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Original research study

The effects of dorso-lumbar motion restriction on EMG activity of selected muscles during running

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ABSTRACT

Abstract: The effects of restricting dorso-lumbar spine mobility on electromyographic activity of the erector spinae, quadriceps femoris, hamstrings and gastrocnemius muscles in runners was investigated. Thermoplastic casting material was fashioned into a rigid orthosis and used to restrict spinal motion during running. Volunteers ran on a treadmill at 2.78 m/sec, under normal conditions and with spinal motion restricted. Surface electromyographic data was collected during both sets of trials. Normal electromyographic data was also compared with previous authors to determine similarity with their electromyographic data.

Results: Casted running resulted in an increase in erector spinae ($p < 0.01$) and quadriceps femoris ($p = 0.02$) electromyography activity. Total stride time and swing time of gait were decreased during casted running ($p < 0.01$), indicating a shift towards shorter and thus more frequent steps to run the same distance. The normal electromyographic data collected was in agreement with previously reported work.

Conclusions: Neurological control over muscle and the fascia surrounding it is responsible for joint movement and load transfer. Experimentally restricting spinal motion during running demonstrated an increase in erector spinae and rectus femoris electromyographic activity. This lends support to the hypothesis that decreased spinal mobility may be a contributing factor to overuse muscle injuries in runners.

1. Introduction

Running or jogging is a popular activity and is associated with health benefits for the cardiovascular system, musculoskeletal system and maintenance of a proper body weight. Research by Slocum and Bowerman (1962), Mann (1980, 1982), and Subotnick (1985), showed that the pelvis and upper body rotate in opposite directions during running, indicating the importance of spinal mobility. This allows for a smooth force transmission throughout the gait cycle. In addition to spinal mobility, muscle activity and neurological controlling mechanisms, Gracovetsky (1985) and Gracovetsky and Iacono (1987), discussed the role of the spine as an energy generator during gait and how connective tissue acts as an energy storage mechanism during gait.

This study assessed the effects of limiting spinal mobility on the erector spinae (ES), quadriceps femoris (QF), biceps femoris (BF) and gastrocnemius (GA) muscles via electromyography (EMG) and the effects on stance and swing phases of gait. Contraction of a muscle yields externally measurable electrical activity. It is this activity that is detected by EMG.

There are three types of muscular activity:

Isometric activity occurs when a muscle exerts tension, but its length remains constant. Milner-Brown and Stein (1975), showed that this is the only type of muscle activity that shows a linear amplitude to force ratio. Concentric activity occurs when a muscle contracts and shortens. It is this activity that moves limbs and propels the body upward and forward during running. It is associated with energy generation. Eccentric activity occurs when tension developed in the muscle is not sufficient to maintain muscle length, or to cause the muscle to shorten. Muscle length increases while the muscle is contracting. Fewer fibers are activated for a given load, so the potential for damage is higher. Eccentric activity is responsible for the deceleration phase of various body parts at and shortly after the heel strike phase of running. It is

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associated with absorption and storage of energy. Winter (1983), demonstrated that the knee muscles absorbed 3.6 times as much energy as they generated.

1.1. Types of EMG

Needle EMG and surface EMG methods can be used to collect data during various activities. Needle EMG can give signals from the individual components of the QF, BF or other muscles, since needle electrodes could be inserted into each component. Surface EMG on the other hand, only gives a global signal from the entire QF group. Thus, needle EMG is more definitive (Basmajian and DeLuca, 1985). Needle EMG is an invasive procedure. In an activity like running, there can be pain associated with the implanted needles; the protruding needles in the ES would be compressed by the tight fitting cast and would be a source of pain. It would have affected signal collection. In addition, the repeated jarring associated with each foot strike and/or the rapid lower limb accelerations could have loosened the needles and thus affected data collection. Subject recruitment and compliance, already difficult to accomplish, would have been affected if they were told that many needles would be inserted into their muscles and there could possibly be pain. Finally, it would have been difficult if not impossible to get IRB approval for an invasive procedure. Therefore, surface EMG was used for this study.

1.2. Previous work

To the authors' knowledge, there is no previous work detailing the effects of restricting spinal mobility on EMG activity of leg and trunk muscles during running.

