Influence of exercise instruction method on the activation of Vastus Medialis Obliques and Vastus Lateralis during a mini-squat

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Summary
The aim of this study was to investigate the effect of different exercise instruction methods on the activation of vastus medialis oblique (VMO) and vastus lateralis (VL) while performing a mini-squat. Thirty healthy volunteers were recruited from the student population of the University of Limerick and were randomised to one of three instruction groups; either (a) verbal instruction, (b) visual demonstration or (c) a combination of both instruction methods. Surface electromyographic activity was collected during the mini-squat for each instruction group and this was expressed as a percentage of maximal voluntary isometric contraction (MVIC). One-way ANOVAs were used to detect differences between groups.

There were no significant differences noted in the muscle activation of VMO and VL, or the ratio of VMO: VL activity, when performing the mini-squat under the three different types of instruction. This finding suggests that the type of instruction method had little influence over the performance of this relatively simple motor task amongst a healthy young population. This contrasts with previous studies of more complex motor tasks. Potential reasons for the discrepancies, and implications for future studies, are discussed.

Key words
Physiotherapy, exercise, mini-squat, instruction.

Introduction
Instruction is defined as information given at the start of practice or during practice but independently of performance. Instruction and teaching of motor skills is of paramount importance in physiotherapy management. Physiotherapists often prescribe exercises to target specific muscle groups as part of rehabilitation or injury management. In order to be effective and avoid injury, patients are expected to perform exercises in the manner that a physiotherapist desires. Instruction can be provided using many different methods, with verbal instruction and visual demonstration through modelling commonly used by clinicians when prescribing home exercise programs. Research examining the effectiveness of different instruction methods is sparse however, especially in a physiotherapy relevant context. Reo and Mercer found that live modelling and using videotape demonstration were significantly more beneficial than written instruction in an upper limb exercise program, highlighting the importance of visual aid for instructions for patients. Weeks et al looked at videotaping versus still-photo illustrations for performance, motivation and confidence in performing simple and complex tasks. Their findings suggest that dynamic modelling in the form of video is more effective for promoting the correct form for lower limb exercises. A systematic review of the effects of mode of exercise instruction on the correctness of home exercise performance and adherence concluded that the provision of both verbal instruction and illustrated handouts led to greater correctness in performance than either in isolation. In contrast, Al-Abood et al found no significant effect for a complex co-ordination skill.

In this study, 15 participants were asked to aim at a target after receiving either visual, verbal or no instruction. It was noted that the verbal instruction group had to practise 100 more shots to achieve the same performance as the visual group after just six demonstrations, possibly indicating a non-significant preference towards visual demonstration. Many previous studies mainly in the field of sports psychology or sports science, used complex co-ordination and open-chain tasks, which differ from the simple close-chain exercises physiotherapists often use. The current study was designed to compare different methods of instruction while carrying out a simple, clinically relevant motor skill. The mini-squat was chosen as it is a commonly used exercise to activate and/or strengthen the quadriceps with studies suggesting it’s usefulness in decreasing symptoms, pain and enhancing motor control in patellofemoral pain syndrome (PFPS). Specifically an imbalance of vastus medialis oblique (VMO) and vastus lateralis (VL) activation is thought to be an important factor in PFPS, with the assumption being that higher VMO activation results in better outcomes.

Therefore, the aim of this study was to determine if the muscle activation of VMO and VL during a mini-squat was significantly different using three different methods of instruction; (1) verbal instruction, (2) visual demonstration and (3) a combination of both verbal instruction and visual demonstration.

Methodology
The University of Limerick Research Ethics Committee approved this study in 2005.

Participants
The population for this study consisted of 30 (mean age = 21.3 years) healthy volunteers from the University of Limerick student population. 77% (n=23) of whom were physiotherapy undergraduate students. Participants were included if they had adequate pain-free range of motion and muscle force for performance of a mini-squat, and...
normal (or corrected to normal) vision and hearing by self-report. They were excluded if they had previous or present lower limb musculoskeletal injury, if they were partaking in exercise/sporting activities involving squat training or if they reported any contraindication to exercise using the Modified Physical Activity Readiness Questionnaire\textsuperscript{18}, which was filled out in advance of testing. All subjects provided written informed consent. Participants were randomised, using a computerised random numbers generator\textsuperscript{19} into three different instruction groups: (1) a verbal instruction group, (2) a visual demonstration group and (3) a combination group receiving both verbal instruction and visual demonstration. One leg from each subject was also chosen randomly, again using a computerised random numbers generator\textsuperscript{19}. Prior to testing, all participants performed a standardised warm up. This consisted of five minutes cycling on a stationary bike at a self-selected low intensity (maintaining the ability to talk) and stretching of the hamstrings, quadriceps and calf muscles.

