77 patients with vertebral body fractures (48 with one, 16 with two and 13 with more than two fractures) were identified with a mean age of 73 (range 60–92) years. The ratio of multifidus CSA to psoas CSA was calculated with mean values of each group (1–4) as 2.56, 1.89, 2.09 and 2.16, respectively. There was statistically significance difference of the CSAR between the cohorts (p-value = 0.0115).

Conclusion Vertebral insufficiency fractures in the elderly are associated not only with atrophy of psoas and the multifidus group of muscles as evident by the CSA values, but they also affect the CSAR depending on the number of fractures. This finding may help to direct targeted patient-specific physiotherapy rehabilitation and interventions to prevent further such fractures.

Keywords
- spinal fractures
- vertebral body
- fragility fracture
- paraspinal muscles
- atrophy
- magnetic resonance imaging

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Introduction

Osteoporosis is characterized by a triad of low bone mass, normal mineralization, and structural deterioration of bone tissue, with a consequent increased risk of fragility fractures.[1] Associated with low bone mineral density (BMD), fragility fractures are most commonly in the spine (vertebrae), hip (proximal femur), and wrist (distal radius). Though hip fractures nearly always necessitate hospitalization, vertebral fractures are by far the most prevalent of osteoporotic fractures.[2] Consequently, osteoporosis-related fractures are a significant, growing social and economic burden on healthcare systems worldwide.[3,4] Vertebral fractures are recognized as a hallmark of osteoporosis and are associated with increased morbidity and mortality.[5] Vertebral insufficiency fractures may occur spontaneously or as a result of routine activities such as bending, walking, etc. As low back pain is common in the elderly, vertebral insufficiency fractures may go unrecognized or result in pain, disability, often leading to a reduced quality of life, inability to cope with daily activities, lengthy rehabilitation, long-term care, and social isolation.[6–9] Studies have been undertaken to evaluate the benefits and effects of both pharmacologic and non-pharmacologic interventions in patients with vertebral fractures to reduce pain and restore functional movement.[10–12]

Cross-sectional area (CSA) of both paraspinal and psoas muscles can be altered in patients with unilateral back pain, monosegmental degenerative disc disease, lumbar spinal stenosis, acute and chronic low back pain. It has been evaluated using magnetic resonance imaging (MRI) studies to assess muscle atrophy, fatty infiltration or direct treatment strategies.[13–15]

In this study, we investigate the effects of vertebral insufficiency fractures on the morphology of psoas and paraspinal muscles by evaluation of CSA and CSAR of these muscle groups. A further assessment is undertaken to explore whether these changes are proportional to number of vertebral insufficiency fracture segments and guide direct targeted patient-specific physiotherapy rehabilitation or interventions to prevent further such fractures.

Materials and Methods

Following local hospital committee ethics approval, a retrospective evaluation of our Radiology Information System (RIS) and Picture Archiving and Communication System (PACS) was performed to identify MRI studies on 100 consecutive patients, older than 60 years referred with lower back pain.

Patients with history of major trauma, hip fractures, hip replacement, and orthopaedic hardware were excluded. The number and level of vertebral insufficiency fractures were noted. Depending on the presence of vertebral insufficiency fractures, four groups were created with none, one, two and more than two fractures, respectively.

The CSA of the psoas and paraspinal muscles (multifidus) at the level of L4/5-disc space was calculated on axial-T2 MRI images at the level of L4/5 by musculoskeletal radiology fellow and fellowship trained consultant musculoskeletal radiologist with more than 2 years' experience (►**Figs. 1** and **2**). We elected to define L4/L5 level as our preferred measurement level. We selected L4/L5 as every MRI of lumbar spine will have axials through L4/5. Axial sequences through L4/L5 are true axial unlike L5/S1, which are planned along the disc and often there is lumbar lordosis making these oblique. Hence, to standardize, we selected L4/L5. We excluded areas of fat infiltration to exclusively measure lean muscle mass as accurately as possible. One reader repeated the measurements after an interval of 2 weeks.

