Combining isometric knee extension exercises with hip adduction or abduction does not increase quadriceps EMG activity

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Objective: To determine if the combined isometric contractions of knee extension/hip adduction and knee extension/hip abduction will elicit a different quadriceps and gluteus medius electromyographic (EMG) pattern as compared to isometric contraction of a uniplanar knee extension exercise.

Methods: Eight healthy young adult volunteers without history of knee or quadriceps injury participated. Surface EMG data were collected from the vastus medialis oblique (VMO), vastus lateralis (VL), and gluteus medius (GMed) muscles of the dominant leg of each subject during three single leg, weight bearing, isometric exercises (uniplanar knee extension, knee extension/hip adduction, knee extension/hip abduction). All exercises were performed at a position of 60° knee flexion. Three trials lasting 5 s each were performed for each of the three exercises. EMG data from each muscle were integrated and the maximum root mean square activity over a 0.5 s window for each trial was averaged. Analyses of variance were performed with exercise (straight extension, extension/adduction, extension/abduction) as the independent variable and VMO, VL, and GMed activity and VMO:VL ratio as dependent variables.

Results: A significant main effect for exercise was found for the VMO (p = 0.006) and VL (p = 0.02), but not the Gmed (p = 0.25) or the VMO:VL ratio (p = 0.13). For the VMO and VL, the uniplanar knee extension task produced significantly more EMG activity than the extension/adduction or extension/abduction tasks.

Conclusions: Uniplanar knee extension exercises may be more appropriate than combining isometric knee extension exercises with hip adduction or abduction when eliciting maximal VMO and VL contractions.
input impedance 2 MΩ (differential), common mode rejection ratio 110 dB, maximum input voltage ±10 V, sampling rate 1000 Hz, gain 1000.

**Procedures**

Prior to electrode placement, the skin was prepared by shaving and vigorously cleaning the appropriate areas with alcohol wipes. The VMO electrodes were placed at an angle of approximately 55° to the long axis of the femur at a location that was over the muscle belly when the knee was in 60° of flexion. The VL electrodes were placed proximal to the distal tendon over the area of greatest muscle bulk. The Gmed electrodes were placed over the proximal third of the line between the iliac crest and the greater trochanter. The inter-electrode distance for all three muscles was 2 cm. A ground electrode was placed on the tibial crest of the test leg. The same experienced researcher (JEE) applied the electrodes in a consistent manner to all subjects.

Subjects performed three types of weight bearing, isometric exercises with their dominant limbs: uniplanar knee extension, knee extension/hip adduction, and knee extension/hip abduction. Three trials of 5 s each were performed for each of the exercises. Each trial was separated by 2 min of rest. Verbal encouragement to perform maximally was given to subjects for all trials. Supramaximal electrical stimulation was purposefully not used because we wanted to study maximal “voluntary” isometric contractions, not absolute maximal muscle capacity.

For the uniplanar knee extension exercises, a custom-made testing apparatus was used. This consisted of a 30° angled platform covered with a non-slip surface. Participants stood with their back against the wall and their test leg on the platform in front of them with their knee positioned in 60° of flexion (fig 1). This position was chosen because it has been previously shown that greatest activation of the VMO is achieved at 60° of knee flexion during the weight bearing exercise. Knee joint angle was measured with a standard goniometer prior to the start of each trial to ensure consistent positioning across the trials of all subjects. The distance of the platform from the wall was adjustable to account for differences in subject height and leg length. A heavy rubber mat was placed in front of the platform to prevent it from sliding. Shoulder straps ensured that subjects did not move their trunk, hip, or knee when they performed the isometric contractions. Subjects were instructed to lift their contralateral foot and to maximally push up and back into the wall with their test leg.

The knee extension/hip adduction task used the same set-up with the addition of a towel roll between subjects’ knees (fig 2). Subjects were instructed to maximally contract their test leg and simultaneously squeeze both knees together (hip adduction). For the knee extension/hip abduction task subjects were positioned with their test leg on the angled platform and their non-test side against the wall. Subjects were instructed to drive their non-test hip into the wall (causing hip abduction contralaterally) with maximal effort as they performed maximal isometric knee extension on their test leg (fig 3).

**Data processing**

EMG data for each muscle were integrated and the maximum root mean square (RMS) activity over a 0.5 s window for each trial was calculated and used as the dependent variables. The data were not normalised because all comparisons made in this study were within-day comparisons of single muscles and the electrodes were left in place for all tests.

**Statistical analysis**

Four separate analyses of variance with repeated measures were performed with exercise (uniplanar knee extension, knee extension/hip adduction, knee extension/hip abduction) as the independent variable and normalised maximal RMS activity of the VMO, VL, and GMed, and the VMO:VL ratio as the dependent variables. Tukey’s post hoc tests were used to identify specific significant differences in the presence of a significant ANOVA. The level of significance was preset at $p < 0.05$ for all analyses.

