The Vastus Medialis obliquus and The Vastus Lateralis Muscle Atrophy is Existed in Patients with Patellofemoral Pain Syndrome

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Research article

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Abstract

Background: whether the vastus medialis obliquus (VMO) atrophy exists in patients with PFPS and whether the amount of atrophy differs between the VMO and vastus lateralis muscle (VLM) is still obscure.

Materials and methods: From June 2016 to March 2019, 61 patients with PFPS were collected into the study group, and an age, sex, and body mass index (BMI) matched cohort of 61 patients with normal knees were randomly selected into the control group. All enrolled subjects had undergone computed Tomography (CT) scans in the supine position. The cross-sectional area of the VMO and VLM in the sections of 0, 5, 10, 15, 20 mm above the upper pole of the patella were measured, and VMO/VLM area ratio were evaluated as well.

Results: In the study group and the control group, the VMO area in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 732.64±306.43 mm2 and 941.66±366.83 mm2 (P<0.001), 876.32±341.47 mm2 and 1119.6±405.01 mm2 (P<0.001), 1039.31±410.21 mm2 and 1302.75±425.14 mm2 (P<0.001), 1178.26±449.10 mm2 and 1496.67±474.70 mm2 (P<0.001), 1289.78±487.78 mm2 and 1643.33±507.08 mm2 (P<0.001); the VLM area in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 127.61±66.74 mm2 and 192.2±152.40 mm2 (P=0.003), 183.47±85.41 mm2 and 262.55±187.98 mm2 (P=0.004), 250.66±133.70 mm2 and 352.35±291.96 mm2 (P=0.015), 326.06±139.94 mm2 and 466.27±343.11 mm2 (P=0.013), 574.19±390.00 mm2 (P=0.005); the VMO/VLM area ratio in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 0.83±0.11 and 7.44±5.13 (P<0.001), 5.37±2.49 and 6.32±4.69 (P=0.168), 4.64±2.43 and 4.15±1.94 (P=0.554), 3.90±1.55 and 3.96±1.66 (P=0.434), 3.42±1.36 and 3.48±1.62 (P=0.826).

Conclusion: In patients with PFPS, the VMO and VLM atrophy was existed in the section of 0-20 mm above the upper pole of the patella in comparison with normal people; and the atrophy of the VMO was more evident than that of the VLM in the section that 0-5 mm above the upper pole of the patella. These findings support the rationale for use of general quadriceps exercise combined with VMO strengthening exercise as part of rehabilitation program for patients with PFPS.

1. Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal complaint, it is characterized as the pain in the anterior knee region when performing activities such as sitting, stair climbing, running, and squatting [24, 25]. The exact pathogenesis of PFPS has been proposed to be multifactorial, and one of the main suggested contributing factors is patellar malalignment or abnormal patellar instability. [26]

The function and the stability of the patellofemoral joint are normally maintained by a complex interaction between the active stabilizers, the passive stabilizers, and the osseous and cartilage morphology [1–4]. Vastus medialis muscle (VMM), especially the vastus medialis obliquus (VMO) which is a dynamic medial soft tissue stabilizer, plays an important role in the stability of the patellofemoral joint [5–7].

The VMO was described as the distal portion of the VMM, with the muscle fibers inserting at 50°angle to the longitudinal patellar alignmen. The structure of the VMO making it potentially able to partially counterbalance the lateral pull of the VLM [8–10]. Studies has shown that the weakness of the VMO caused the patellar lateral shift at 0 and 15 degree of knee flexion and and correlated with patellofemoral pain syndrome [5, 7].

However, whether the VMO atrophy is existed in PFPS patients is still obscure. Doxey et al. [11] shown that 28 of 49 participants with PFPS had quadriceps atrophy by measuring the thickness of the quadriceps. Kaya et al. [12] and Pattyn et al. [13] found the cross-sectional area of the VMO in patients with PFPS was smaller in comparasion with their asymptomatic side. But Balcarek et al. [14] and Callaghan et al. [15] reported that there was no significant difference in cross-sectional area of the VMO between knees with PFPS and normal knees.

In addition, most studies focused on the VMO and overlooked the change of the VLM in patients with PFPS, which was also present decreased muscle strength. Therefore, we measured the cross-sectional area of the VMO and VLM in the sections of 0, 5, 10, 15, 20 mm above the upper pole of the patella on CT scans, and VMO/VLM area ratio were evaluated as well.

The purpose of this study is to evaluate whether the VMO and VLM atrophy exists in patients with PFPS and whether the amount of atrophy differs between the VMO and VLM. It is speculated that the VMO and VLM atrophy was existed in patients with PFPS; and the atrophy of the VMO was more evident than that of the VLM.