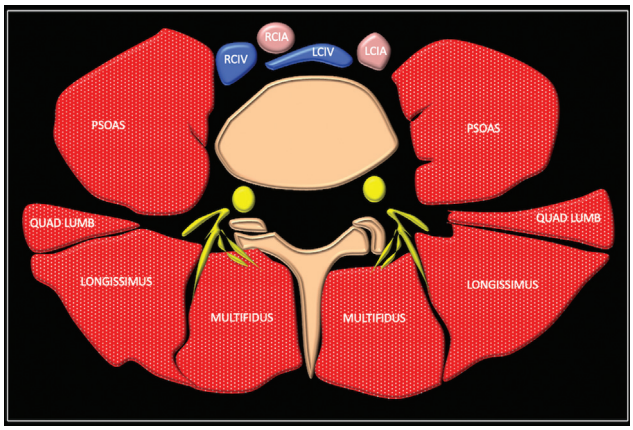

Fig. 1 Schematic anatomy of axial of lumbar spine at the of level of L4. RCIV, right common iliac vein; LCIV, left common iliac vein; RCIA, right common iliac artery; LCIA, left common iliac artery; QUAD LUMB, quadratus lumborum.

Demographic details, site, and number of vertebral body insufficiency fractures data for the four groups of patients in the study cohort were recorded. Microsoft Excel data sheet was used for data collection, and SPSS 24.0 software (SPSS Inc. Chicago, IL, USA) was used for descriptive analysis. Mean and standard deviation or median (range) were used to summarize the data. Analysis of variance (ANOVA) was used to analyze the difference of CSA and CSAR. We undertook ICC analysis as well. The ICC is a value between 0 and 1, where values below 0.5 indicate poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability. The level of statistical significance was defined as $p < 0.05$ in this study.

Results

A total of 100 consecutive patients were identified as 29 males (M) and 71 females (F), with a mean age of 73 years (range 60–92). Demographic and distribution of the patients in the four groups is highlighted in ►**Table 1**.

All fractures showed features of a chronic nature. A total of 23 patients were in group 1 (M:F 8:15, mean age 71.6 years), 48 in group 2 (M:F 14:34, mean age 74.9 years), 16 in group 3 (M:F 4:12, mean age 75.2 years), and 13 in group 4 (M:F 3:10, mean age 71.09 years).

The mean value of our multifidus to psoas muscle CSAR for each group (1–4) was 2.56, 1.89, 2.09, and 2.16 respectively

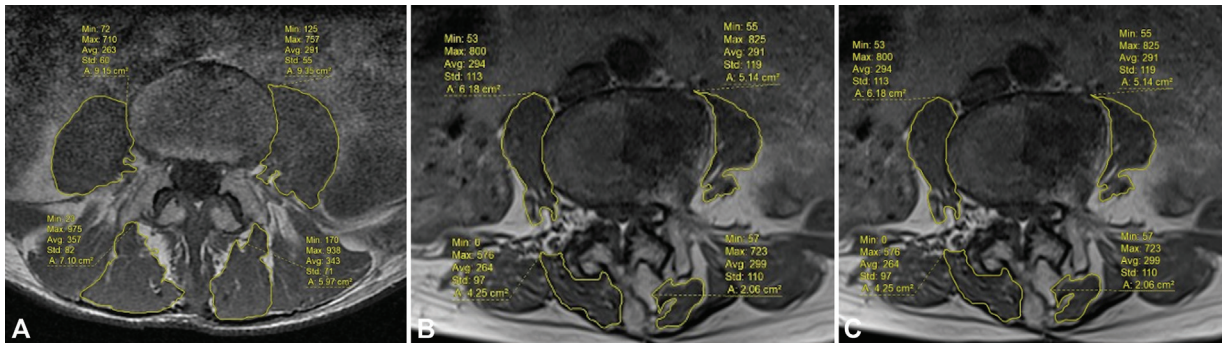

Fig. 2 Axial T2 image at the level of L4/L5 disc showing CSA of psoas and multifidus in normal (**A**), vertebral fracture (**B** and **C**).