**Instrumentation**

Surface Electromyography (sEMG) was collected using a Powerlab 4/20T electromyography system and data was analysed using Powerlab Chart 5.2 (AD Instruments, USA). The sampling frequency was set at 2000Hz, the amplitude range was 5mV with a gain of 1000, and a bandwidth pass filter of 10Hz – 200Hz was applied. The skin was prepared in advance by shaving the skin, followed by cleansing with isopropyl alcohol (70\%) to decrease skin impedance prior to attachment of the electrodes in line with previous studies\textsuperscript{20,21,22}. Palpation of the anterior superior iliac spine and the centre of patella allowed an orientation line to be drawn to define the correct inclination angle of each portion of the quadriceps muscle for electrode positioning\textsuperscript{22}. sEMG electrodes were then placed on VMO and VL of the chosen leg with the knee at 45\(^\circ\) of flexion to ensure electrodes stayed in place securely during the mini-squat exercise. The electrodes used were latex free Ag/Ag Cl sEMG electrodes, (10 x 1mm) (Kendall Medi-trace). A bipolar electrode configuration, with an inter electrode distance of 2cm, for both muscles was used as recommended\textsuperscript{21,22,23}. For VMO, the electrodes were secured at an oblique angle of approximately 55\(^\circ\) to the long axis of femur, 2 cm medial and 4 cm superior to the superior rim of the patella. For VL, the electrodes were secured approximately 3-5 cm above the patella just lateral to the midline of knee, placed at a 10-15\(^\circ\) oblique angle to the long axis of the femur\textsuperscript{24}. In addition, a reference electrode was placed over the bony surface of the tibia 3 cm below the tibial tuberosity; Seated maximal voluntary isometric contraction (MVIC) knee extensions using the ConTrex dynamometer (Contrex AG, Dubendorf, Switzerland) formed baseline sEMG data for normalisation purposes (Figure 1). Although a mini-squat is a closed chain exercise, MVIC collected in open chain testing has been shown to be similar\textsuperscript{25} and is a common protocol for studies analysing the activity of VMO and VL\textsuperscript{20,25,26,27}. Participants were positioned in sitting on the isokinetic dynamometer, in line with manufacturer guidelines. Thoracic, pelvic and thigh straps were fastened for stabilisation so that the required muscles could be safely activated, without unwanted compensatory movements. Backrest and seat angles were adjusted to facilitate 90\(^\circ\) of hip flexion and 45\(^\circ\) of knee flexion, as measured by a handheld goniometer\textsuperscript{22}. The axis of the dynamometer rotation arm was positioned in line with the lateral femoral condyle, with a resistance pad positioned 2.5 cm above the medial malleolus. Participants were given an abort switch so that they could cease testing at any time should they feel any pain or discomfort. The participants were then instructed to push as hard as possible and given continuous verbal encouragement but no visual feedback during the isometric contraction. This was maintained for a total of three seconds and repeated three times. A 30-second break was given between each MVIC trial and a five-minute rest before commencement of mini-squat instruction. The average Root Mean Square (RMS) amplitude of the sEMG for a one second window centred about the peak activity for each MVIC was taken as the maximum value for normalisation purposes.

**Mini-squat instruction**

All participants wore shorts and were seated in a designated area with the investigator seated directly in front. All interaction with the participant aside from instruction method was standardised. Participants in the verbal instruction group were given a verbal description of the task with an emphasis on the most critical components as stated in table 1. This was repeated twice in a slow clear tone. These instructions were constructed from analysis of the literature\textsuperscript{7,21,22,27} and discussions with two musculoskeletal physiotherapists each with
seven years experience, and the final instructions were very similar to those used in other studies.

A healthy model that had been previously screened and instructed in effective mini-squatting technique gave the visual demonstration while wearing shorts. The visual demonstration was provided from both a frontal and sagittal angle to the subject with a total of four demonstrations, twice from each angle. The combination group received the same verbal instructions once, followed by visual demonstration once from each angle in an attempt to standardise the amount of information given to each group. No additional feedback or extra interaction took place. Any questions asked that might have confounded the study e.g. "Am I doing this right?" were not answered. Instructions at the start and end were the same in each group as shown in table 1. Prior to commencement, each participant performed one mini-squat in order to ensure that the electrodes were securely placed and that data was being collected correctly.