2. Materials And Methods

2.1. Participants

In the present study, 61 patients were collected into the study group. Our inclusion criteria were as follows: (1) patients treated at the Third Hospital of Hebei Medical University from June 2016 to March 2019; (2) aged from 18 to 45 years (to reduce the likelihood of osteoarthritic changes in the patellofemoral joint); (3) patients had undergone CT examination in the spine position; (4) anterior knee pain provoked by at least 2 of the following activities: prolonged sitting with flexed knees, stair climbing, squatting, running, kneeling, and jumping; (5) exhibition of 2 or more of the following clinical criteria on assessment: pain on direct compression of the patella against the femoral condyles with the knee in full extension, tenderness on palpation of the posterior edge at the medial and/or lateral border of the patella, pain on resisted knee extension, and pain on direct compression of the patella against the femur during isometric quadriceps contraction with the knee in slight flexion [24].

The exclusion criteria were: (1) previous knee surgery or trauma that resulted in a period of non–weight bearing, or any internal knee derangement; (2) other knee disorders like fracture, ligament injury, meniscal injury; (3) patellofemoral arthritis greater than grade II, the patellofemoral joint surface represented a bony contact (Iwano classification)[16]. 2 patients were excluded from the study group because of the previous knee surgery.

The control group which was matched with the experimental group according to sex and age included 61 subjects without a history of patellofemoral joint related diseases. All patients underwent CT examination before admission to reduce muscle atrophy caused by physical rest in the hospital.

2.2.CT protocols

All patients underwent CT examination in the supine position, with the knee fully extended, and the quadriceps muscles was relaxed. The limbs were fixed by equipment to minimize motion. All examinations were performed with the same CT scanner (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany). The CT scanning parameters included a tube voltage of 120 kV, 100 effective mAs, 1 mm slice thickness, a gantry rotation time of 1 s, and a matrix size of 512× 512. All measurements were performed using RadiAnt DICOM software (Medical Ltd., Poznan, Poland).

2.3. Assessment

All patients obtained CT images of the hip and knee to measure the cross-sectional area of the VMO and VML, the measurement was obtained using the annotation tool of the picture archiving and communication system (PACS) workstation (Cen- tricity, GE Healthcare, St. Gilles, United Kingdom).

We first ensured that the scans of the hip and the knee were in the same position. Second, defined the sections that 0, 5, 10, 15, 20 mm above the upper pole of the patella respectively, and measured the cross-sectional area by manually drawing contours around the muscle boundaries by two trained observers (Dong and Li) in each section. (*Fig.1*)

Our measurement methods had an accuracy of 0.01 mm^2. The 2 observers were blinded to the characteristics of the patients and obtained all measurements independently. Intra-class correlation coefficient values (ICC) were calculated to test intra- and inter-observer reliability.

2.4.Statistical analysis

We used SPSS statistical software (version 21.0; SPSS Inc., Chicago, IL, USA) for statistical analyses. The VMO/ VLM area ratio, the cross-sectional area of the VMO and VLM were evaluated by Student's paired t-test. P-values less than 0.05 were defined as significantly different.

3. Results

In this study, all data were expressed as mean ± standard deviation. And there were no significant differences in the BMI and ages between the study group and control group. The demographics of the patients were summarized in Table 1. The intra-rater reliability was excellent for all the measurements, and the inter-rater reliability was high. (Table 2)

Table 1
The demographics of the patients

	Patients	Age	Males/ Females	Side (left/right)	BMI
Study Group	61	25.03 ± 5.94	30/ 31	27/34	23.76 ± 4.65
Control Group	61	21.85 ± 7.40	37/ 24	32/29	26.08 ± 4.37
P value	/	0.01	/	/	0.006

Table 2
Intraclass Correlation Coefficients

		Intratester Reliability ICC (95% CI)	Intertester Reliability ICC (95% CI)
Study Group	VMO area	VMO area	0.98 ^{b} (0.95–0.99)
	VML area	VML area	0.97 ^{b} (0.94–0.99)
Control Group	VMO area	VMO area	0.99 ^{b} (0.98–0.99)
	VML area	VML area	0.98 ^{b} (0.95–0.99)
ICC, intraclass correlation coefficient; CI, confidence interval; VMO, vastus medialis obliquus; VLM, vastus lateralis muscle			
^{b} p < 0.001			

