THE THERAPEUTIC POTENTIAL FOR CHANGING PATTERNS OF LOCOMOTION: AN APPLICANTION TO THE ACL DEFICENT KNEE

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INTRODUCTION

Quadriceps muscle atrophy is a substantial and common problem following anterior cruciate ligament (ACL) injury. Quadriceps atrophy has been related to the changes in patterns of locomotion that tend to reduce the net quadriceps moment during walking [1-3] following ACL injury. These adaptations appear to primarily take the form of increased hamstrings and decreased quadriceps activity [4,5]. Typical methods of rehabilitation for the ACL deficient or ACL reconstructed patients are complicated by the increase strain on the ACL caused by quadriceps contraction or co-contraction of gastrocnemius with either quadriceps or hamstrings has been shown to [6]. Houck and Yack observed that additional research to understand how interventions may impact gait could be immediately useful to clinicians [4].

The purpose of this study was to examine the therapeutic effects of several common noninvasive strap and shoe insert systems on the loading patterns of gait. Gait modification through simple cutaneous stimulation could reduce risk of injuries such as ACL rupture or aid in post-injury gait retraining and physical therapy. This study tested the hypothesis that compression applied to limbs by straps placed in various locations on the thigh, knee, and shank would affect the moments generated by muscle contraction during walking

METHODS

Four different strap systems were tested to measure the effects on the gait characteristics of the subjects. The interventions consisted of patellofemoral knee braces applied at different locations along the leg and an elastic knee brace applied around the shank. The first intervention, figure 1A, was a strap wrapped tightly just under the knee joint. The second intervention, figure 1B, was a strap wrapped tightly around the upper-shank. The third intervention, figure 1C, was a combination of a strap around the upper-shank and one around the lower part of the thigh. The fourth intervention, figure 1D, was the knee brace placed around the upper part of the shank, just under the knee joint.

To determine the effects of the interventions, the external joint reaction forces and moments were measured by gathering motion and force plate data from the subjects during their gait trials. A three-dimensional optoelectonic system gathered the motion data, while a multi component force plate was used to measure the ground reaction force.

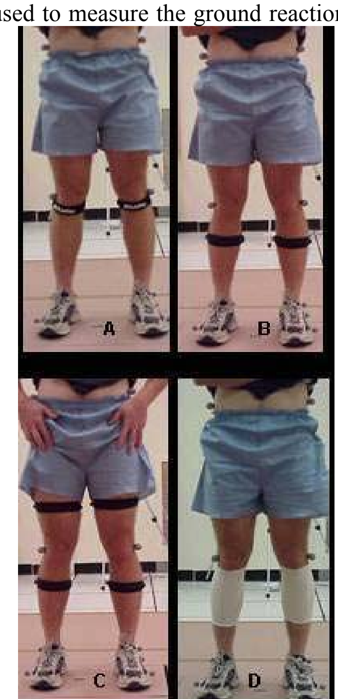

Figure 1: Interventions

Six normal subjects were tested in this study, 2 females and 4 males (25.3 ± 3.7 years, 174.2 ± 17.3 cm, 709.6 ± 232.6N), with Institutional Review Board approval and signed consent obtained for all subjects. The subjects performed three gait tests per side at their normal walking speeds. Each subject performed six control trials on the left and right side, three before the intervention trials and three after the intervention trials. The peak knee flexion and extension moments of each trial, for each subject and strap intervention were calculated at the hip, knee, and ankle. The average walking speed of each subject was also determined. The peak moment occurring in the trial with the walking speed closest to the average speed of that subject was chosen for analysis. The peak moments were found for all stimulus methods and the control. To determine the effects of the intervention, the difference between the peak moment of the strap trial and the peak moment of the control trial was found. The significance of these differences was found using a Student's t-test.

RESULTS

The three strap interventions significantly influenced patterns of locomotion by changing the magnitude of the flexion or extension moments during walking (Figures 2 and 3). The individual shank strap increased the maximum knee flexion moment (balance by a net quadriceps moment) during walking by 17 % over the control value. By contrast, the shank strap produced a significant reduction ($p<0.03$) in the hip extension moment.

