A Comparison of two Knee Joint Angles in the Measurement of MVC Decrease due to Tendon Vibration

Bobby Edwards, Tony Gui, Kenneth Henderson, Jonathan Tom-Yew & Shawn Turnau
Outline

• Review of literature / Previous Research
• Aims/Hypothesis
• Methods
• Statistics & Results
• Discussion
• References
Introduction

• Vibration applied to muscle affects its force generating capability
  ▫ Short term vibration -> facilitates muscle force production
  ▫ Prolonged vibration (2+mins) -> reduces force production
Effects of Vibration involves a complex relationship

Short Term Vibratory Stimuli → Muscle spindle afferents (Iα afferents) → Increases Muscle force production
Review of Neurophysiology with exposure to short term vibration

- Exposure to short term vibration:
  
  - Excitatory effect on Iα afferents
  
  - Enhances ability α-motor neuron pool to recruit muscle fibres
  
  - Leads to increase in maximum force production (Ushiyama et al 2005)

http://edoc.huberlin.de/dissertationen/mueller-katja-2006-01-16/HTML/image001.jpg
Effects of Vibration involves a complex relationship

Prolonged Vibratory Stimuli → Muscle spindle afferents (Ia afferents) → Decreases Muscle force production
Review of Neurophysiology with exposure to long term vibration

- Exposure to prolonged vibration:
  - Tetanic effect on Iα afferents
  - Suppressive effect on Iα afferents
  - Reduces ability α-motor neuron pool to recruit muscle fibres
  - Leads to decrease in maximum force production (Ushiyama et al)

http://edoc.huberlin.de/dissertationen/mueller-katja-2006-01-16/HTML/image001.jpg
Vibration does not affect alpha motor neurons equally

- High threshold motor neurons – innervate powerful, fast twitch fibres

- Low threshold motor neurons – innervate postural, slow twitch fibres
Alpha Motor Neuron Size and Force Production

http://www.ncbi.nlm.nih.gov/books/NBK27220/figure/
http://jdr.sagepub.com/content/84/9/774/F4.large.jpg
A6996/?report=objectonly
Vibration does not affect motor neurons equally

Detrimental effect on firing within high threshold motor neurons vs. low threshold motor neurons and results in a decrease in the ability to generate maximal force (Bongiovonni et al 1990)
Vibration does not affect motor neurons equally

- Triceps Surae group used to highlight the different effects of vibration on high threshold and low threshold motor neurons
  - Gastroc has 50-70% type II fibres
  - Soleus has 80-100% type I fibres
  - (Johnson et al, 1973)

- It has proposed that suppression of muscle activity after prolonged vibration will be more prominent in the Gastrocnemius compared the Soleus
  - Generally high threshold motor neurons supply fast twitch fibres
    - (Eccles et al, 1958)
Ushiyama et al (2005)

- Subjects seated with knee joint angle at 180°
- Exposed Achilles tendon to 30mins vibration

- Plantar flexion MVC decreased post vibration
Ushiyama et al (2005)


- Significant reduction in EMG activity of the Gastrocnemius with no change in Soleus

- Tested only in one knee angle position
  - Gastrocnemius muscle length remained constant
Anatomy of Triceps Surae

• Main action: Plantar Flexion

• Gastrocnemius: bi-articular, cross knee and ankle joint
  ▫ Muscle length changes as knee joint angle changes

• Soleus: mono-articular, crosses ankle joint
Gastrocnemius muscle length

- Maximal force production is a function of muscle length
- What we don’t know is if Vibration affects the Gastrocnemius equally at varying muscle lengths
Muscle-length & force production relationship

- Cresswell et al (2005) investigated plantar flexion MVC at various knee joint angles
  - Gastrocnemius EMG activity & force production decreased as knee joint angle changes from $180^\circ \rightarrow 90^\circ$

- Modifying knee joint angle influences plantar flexion MVC
Muscle-length relationship

- Optimal sarcomere length = maximal force production (Brown et al 2006)

- Moving away from optimal length reduces force production

- Limited actin-myosin cross bridges

[Graph showing force and sarcomere length relationship with key points labeled: ascending limb, plateau region, descending limb.]

Rassier et al 1999
Linking it all together

1. • Prolonged vibration negatively affects high threshold, fast twitch fibres
   • Gastrocnemius force production is reduced by vibration

2. • Muscle length influences muscle force production
   • Gastrocnemius force production affected by its muscle length

3. • Gastrocnemius muscle length changes as knee joint angle change, fixed ankle joint
   • Knee joint angle of 180° will result in longer gastrocnemius muscle length compared to knee joint angle of 90°
Aim

- Investigate the aftereffects of 30mins prolonged vibration on two different gastrocnemius muscle lengths and it’s consequence to plantar flexion MVC
Hypothesis

We hypothesized that prolonged vibration to the Achilles tendon will cause a greater reduction in plantar flexion MVC with knee angle at $180^\circ$ compared to $90^\circ$
## Methods

### Subjects
- 16 subjects (5 women, 11 men)
  - Ages 23-37
  - Height 161-193 cm
  - Weight 57.5-92 kg

### Screening
- ACSM screening questionnaire
- No neurological disorders
- Informed consent
- No alcohol or caffeine 24 hours prior to testing
- No heavy exercise before testing
Equipment used

**Biodex System Pro 4**
- Used to measure peak torque of plantar flexors

**Vibrator (110 Hz, 3 mm amplitude)**
- Produces vibratory stimulus to Achilles Muscle-Tendon junction

Methods: testing
2 different knee joint angles

1. Knee 180°
2. Knee 90°
Methods: Experimental Protocol

• Each subject completed a trial at both knee joint angles
  ▫ Order of testing randomized
  ▫ 1 week separation between the two trials

• Subjects have their upper bodies secured into the chair using the straps provided.
Methods: protocol continued...