In the study group and the control group, the VMO area in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 732.64 ± 306.43 mm^2 and 941.66 ± 366.83 mm^2 (P < 0.001), 876.32 ± 341.47 mm^2 and 1119.6 ± 405.01 mm^2 (P < 0.001), 1039.31 ± 410.21 mm^2 and 1302.75 ± 425.14 mm^2 (P = 0.001), 1178.26 ± 449.10 mm^2 and 1496.67 ± 474.70 mm^2 (P < 0.001), 1289.78 ± 487.78 mm^2 and 1643.33 ± 507.08 mm^2 (P < 0.001); the VLM area in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 127.61 ± 66.74 mm^2 and 192.2 ± 152.40 mm^2 (P = 0.003), 183.47 ± 85.41 mm^2 and 262.55 ± 187.98 mm^2 (P = 0.004), 250.66 ± 133.70 mm^2 and 352.35 ± 291.96 mm^2 (P = 0.015), 326.06 ± 139.94 mm^2 and 466.27 ± 343.11 mm^2 (P = 0.013), 574.19 ± 390.00 mm^2 (P = 0.005); the VMO/ VLM area ratio in the section that 0, 5, 10, 15, 20 mm above the upper pole of the patella were 0.83 ± 0.11

and 7.44 ± 5.13 (P < 0.001), 5.37 ± 2.49 and 6.32 ± 4.69 (P = 0.168), 4.64 ± 2.43 and 4.15 ± 1.94 (P = 0.554), 3.90 ± 1.55 and 3.96 ± 1.66 (P = 0.434), 3.42 ± 1.36 and 3.48 ± 1.62 (P = 0.826). (Table 3–5)

Table 3
The cross-sectional area of the VMO in different sections

Group VMO area Sections	**0 mm above the upper pole of the patella (mm^2)**	**5 mm above the upper pole of the patella (mm^2)**	**10 mm above the upper pole of the patella (mm^2)**	**15 mm above the upper pole of the patella (mm^2)**	**20 mm above the upper pole of the patella (mm^2)**
Study Group	732.64 ± 306.43	876.32 ± 341.47	1039.31 ± 410.21	1178.26 ± 449.10	1289.78 ± 487.78
Control Group	941.66 ± 366.83	1119.16 ± 405.01	1302.75 ± 425.14	1496.67 ± 474.70	1643.33 ± 507.08
P value	0.001	< 0.001	0.001	< 0.001	< 0.001
VMO, vastus medialis obliquus					

Table 4
The cross-sectional area of the VLM in different sections

Group VLM area Sections	**0 mm above the upper pole of the patella (mm^2)**	**5 mm above the upper pole of the patella (mm^2)**	**10 mm above the upper pole of the patella (mm^2)**	**15 mm above the upper pole of the patella (mm^2)**	**20 mm above the upper pole of the patella (mm^2)**
Study Group	127.61 ± 66.74	183.47 ± 85.41	250.66 ± 133.70	326.06 ± 139.94	413.27 ± 190.18
Control Group	192.27 ± 152.40	262.55 ± 187.98	352.35 ± 291.96	446.22 ± 343.11	574.19 ± 390.00
P value	0.003	0.004	0.015	0.013	0.005
VLM, vastus lateralis muscle					

Table 5
The ratio of the cross-sectional area of the VMO to VLM in different sections

Group VMO /VLM area ratio Sections	0 mm above the upper pole of the patella	5 mm above the upper pole of the patella	10 mm above the upper pole of the patella	15 mm above the upper pole of the patella	20 mm above the upper pole of the patella
Study Group	0.83 ± 0.11	5.37 ± 2.49	4.64 ± 2.43	3.90 ± 1.55	3.42 ± 1.36
Control Group	7.44 ± 5.13	6.32 ± 4.69	4.15 ± 1.94	3.96 ± 1.66	3.48 ± 1.62
P value	< 0.001	0.168	0.554	0.434	0.826

VMO, vastus medialis obliquus; VLM, vastus lateralis muscle

4. Discussion

The main findings of this study showed that compared with asymptomatic control group, the VMO and VLM atrophy was existed in the sections that 0–20 mm above the upper pole of the patella in PFPS patients; and the atrophy of the VMO was more evident than that of the VLM in the section that 0–5 mm above the upper pole of the patella. These findings support the rationale for use of general quadriceps exercise with VMO strengthening exercise as part of rehabilitation program for patients with PFPS. As far as we know, this is the first study to evaluate the cross-sectional area of the VMO and VLM and their ratio between normal people and patients with PFPS on CT scans.