The combination of knee and shank straps also significantly ($p<0.05$) reduced the hip extension moment by 10% relative to control. Finally, the knee strap had a substantial influence on the magnitude of the knee flexion with a 21% reduction in the magnitude in the magnitude of the flexion moment. While the results did not reach a significant level for some of the intervention (shank $p<.06$ and combination $p<.11$), the results indicated that testing more subjects would produce a significant result.

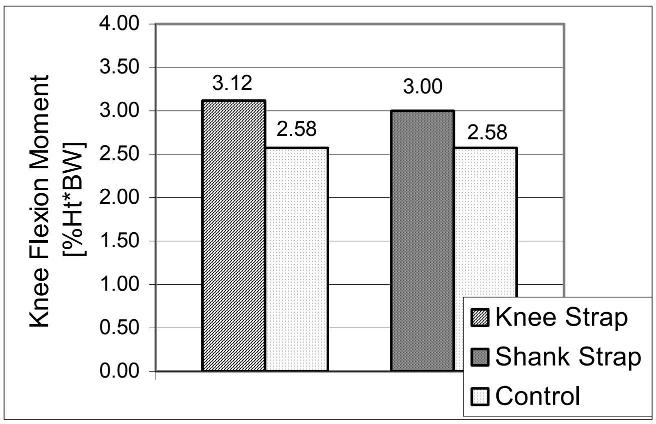

Figure 2: Knee Flexion Moment

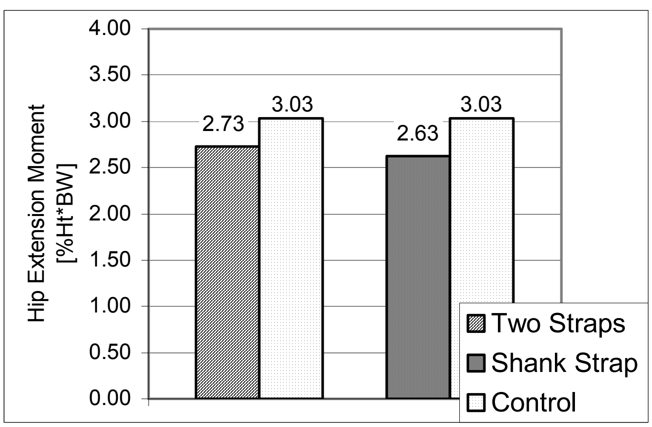

Figure 3: Hip Extension Moment

CONCLUSION

The results of this study indicate that an intervention as simple as wearing straps on the thigh and shank can significantly change the pattern of locomotion during walking. These findings have important implications for the rehabilitation of the ACL deficient knee where increases in quadriceps activation during walking would help to address problems of quadriceps atrophy following injury. In addition, maintaining strength is important for patients following reconstruction of the ACL. Use of knee or shank straps to stimulate additional quadriceps activity in addition to physical therapy will assist clinicians in treating these patients.

It is likely that these straps primarily affect the timing and contraction intensity of the muscles located directly under the strap. Thus, knee and shank straps should significantly affect only the gastrocnemius, which does function as a knee flexor. This indicates that pressure applied by the strap causes gastrocnemius to develop less force than without straps. Reduction of gastrocnemius contraction can reduce ACL strain [5], lowering the risk of rupture. The knee strap may also apply compression to the knee external and internal lateral ligaments, increasing the applied flexion moment. If this is the case, further study should be undertaken to determine the effects of transverse loading on these ligaments.

The decrease in hip extension moment observed with the shank strap and shank and thigh straps indicates less involvement of the gluteus medius and gluteus maximus. Decreased hip involvement is the opposite of gait adaptation generally observed when deficits occur in knee extensors or ankle plantar flexors [8]. Therefore, the observed decrease in hip flexor activity may be due to greater extension in the knee extensors or ankle plantar flexors stimulated by the straps. While further investigation is necessary to determine what other effects may be associated with lowered hip extension moments, this effect may be useful to discourage patients with weakened quadriceps or gastrocnemius because of trauma or surgery such as ACL reconstruction [9] from adopting abnormally compensated gait.

This study shows that strap placements can cause desired modifications in muscle activity, giving clinicians another tool for post-operative gait retraining therapies.

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ACKNOWLEDGEMENTS **NIH Grant # AR20702**