Optimal Placement and Angulation of the Dorsal Foot Control Strap for Lower Limb Orthoses

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INTRODUCTION

Limiting movement of the foot and shank in Ankle Foot Orthoses (AFO) and Knee Ankle Foot Orthoses (KAFO) is a relatively common clinical objective to optimize functional performance for the user. Orthotic control of the foot and ankle in the sagittal plane is achieved with a three-point force couple with a "corrective" fulcrum force applied at the dorsum of the foot by a strap or shoe enclosure to resist plantarflextion during swing phase (Lusardi, 2013). Current clinical practice has few guidelines as to the dorsal strap placement in patients' devices or specifications for shoe enclosures (Ed. Weber, 1993). The literature states the control force should be placed diagonally downwards to stabilize the calcaneus (Lusardi, 2013; Micheal, 2008).

The purpose of this study was to determine the optimal angle and longitudinal axis placement to minimize foot motion within an orthosis. An in vitro study was conducted using fresh frozen cadaveric limbs. Test condition evaluated the dorsal force application position along the longitudinal access of the foot and the angle of the force application point.

METHOD

Specimens: *F*resh frozen cadaveric limbs (n=5) disarticulated at the knee were used in the study.

Test Apparatus: A biomechanical test apparatus was designed for the study that simulated heel rise from a planar surface. The 1st and 2nd hallux were fixed the the loading platform of the test fixture with a plate and screw. A threaded rod surgically implanted through the proximal portion of the tibia. A metal cable attached to the medial and lateral aspect of the rod and looped over a pulley permitted a weight to be attached a hook.

Procedures: To simulate heel rise, a 111N force distracted the tibia in a proximal direction. After a preconditioning routine simulating the heel rise test, the three tests were conducted for each of the nine test conditions. The order of testing was randomized for all test conditions.

Test Conditions: Longitudinal axis position - Proximal (at talus), Middle (2 cm distal to talus) Distal (4cm distal to talus. Force angulation from the dorsum of the foot; Perpendicular: 90 deg, Obtuse:105 deg, Acute:15 deg

Data Analysis: Statistical analysis was conducted using paired t-tests and one way ANOVAs.

RESULTS

The simulated strap force application point that was proximal and obtuse required the least force to constrain the foot and shank (mean 54.8 N). The distal acute force application point required the largest force to constrain the foot and shank (mean 91.5 N). In general, the force increased with decreasing angulation and increased distal force location as seen in Table 1.

When angulation remained perpendicular, an average of 12.8% more force was needed to constrain the limb with the force application in the middle than when the force was applied proximally ($p<0.05$). 36.6% more force was required to restrain the limb in the distal force location than the proximal location ($p<0.05$).

Increase in control force needed from obtuse angulation to acute angulation is significant ($p<0.05$)

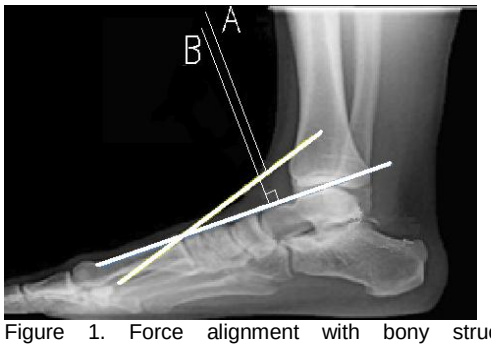

Figure 1. Force alignment with bony structure. Experimental (A) obtuse angle to the soft tissues actually closer to theoretical (B) perpendicular with respect to the boney anatomy

Force Increase with Location and Angulation			
	Acute	Right	Obtuse
Proximal vs Middle	27.7%	12.8%	17.3%
Proximal vs Distal	43.9%	36.6%	38.2%

Table 1. Percent increase in force as point of force application moves distally in all angular conditions

DISCUSSION AND CONCLSIONS

As was speculated the optimal longitudinal axis position of a dorsal control strap should be proximal rather than distal to maximize leverage. This placement will reduce the force applied to the foot and minimize foot displacement within the orthosis. The optimal angular orientation of the strap should be at a right angle to the bony structure. This optimal angular

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orientation may differ from the actual soft tissues that cover the dorsal skeletal bones. Determining the angle of the strap relative to the bony structure may require careful clinical judgement to insure that the force application point of the strap is 90 degrees to the bony structure. The results also showed that it is more favourable, erring toward an obtuse angle compared from the optimal perpendicular bony structure orientation.

Optimal control force placement lowers the force required to constrain the foot and shank leading to reduced risk in soft tissue complications, increased comfort to the user and decreased wear on the orthosis without compromising the clinical motion control objectives.

CLINICAL APPLICATIONS

To minimize foot displacements in lower limb orthoses and to maximize comfort through lower corrective forces a dorsal control strap should be located as proximal as possible and the force application point should be angled 90 degrees to the bony structure.

REFERENCES

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