sEMG activity from both VL and VMO were collected throughout the entire set of 10 squats. To minimise any effects associated with beginning or ending performance effort, fatigue, learning or changes in skin-electrode interface characteristics only the middle four squats were used for analysis. Clinically muscle activation throughout the exercise is of importance, so to reflect clinical practice; there was no separation of the descending or ascending phases of the squat. Average sEMG activity was noted during the middle four mini-squats and this was normalised to the MVIC values obtained earlier. The VMO:VL activation ratio was analysed by comparing their mean emg activity during the mini-squat, along with a separate analysis of VMO and VL activation.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Specific instruction components of the individual groups</th>
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| **Beginning of Instruction** | **Verbal:** "The exercise you shall be instructed in is a mini-squat" OR  
**Visual:** "The exercise that shall be demonstrated to you is the mini-squat" OR  
**Combination:** "The exercise you shall be instructed in is a mini-squat in which you will receive firstly verbal instructions once and then view a demonstration once".  
**AND**  
**All:** "I shall not give any more details or instruction than what I give you now. After my instructions/demonstration you will be asked perform it ten times to the best of your ability. Please remain seated throughout the instruction." |

| Critical components emphasised for verbal instruction |  
- Stand comfortable with your body in a straight alignment.  
- Keep feet shoulder width apart parallel to each other with toes pointing straight out.  
- Keeping your back straight, bend at the knees.  
- Bend until your knees come just over your toes.  
- Keep your knees pointing straight out and keep your heels on the ground throughout.  
- Raise yourself back up to the starting position and repeat ten times. |

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Subject characteristics: Mean (SD). There were no significant differences between the groups (p &gt;0.05).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verbal (n=10)</strong></td>
<td><strong>Visual (n=10)</strong></td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.1 (3.2)</td>
</tr>
<tr>
<td>Sex (f/m)</td>
<td>8f, 2m</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.6 (10.0)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.2 (7.4)</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>21.4 (5.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Mean (SD) muscle activity, normalised to %MVIC, of VMO, VL and VMO:VL ratio during a mini-squat for each instruction group. There were no significant differences between the groups (p &gt;0.05).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td><strong>VMO</strong></td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td>33.49 (20.25)</td>
</tr>
<tr>
<td><strong>Visual</strong></td>
<td>30.18 (23.99)</td>
</tr>
<tr>
<td><strong>Combination</strong></td>
<td>36.00 (21.29)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>34.27 (16.51)</td>
</tr>
</tbody>
</table>

Statistical Analysis

Data was analysed using SPSS 11.0. The level of statistical significance was set at p<0.05. Data was analysed for normality of distribution. Some data from the verbal group was non-normally distributed, and this data was transformed into normally-distributed data using SPSS. Descriptive statistics and independent t-tests were performed on the baseline subject characteristics, to compare the three groups (Table 2). The relationship between mean VMO and VL muscle activation across all three groups was analysed using a Pearson's correlation. A one-way ANOVA was used to determine if there was any significant difference between groups for VL, VMO and VMO:VL ratio activation.
Results
There were no significant differences in age, sex, weight, height, or Body Mass Index (BMI) between groups (Table 2). There was a significant correlation between the muscle activation (mean+/−SD) of VMO (33.5%/+−20.3%) and VL (38.3%/+−24.8%) across all groups combined (Pearsons correlation = 0.814) (Table 3). This demonstrates the consistently close relationship between VMO and VL activation, with the average VMO:VL ratio during the mini-squat being 0.816. The percentage activation of VMO, VL and the VMO:VL ratio during the mini-squat for the three instruction groups is displayed in Table 3. While VL activation was highest in the visual demonstration group, and the VMO:VL ratio was higher in the verbal instruction group, ANOVA demonstrated that none of these differences were statistically significant (p>0.05). The greatest variability was found within the combination group, as can be seen from the larger standard deviation values for the combination group in Table 3.

Discussion
This study compared the influence of three types of instruction on the performance of a mini-squat, using sEMG recordings of VMO and VL. There were no significant differences in muscle activation between the groups while performing the mini-squat. This finding suggests that the instruction method used had little influence over the performance of this relatively simple task amongst a healthy young population. Previous studies have found the addition of visual instruction, either by demonstration or video, to improve performance in healthy subjects in a wide variety of tasks, albeit mainly in upper limb tasks without the use of emg4,29,30. The results of the current study disagree with these studies, but is in agreement with Al-Abood et al7 who found no significant difference with various instruction methods during an upper limb co-ordination task involving aiming at a target. Since most existing research6,10 used complex movements and actions that are rarely used by physiotherapists in clinical practice e.g. learning a drawing task6, this study examined an exercise which is used by physiotherapists in the literature21. This had not been examined previously. The task chosen may have been too straightforward for the method of instruction to have an effect, since it involved only lower limb motion in the sagital plane. This may also have not been difficult for participants to perform and detailed instruction (visual or verbal) may not have been vital to understand the movement. This may be particularly true since 80% of participants were physiotherapy undergraduate students, who may have had an existing visual representation of a mini-squat in their minds and which may have overridden the need for a visual demonstration. Instruction may therefore be more important in complex tasks, or tasks with which the subjects are not familiar, as was the case in some previous research7.