Table 1 Demographics of cohorts of patients with 0,1, 2, and more than 2 vertebral fractures

Number of fractures	0	1	2	>2
Male	8	14	4	3
Female	15	34	12	10
Average age (y)	71.6	74.9	75.2	71.09
Max age (y)	89	92	87	81
Min age (y)	60	60	62	63

Table 2 Descriptive statistics of cohorts showing CSAR in patients with 0,1, 2, and more than 2 vertebral fractures

Number of fractures	0	1	2	>2
Mean	2.56	1.89	2.09	2.16
SD	1.47	1.014	1.36	1.52
SEM	0.2	0.1	0.24	0.32
95%CI	2.14–2.98	1.68–2.0	1.6–2.58	1.48–2.8
Median	2.13	1.85	2.09	2.03

Abbreviations: CI, confidence interval; SD, standard deviation; SEM, standard error of mean.
Note: Group 1–no fracture, Group 2- one vertebral fracture, Group 3- 2 vertebral fractures, Group 4- more than 2 vertebral fractures.

(►**Table 2**). There was statistically significant decrease in the ratios with *p*-value of 0.0115 in patients with fractures. However, there was no significant proportional decrease in the CSA with increase in the number of vertebral fractures. There was excellent intra and inter-observer reliability on ICC analysis with intra-class correlation of 0.77 and 0.9, respectively.

Discussion

Based on our findings, there is quantitative evidence that a lower paraspinal to psoas muscle CSA correlates well with presence of lower thoracolumbar vertebral fragility fractures. We elected to perform a ratio of psoas CSA to paraspinal muscle CSA to increase the robustness of our study given parasapinal CSA can be different in patients even in cases of monozygotic twins[16].

Most physical therapists include strengthening exercises in treatment of patients with lower back pain and it is known that training to increase strength is usually expected to result in an increase in muscle CSA as it is a primary determent of the capacity of a muscle to generate force[16]. Similar to other studies we found low CSA values of paraspinal muscles to psoas in patients with fragility fractures when compared with age-matched controls. By taking fat infiltration into account and concentrating on lean muscle mass to calculate our values, we confirmed our being hypothesis following our extensive literature review described, that there is a statistically significant difference between increasing number of vertebral fractures to psoas and paraspinal muscles CSA ratio.

A recent update to the physiotherapy rehabilitation for osteoporotic vertebral fracture concluded that although there is inadequate evidence, a short physiotherapy intervention of either manual therapy or home exercise provides long-term benefits, but arguably short-term benefits are valuable[17]. A very recent systematic review and meta-analysis[18] also concluded that exercise as part of management of

patients with fragility fractures may have benefit for pain. Therefore, early involvement of physiotherapy in patients with back pain and osteoporotic vertebral fractures would help with pain control and build-up of muscle strength which leads to increased back strength, endurance and improved balance as well as associated with reduce fear of falling[17].

The strength of this study therefore lies in a large sample size, by which we propose a predictive ratio based on MRI assessment of psoas and paraspinal muscles which can be used to quantify risk of vertebral fractures, and therefore target these patients for early identification and physiotherapy based on imaging undertaken for lower back pain, thus potentially reducing the likelihood of falls.

We suggest more studies with larger cohorts in different centers to further confirm our hypothesis.

Conclusion

We conclude that vertebral insufficiency fractures in the elderly demonstrate not only a statistically significant association with atrophy in psoas and the multifidus group of muscles as evident by the CSA values, but they also affect the CSAR depending on the number of fractures. This finding may help to direct targeted patient-specific physiotherapy rehabilitation and interventions to decrease fracture risk.

Conflict of Interest
None declared.

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