**RESULTS**

Muscle activation patterns were significantly different between the three exercises for the VMO ($F_{2,14} = 7.38$, $p = 0.006$) and the VL ($F_{2,14} = 5.17$, $p = 0.02$). Post hoc
analysis revealed that for the VMO and VL both the knee 
extension/hip abduction task and the knee extension/hip 
adduction task produced significantly less EMG activity than 
the uniplanar knee extension task ($p<0.03$). There were 
no significant differences between the knee extension/hip 
adduction and knee extension/hip abduction exercises for 
either the VMO or VL. There were no significant differences 
for GMed activity ($F_{2,14} = 1.53$, $p = 0.25$) or VMO:VL ratio 
between exercises ($F_{2,14} = 2.39$, $p = 0.13$). Means and 
standard deviations for all dependent measures may be seen in 
table 1.

**DISCUSSION**

Our primary finding was that maximal surface EMG activity 
of the VMO and VL was greater when performing weight 
bearing, isometric, uniplanar knee extension exercises 
compared to exercises combining knee extension with hip 
abduction or adduction. The VMO and VL responded 
similarly in our study as the VMO:VL ratio was not 
significantly different between the three exercises.

Our findings are inconsistent with previous literature 
that identified enhanced VMO activity with combined knee 
extension and hip adduction during weight bearing.4 19 23 
We had subjects perform the knee extension/hip abduction 
in single leg stance whereas previous studies have utilised 
bilateral squatting exercises.4 19 23 We chose single leg 
extension/hip adduction because our knee extension/hip 
adduction exercise required single leg stance. It could be 
that these novel, single leg stance exercises required 
volunteers to focus on maintaining their balance and they 
thus were concentrating more on recruiting postural stabilisers 
than the quadriceps. Another explanation could be that concentration 
on producing horizontally directed force (hip 
abduction and adduction) may have diminished the ability to 
produce vertically directed force (knee extension). Previously, 
Yamashita14 suggested that VMO activity is enhanced by 
combining knee extension with hip extension. This is most 
likely more easily accomplished in the closed kinetic chain 
with a pure sagittal plane exercise than with multiplanar 
exercises.

Previous studies demonstrating increased VMO activity 
with knee extension/hip adduction activities used isotonic 
exercises4 19 23 while we studied isometric exercises. Isotonic 
squatting exercises may lead to increased VMO activity 
because the VMO must be more active in the dynamic 
stabilisation of the patella during knee movement. While 
more dynamic activities are certainly a necessity in advanced 
rehabilitation, uniplanar knee extension isometric exercise 
may be more appropriate during early rehabilitation where 
retraining of the VMO is critical to restoring normal 
patellofemoral mechanics.

Patellofemoral dysfunction may also be related to inade-
quate control of femoral rotation.22 26 Excessive internal 
rotation of the femur may contribute to increased lateral 
tracking of the patella. During weight bearing activities, the 
GMed eccentrically controls femoral internal rotation.27 The 
GMed has also been shown to be an important contributor to 
pelvic stability during weight bearing.28 Inadequate strength 
or recruitment of the GMed alone, or in combination with 
VMO dysfunction, may lead to PFPS. While we did not find 
significant differences in GMed activity during our three 
exercises, the knee extension/hip abduction task was 
associated with the greatest amount of GMed activity. 
Because this task was isometric and did not involve dynamic 
hip and knee flexion (and associated femoral internal 
rotation), it may not have caused maximal GMed activity.

Our study was not without limitations. We only examined 
variables of EMG amplitude and did not measure timing 
variables. Onset of muscle activation has been shown to be 
altered in PFPS patients27 28 and clinicians should be 
mindful of these changes when implementing neuromuscular 
rehabilitation programs. Another limitation is that our 
comparisons were of non-normalised EMG signals. While 
using non-normalised signals allowed us to answer our 
research question, it may limit the ability to compare our 
results to those of others who analysed normalised EMG 
signals. Lastly, our sample size was not large ($n = 8$) and the 
generalisability of our findings to more diverse populations 
may be limited. These data provide preliminary answers to 
our research questions, however a larger study utilising more 
subjects both with and without PFPS would better control for 
the considerable intersubject variability of surface EMG, 
provide for increased statistical power, and expand the 
generalisability of the results.

**CONCLUSION**

We found that there was significantly greater surface EMG 
activity of the VMO and VL during weight bearing, isometric
uniplanar knee extension exercises than with either combined knee extension/hip abduction or knee extension/hip abduction exercises. Further research investigating the muscle activation patterns during various isometric and isotonic exercises commonly prescribed for PFPS is warranted.

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REFERENCES