Verbal instruction is the most traditional form of instruction, albeit with limitations regarding the ability of the listener to interpret instructions and the speaker’s verbal ability. Evidence has shown that detailed knowledge of movement biomechanics may however be unnecessary and detrimental to acquisition and retention of motor skills31. It has been shown that complex instructions can overload the individual and retard behaviour, with several papers9,32,33 showing that instruction can actually degrade motor learning. Others highlight the importance of an external focus of instruction rather than an internal focus of instruction9,34, such that the focus is on the task rather than the individual. Verbal instructions have been suggested to distract from processing more important information such as kinaesthetic or visual information that may be integral to task performance33. Therefore, learning a motor skill within clinical practice is often done by visual demonstration, which has been shown to be a useful adjunct to teaching4,29,30. It is suggested to give the learner an understanding of the way a skill is performed29,35,36, and forms an external reference of performance. Shea et al29 noted that observation can increase the learning efficiency of clinical practice through decreased energy expenditure and risk of injury. In the current study however, there was no significant difference between the three instruction types.

Many authors report that an imbalance in muscle activation between VMO and VL may be an important factor in PFPS, and that mini-squatting or other closed chain exercises may address a suggested deficit in VMO activation57,28,39. While previously it had been suggested that it was possible to isolate the effect of exercises to activation of VMO and not VL, recent research indicates that there is a high degree of synchronisation between them during activity in healthy subjects40,41. The high degree of correlation between VMO and VL activation observed in this study confirms this close relationship, and is in agreement with other studies demonstrating that it does not appear to be possible to selectively activate VMO without also increasing VL activation in healthy subjects20. This close relationship does appear to change in PFPS however, where the activation timing of VMO is relatively delayed27,42. A recent study demonstrated the effectiveness of physiotherapy, including exercises similar to mini-squats, in treating PFPS by showing that the timing of VMO activation could be enhanced, and this was associated with a greater reduction in pain compared to a control group14. The current study did not examine timing of muscle activation, therefore we cannot comment on whether the method of instruction affected this parameter, as well as the fact that the current study was on normal subjects who were unlikely to display any abnormal pattern of emg activation. The values for VMO:VL ratios are similar to those described in previous research on healthy subjects during similar exercises and activities37, confirming the findings of the current study.

Limitations
This study was limited to a small sample of healthy young people and therefore results may not be applicable to patients with musculoskeletal disorders. There is a lack of information regarding what constitutes an optimum squatting position. Due to this lack of conclusive evidence, and to simplify instructions, we taught the exercise in the neutral hip plane, while attempting to standardise knee
flexion to approximately 45° for all groups and keeping feet shoulder width apart, facing straight ahead. However, a large body of research suggests that different results could have been obtained with different limb positions and angles. Finally, although sEMG is valid and reliable for static activity measures it is less reliable with dynamic movement since the signal can be changed by electrode movement relative to the contracting muscle fibres. Kollmitzer et al. however proved its reliability on the quadriceps muscle at short-term intervals, which is relevant to this study as the recordings took place over a half hour period.

Future research

Trials similar to this could be repeated in symptomatic populations, ideally with simultaneous kinematic or video analysis, which would enable comparison of the consistency of the exercises performed. The timing of muscle activation, as well as muscle amplitude, could be considered in future trials. Other physiotherapy-related studies on the effect of instruction method on common, but more complex, exercises are required e.g. which form of instruction best facilitates activation of transversus abdominis or the pelvic floor.

Conclusion

There was no significant difference in the muscle activation of VMO or VL, regardless of the method of instruction used when teaching participants a mini-squat exercise. This is in contrast to previous research examining more complex tasks where visual demonstration is seen to be superior to verbal instruction. It is possible that instruction method is not as critical in relatively simple tasks. Further research is needed to examine the effect of instruction on more complex tasks related to physiotherapy clinical practice and in symptomatic populations. Identifying the most effective instruction methods may lead to improved clinical outcomes.

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References