2. Methods

This study was approved by the University of Surrey (UK). Male subjects were recruited from the running club at the University of Surrey. The tight fitting cast would have caused discomfort and possible injury for female subjects by tightly compressing breasts. It proved to be difficult to recruit subjects from the running club, so reaching the sample size target of twenty was not possible. Recruitment for the EMG studies resulted in ten subjects for the two preliminary pilot studies and fourteen subjects for the main study. All EMG subjects participated in one study only.

All subjects were pain free male student volunteers from the University of Surrey running club. They were between the ages of 19 and 39 and had no history of back, leg or neck pain or injury and were current runners. Potential risks were explained and subjects signed an informed consent form. All subjects were experienced runners and ran a minimum of 8 km per week. All subjects served as their own control, running both normally and casted.

A lightweight (700 g) piece of re-usable casting material (Sansplint, Smith and Nephew Medical, Hull) was chosen for use as the spinal restriction cast. It was molded to the contours of the trunk and spine and was made in two parts, one each for the left and right side of the trunk. It over-lapped in front and back for easy adjustable fastening in each volunteer. When applied, it extended from approximately T7 to the pelvis, covering the anterior superior iliac spines, iliac crests, posterior superior iliac spines and the top of the sacrum. Tiny perforations throughout the entire cast made it possible to use shoestrings to tighten the cast both at the top and the bottom, front and back, according to the size of the subject. The cast material was flexible in a posterior to anterior direction. Thus, the flexibility and the ability to tie the top and bottom separately gave us a good degree of fitting the cast tightly to the individual, maximizing restriction of spinal mobility. In addition, a belt was placed at waist level on the cast to enhance further tightening, as required. Costs did not permit an individual cast to be made for each subject. Trials were repeated in the normal running state, and in the casted state. The order of the trials was decided randomly via coin toss for each subject individually.

The effect of the cast was studied in preliminary experiments to demonstrate that it produced its restricting effect independent of its 700 g weight and with no pain so as not to introduce unwanted variables. All subjects ran with sweatshirts and t-shirts on during uncasted running in order to approximate the weight of the cast. The weight of the garments ranged from 450 g to 650 g.

All subjects had the experimental procedure and potential risks explained and then had to sign an informed consent form before being accepted. Since this was the first time a spinal casting method has been used in assessing parameters of running gait, 3 groups of subjects were used. The first group formed a pilot study to assess EMG and footswitch methods during normal, uncasted treadmill running, at various speeds, and to resolve problems prior to collecting data from the main study group. The second group, also a pilot study group, was used to determine the best speed to use for our data collection during normal and casted running. The third group was the main study group; therefore, methods used for the third study group, the main group, will be explained first.

2.1. Main study group

EMG signals were collected from the ES, BF, QF and GA muscle groups during treadmill running. The skin for the electrode sites was abraded with a gel in order to decrease the resistance due to dead skin or oil. Data acquisition was made using a pair of self adhering, pre-gelled silver/silver chloride electrodes (Cambridge Electronics) attached over the muscle sites as follows:

ES - midpoint of the electrode at the level of the fourth lumbar vertebra, 50 mm to either side of the median furrow. During casted running, cotton balls were placed over the electrode attachment site in order to eliminate potential motion artifacts due to the cast rubbing on the electrodes.
QF - The top electrode was placed 50% of the way between the anterior superior iliac spine (ASIS), and the beginning of the common patellar tendon.
BF - The midpoint on the gluteal fold was chosen. The distance from here to the mid-line of the popliteal space was then measured. A point half way down this line, and 20 mm lateral, was chosen. The medial edge of the bottom electrode was placed here.
GA - The point one half of the distance between the popliteal space and the split of the two heads of the gastrocnemius was found. The center of the top electrode was placed 20 mm lateral to this. The second electrodes on the ES and BF were placed superior to the first electrode, so that the inter electrode centers were 40 mm apart. The second electrodes for the QF and GA were placed inferior to the first electrode so that the inter electrode centers were 40 cm apart. The adhesive borders of both electrodes were not touching.

In order to minimize motion artifacts, all wires were taped or fastened with Velcro. They were fastened at 2 sites. The first was to the skin, 60 mm from the site of electrode attachment. This was where the two electrode leads were contained within the common insulation sheath, before they bifurcated. The second was site was at the waist with a belt. This was a convenient site because all electrodes passed by this area.

A Medelec amplifier was used for EMG signal collection. The EMG set-up included a preamplifier, signal rectifier and AD