METHODOLOGICAL CONSIDERATIONS AND THE EFFECT OF PAIN ON THE H-REFLEX AND MAXIMAL M-WAVE IN THE HUMAN TRICEPS SURAE

A thesis submitted for the degree of

DOCTOR OF PHILOSOPHY

by

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Abstract

The control of skeletal muscle relies on a complex integration between descending central input and information that originates from receptors that lie within peripheral tissue. The following investigations were performed to contribute to our understanding of this control.

Study 1 (Chapter 2) was designed to determine (using the H-reflex) if muscle spindle feedback is similar in the gastrocnemius and soleus. The strength of the H-reflex at rest and during contraction was compared between muscles. The results showed that the maximal H-reflex obtained at any level of contraction is larger in the soleus than in the gastrocnemius. We argue that along with the muscles having different structures and functions, the recruitment capabilities of their motoneurons are quite different. We also found that the maximal M-wave, which has for years been thought to be a consistent measure of maximal muscle activity, was quite variable within subjects during different conditions.

Review of the maximal M-wave literature showed evidence that variability in this response did exist between conditions, but that the variability was rarely seen in pooled data, and was therefore not often reported. Study 2 (Chapter 3) was developed to determine if experimental recording techniques, or analysis methods, could affect the magnitude of the maximal M-wave within subjects. The first finding of this study showed that the two most commonly used analysis methods (peak-to-peak amplitude and area) provided comparable results, and could not account for the differences seen in the maximal M-wave magnitude. The study did however suggest that the orientation of surface recording electrodes can significantly alter the recorded signal. We argue that although bipolar surface recording is considered superior to monopolar recording in its ability to record a clean signal, it has a large limiting factor, which we call “signal cancellation”.

The third study (Chapter 4) focused on the variability in M-wave strength in the gastrocnemius and soleus during a variety of ankle orientations and voluntary contraction levels. This study supported our previous work, and showed that when monopolar recording is used, consistent and significant differences exist in the

strength on the M-wave obtained during different conditions that were not seen in bipolar recordings. It was concluded that the difference in maximal M-wave strength obtained during different muscle conditions may be related to a change in the recording electrode to muscle bulk relationship. This finding is important as M-wave strength is consistently used as a normalisation factor in reflex studies, and therefore variability in this measure may seriously affect the results obtained during muscle reflex investigations.

The final study (chapter 5) considered the size of the H-reflex, the level of background muscle activity, and the subjects' weight distribution, during painful and non-painful conditions. We determined that these factors were not modified by pain induced in either agonist or antagonist muscles.

The final chapter outlines the major findings from this work, highlights limitations to the research conducted using the H-reflex, and makes suggestions for future research in this area.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Publications

The following is a list of peer reviewed journal publications arising from this thesis to date. Each article is included in the appendix of this thesis.

Chapter 1:

Tucker KJ, Tuncer M, Türker KS. A review of the H-reflex and M-wave in the human triceps surae. Hum Mov Sci. 2005; 24(5-6):667-88.

Chapter 2:

Tucker KJ, Türker KS. Muscle spindle feedback differs between the soleus and gastrocnemius in humans. Somatosensory and Motor Research 2004; 21(3-4):189-97

Chapter 3:

Tucker KJ, Türker KS. A new method to estimate signal cancellation in the human maximal M-wave. Journal of Neuroscience Methods. 2005; 149(1):31-41

Chapter 4:

Tucker KJ, Türker KS. Triceps surae stretch and voluntary contraction alters maximal M-wave magnitude. Journal of Electromyography and Kinesiology 2006 (In Press)

Further possible publications arising from this thesis include:

Chapter 5: (Currently in submission)

Tucker KJ, Brinkworth, RS, and Türker KS. Hypertonic saline induced pain does not affect agonist or antagonist H-reflex strength in the triceps surae.

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It is very important at this point to acknowledge the wonderful team of collaborators, workmates and friends that have helped to make this possible. Firstly I must thank my supportive and caring supervisor, Associate Professor Kemal Türker. Kemal has not only provided me with the scientific background and research direction that I have needed to accomplish this goal, but also the support of a friend. I am grateful to have had the opportunity to work with Kemal in different roles over the last 8 years.

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Summary

The control of skeletal muscle relies on complex communication between the central and peripheral nervous system. Constant integration in the spinal cord of information that originates from receptors lying within many peripheral tissues and continual descending central input, contribute to ensure that the level on ongoing muscle activity is appropriate for each condition. A large amount of research has been conducted into this complex integrative system. With every answer however, more questions are posed. The following investigations were performed to add to this body of research.

When these investigations began, the main aim of my PhD was to investigate how musculo-skeletal pain may affect the control of muscle activity. The first investigation was designed to determine if pain alters muscle activity at the spinal cord level. To do this the Hoffmann reflex (H-reflex described in chapter 1) was elicited in the triceps surae of asymptomatic human subjects, before, during, and following, the induction of short-term pain. The results of this preliminary investigation were quite varied, and this variability led to a change in direction of the research. Through discussions with my supervisor it was determined that some of the variability in the results may have been due to the different structure and function of the muscles that make up the triceps surae. Subsequently, the first investigation that is described in this thesis was proposed.

Study 1 (Chapter 2), was designed to determine if the muscle spindle input to the gastrocnemius and soleus muscles were different. In this investigation the strength of the H-reflex during rest and different levels of contraction were compared between muscles. The results showed that the maximal H-reflex obtained at any level of contraction is larger in the soleus than in the gastrocnemius. The study also showed

that while the size of the maximal H-reflex increased steadily with increased contraction in the gastrocnemius to approximately 50% of the maximal muscle response (maximal M-wave), the maximal H-reflex in the soleus peaked, when it reached almost 100% of its maximum possible size, at just 40% maximal voluntary contraction. The findings of this study suggest that the along with the muscles having quite different structures and functions, the recruitment capabilities of the motoneurons are also quite different. The other main finding of this study was that the maximal M-wave, which has for years been thought to be a consistent measure of maximal muscle activity, was quite variable within subjects at different levels of voluntary contraction.

Further review of the maximal M-wave literature showed that some variability in the response did exist between conditions within subjects, but that the variability was rarely seen in the pooled data. This intriguing finding led to the second study presented in this thesis. Study 2 (Chapter 3) was developed to determine if the experimental recording techniques, or analysis methods commonly used in human muscle response investigations, could further change the magnitude of the reported maximal M-wave within subjects.

To investigate this, a variety of techniques were utilized to record and analyse the maximal M-wave as it was elicited in the gastrocnemius and soleus of human subjects. The first finding of this study showed that the two most commonly used analysis methods (peak-to-peak amplitude and area) provided comparable results, and could not account for the differences seen in the maximal M-wave magnitude between conditions. The study did however suggest that the orientation of surface recording electrodes could significantly alter the signal that is recorded in such studies. It was concluded from this study that although bipolar surface recording is

considered superior to monopolar recording in its ability to record a clean signal, it has a large limiting factor, which we called “signal cancellation”.

Signal cancellation occurs when the second negative electrode is recording part of the muscle response, before the wave has completely passed the first positive electrode. This study showed that bipolar recording reduced the signal strength by up to 80% of its actual size, and that when this occurred no consistent variability existed between experimental conditions. In contrast, when monopolar recording electrodes were used, a consistent and significant difference in maximal M-wave strength was seen between the resting and voluntary contracting test muscles. This finding reinforces the importance of using the correct tools, in particular when recording large muscle responses during different conditions.

The finding also led to the third study (Chapter 4), which focused on the variability in M-wave strength in the gastrocnemius and soleus muscles during a variety of different ankle orientations and voluntary contraction levels. This study supported our previous work, and showed that when monopolar recording is used (as opposed to bipolar recording electrodes), consistent and significant differences existed in the strength of the M-wave obtained during different muscle conditions. It was concluded that the difference in maximal M-wave strength obtained during different muscle conditions may be related to a change in the recording electrode to muscle bulk relationship. This finding is important as the M-wave strength is consistently used as a normalising factor in many reflex studies, and therefore variability in this measure may seriously affect the results obtained during many reflex investigations.

Once the first three studies had been concluded, we decided to reassess the initial question of this thesis. Does pain affect muscle activity by influencing the excitability of the H-reflex circuit? From the results of the first study, it had been determined that

the gastrocnemius and soleus muscles were quite different in their recruitment tendencies, so both muscles were to be recorded simultaneously and independently. Furthermore both monopolar and bipolar recording electrodes were used to record the H-reflex and M-wave to determine if the results would be affected by the signal cancellation error as seen in the M-wave during study 2 and 3.

The final study considered both the size of the H-reflex, the level of background muscle activity, and the weight distribution of subjects during control, painful and sham conditions. Subjects stood comfortably throughout the duration of the investigation, which ensured some postural background muscle activity. The major findings from this study were that the use of hypertonic saline induced pain in either agonist or antagonist muscles in the leg did not alter the H-reflex size in the soleus or medial gastrocnemius. It also showed that this kind of pain did not significantly alter the level of background muscle activity in the soleus, medial gastrocnemius or tibialis anterior. Finally, the study also showed no change in the weight distribution of the subjects on the test leg between the different experimental conditions. This work supports some, but refutes other data published in the area of pain and the H-reflex. We suggest that the variability in the results seen by different authors may be specifically due to the degree of motor control required to complete the tasks required of the test muscle during the experimental conditions. We therefore suggest that greater changes in the H-reflex and background muscle activity may occur in the test muscle when it is completing more complex tasks during pain compared to non-pain conditions. Due to the conflicting results in this area, much further research is required before definite conclusions can be drawn as to the location and the extent of the influence that pain may have on the human H-reflex circuit.

All of the work completed as part of this thesis helps to improve our understanding of the methodological considerations required to maintain a high standard of research

when studying the H-reflex and M-wave. It also adds to our understanding of the influence that both voluntary contraction and pain has on the human motoneuron pool, with particular focus on the triceps surae.