It is worth noting that the VMO as a dynamic medial soft tissue stabilizer plays an important role in the stability of the patellofemoral joint, and this is attributed to its special structure: the VMO has the distal muscle insertion that is 50°angle to the longitudinal patellar alignmen, and it also has the strong meshing fibers with the medial patellofemoral ligament near its distal insertion [9, 10, 17].

Studies shown that in patients complaining of PFPS, the quadriceps manifested as weakness [7, 18]. Though it is well known that maximum strength is related to muscle size [19], whether the VMO atrophy is existed in PFPS is still controversy [11–15].

Three measurements were used to evaluate the atrophy of the VMO: tape measurement, ultrasound and MR imaging. In the clinical setting, girth measurements with a tape is the most common estimations of quadriceps atrophy, but this method involves other thigh muscles as well as bone and subcutaneous fat. MR imaging is the "gold standard" of muscular measurement, the mean differences between ultrasound and MR imaging was only 0.8% [15].

Like MRI, CT is also considered as a highly precise imaging modality in investigating area and volume of muscle and has a reported precision error of about 1.4% for tissue areas, both scanning methods are able to distinguish muscle mass from fat [20]. In the present study, we first selected CT as our measurement method, and we found the cross-sectional area of the VMO was significantly smaller in patients with PFPS in comparison with normal people, the VMO atrophy was certainly existed in this population.

Not only the VMO, the VLM in the subjects with PFPS had decreased muscle strength according to electromyography [7]. But there is a lack of literature comparing the size of the VMO relative to the VML between PFPS and asymptomatic limbs. Only Giles et al. [21] and Pattyn et al. [13] reported that selective atrophy of the VMO relative to the VLM was not identified in people with PFP by using ultrasound and MR imaging respectively. But Giles did not measure the cross sectional area of the muscle but the thickness, and Pattyn only measured the VMO/VLM area ratio on the patellar level and mid-thigh level.

In the present study, we remeasured the cross-sectional area of the VLM, and evaluated VMO/VLM area ratio on CT scans in the section that 0–20 mm above the upper pole of the patella. We found that the VLM atrophy was existed in the study group; and the atrophy of the VMO atrophy was more evident than VLM 0–5 mm above the upper pole of the patella. The distal portion is the main functional area of the VMO to confine the patellar maltracking, the obvious VMO atrophy must influence the patellar stability.

The finding of the VMO and VML atrophy, especially the distal insertion of the VMO in the subjects with PFPS contributes to understanding the mechanisms of PFPS [7, 18]. Decreased quadriceps weakness that was resulted from atrophy or pain limiting force production, pain-induced inhibition of the quadriceps musculature, or physiological changes of the quadriceps musculature has been suggested as a potential cause of PFPS [12, 15, 23]. Though we can not decided that whether atrophy was a predisposing factor or developed after the onset of PFPS, because of the exist of the VMO and VLM atrophy, physiotherapy with strengthening of the quadriceps must be beneficial for patients to restore quadriceps strength and relieve pain [22].

Isolated VMO activation protocol has been used to treat patellofemoral pain and instability, but Syme et al. [22] indicated that there was no different between rehabilitation with selective VMO exercise and general quadriceps strengthening exercises. In the present study, we still suggested VMO strengthening exercise to patients with PFPS, because of the atrophy of the VMO, especially its distal portion. But we should not overlook the contribution of the VLM and other muscles of the quadriceps to the patellar stability, general quadriceps exercise was also suggested. In conclusion, the protocol that general quadriceps exercise combined with VMO strengthening exercise maybe a better choice.

One of the limitations of this study is that the sample size was small and the present study was a single-center retrospective study, which could lead to deviations. And the CT examination is performed after patients complaining of PFPS. Therefore, we cannot determine whether the change of the VMO and VLM is the cause or result of PFPS.

5. Conclusions

In patients with PFPS, the VMO and VLM atrophy was existed in the section of 0–20 mm above the upper pole of the patella in comparison with normal people; and the atrophy of the VMO was more evident than that of the VLM in the section that 0–5 mm above the upper pole of the patella. These findings support the rationale for use of general quadriceps exercise with VMO strengthening exercise as part of rehabilitation program for patients with PFPS.

6. Abbreviations

VMO: vastus medialis obliquus

VLM: vastus lateralis muscle

PFPS: patellofemoral pain syndrome

BMI: body mass index

CT: computed Tomography

7. Declaration

7.1.Ethics approval and consent

The present study was approved by the Academic Ethics Committee of the Third Hospital of Hebei Medical University, and all patients gave their informed consent to participation and publication. All of the data and materials are available.

7.2.Competing interests

The authors declare that they have no competing interests.

7.3.Funding

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7.4.Authors' contributions

Wang Fei contributed to the conception of the study; Conglei Dong and Ming Li measured the CT scans and collected the data; Chao Zhao, Kuo Hao and Ming Li contributed significantly to analysis and wrote the manuscript; Kang Piao, Wei Lin, Chongyi Fan and Yingzhen Niu helped perform the analysis with constructive discussions.

7.5.Acknowledge

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Figures

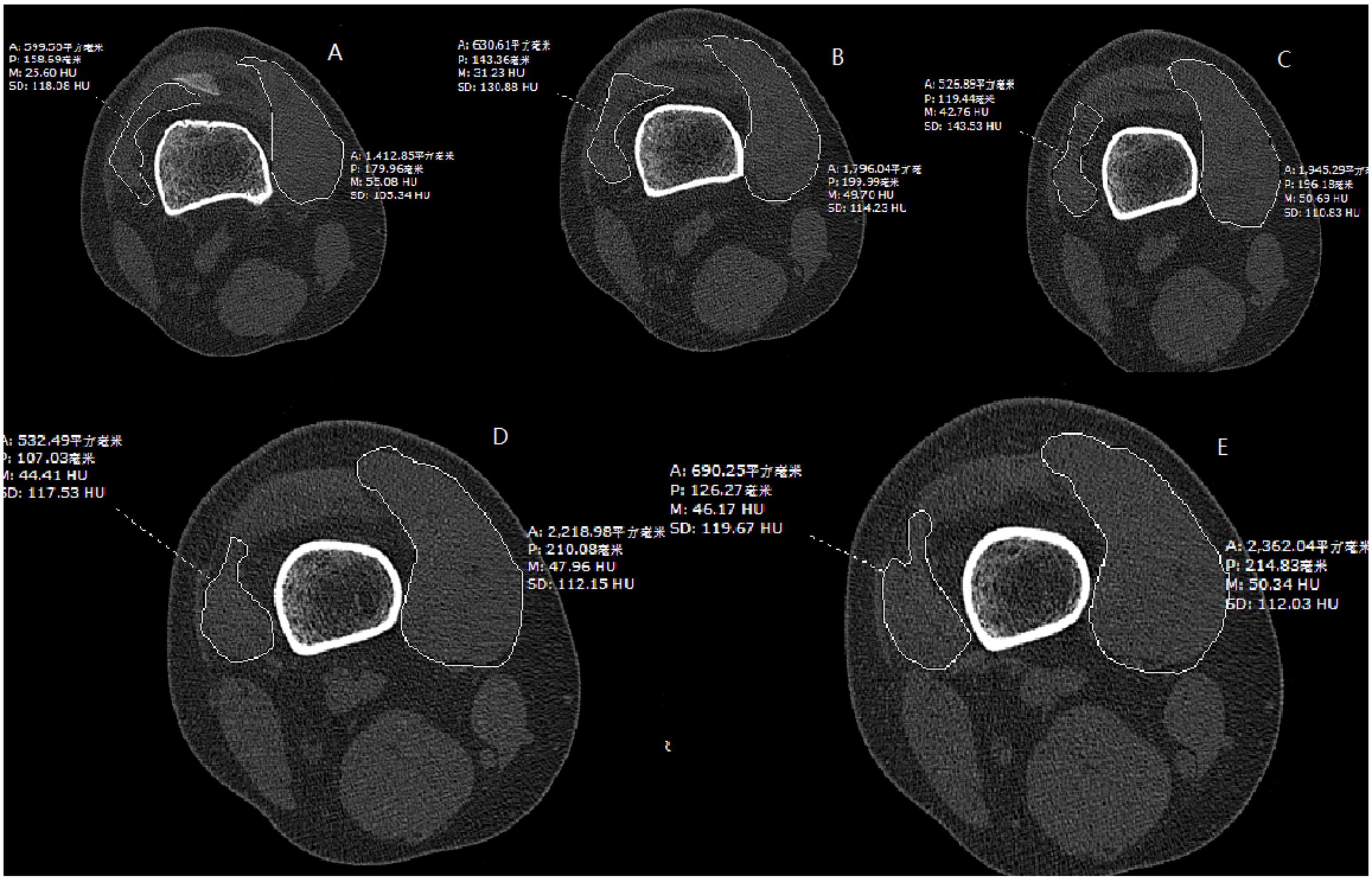

Figure 1

A-E Measurement of the cross-sectional area of the VMO and VLM in the section that 0-20 mm above the upper pole of the patella