Pre- Vibration Maximal Voluntary Contractions

Post- Vibration Maximal Voluntary Contractions
Data Analysis

- Each subject performed 3 MVC trials Pre and Post vibration
- The greatest value was considered to be the true MVC.
Statistics

- A 2 X 2 Repeated Measures ANOVA was used

<table>
<thead>
<tr>
<th></th>
<th>Vibration (PRE)</th>
<th>Vibration (POST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of 180</td>
<td>131.5 ± 42.7 Nm</td>
<td>110.3 ± 21.2 Nm</td>
</tr>
<tr>
<td>Angle of 90</td>
<td>80.5 ± 25.2 Nm</td>
<td>65.5 ± 21.5 Nm</td>
</tr>
</tbody>
</table>
Result #1: Effects of Joint Angle

- MVC torque at 90° was less than MVC torque produced at 180°. A comparison via two-way ANOVA yields a statistically significant finding ($p \leq 0.000181$)
  - Average MVC at 90° = 80.5 ± 25.2 Nm
  - Average MVC at 180° = 131.5 ± 42.7 Nm
Result #2: Effects of Vibration

- Two way ANOVA analysis showed a statistically significant decrease in MVC due to vibration to a p-value of 0.002

  - Average 19.3 % decrease at 180°
  - Average 16.6% decrease at 90°
Result #3: Interaction of Joint Angle and Vibration

- No interaction effect was demonstrated between these factors
- Two Way ANOVA analysis yielded p-value of 0.4346
- Similar slopes for each of the MVC vs. pre/post vibration plots
TIME*ANGLE; LS Means
Current effect: F(1, 15)=.64431, p=.43469
Effective hypothesis decomposition
Vertical bars denote 0.95 confidence intervals
Discussion of Result #1: Effects of Joint Angle

- This research study confirms the findings of several previous research studies (Creswell 2005)
  - Significant decrease in the MVC with changes in the joint angle
  - Length tension relationship of the gastrocnemius
Discussion of Result #2: Effect of Vibration on MVC

- This research study confirms the findings of several previous research studies
  - Significant decreases in the MVC with prolonged vibration
  - Ia afferent attenuation
    - MVC torque is reduced following exposure to prolonged tonic vibration by a factor of about 20% (Kouzaki et al., 2000 and Ushiyama et al., 2004)
Discussion of Result #3: Interaction between Joint Angle and Vibration on MVC

• There is no difference in the plantar flexor MVC when it is vibrated at two different joint angles.
  • Supports the acceptance of the null hypothesis
  • Several limitations that could have influenced this deduction
Limitations and Sources of Error

1. Test subject positioning
2. True MVC production – no ability to validate
#1: Subject Positioning

- Biodex protocol specifies 60° knee joint angle for plantarflexion MVC—allowing for the use of a blocking pad isolation of the muscle group

- Study Design:
  - Modified the protocol to two positions of 90° and 180° to create greatest difference in muscle length –
    - Insufficient stabilization of the knee during MVC 90° task
    - Isolation of plantar groups
      - Auxiliary muscle use during trials
#1: Subject Positioning

#1: Subject Positioning

1. Knee 180°

2. Knee 90°
#1: Error in measurement of MVC at 90 degrees

<table>
<thead>
<tr>
<th></th>
<th>Knee joint angle 180°</th>
<th>Knee joint angle 90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Established Research</td>
<td>135Nm ± 23Nm (Creswell)</td>
<td>103Nm ± 23.72Nm (Creswell)</td>
</tr>
<tr>
<td>Our data</td>
<td>131.5Nm ± 42.7Nm</td>
<td>80Nm ± 25.2Nm</td>
</tr>
<tr>
<td>Difference to Expected Values</td>
<td>2.6%</td>
<td>22.3%</td>
</tr>
</tbody>
</table>
#2: True MVC production - no ability to validate

- Unable to confirm true MVC of the subjects
  - Review from the methods:
    - Trained subjects on MVC trials
    - Took greatest value of 3 trials
  - Other experiments have employed the interpolated twitch method
    - No suitable stimulator
    - Biodex, data analysis software is unsuitable to collect data with this method, additional equipment is needed
Conclusions

This study has confirmed two common findings in the literature:

1. Prolonged tonic vibration reduces plantar flexor MVC torque.
2. Plantar flexor torque is less when the knee is at 90° when compared to a 180° knee joint angle.
3. There is no difference in the reduction of plantar flexion MVC due to tonic vibration at 90° and 180°.
References:

References:

References:

References: