A Comparison of Vertical Shoulder Joint Reaction Force and Stride Characteristics During Walking with a Walker and Forearm Crutches in Persons with Incomplete Spinal Cord Injury: A Preliminary Report

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Introduction: Ambulatory status following incomplete spinal cord injury (SCI) is primarily dependent on lower extremity (LE) muscle strength.[1] When LE weakness is so pronounced that a manual walking aid is needed, the upper extremities become weight bearing structures. The mobile shoulder joint, however, is structurally ineffective for such repetitive weight bearing, with its shallow socket and vertical joint plane. As a result, the prevalence of shoulder pain in the SCI population has been reported to be as high as 72%.[2,3] The impact of shoulder pain and injury is deleterious for a population which relies on their upper extremities (UE) for independent mobility. Although peak axial loads exerted on assistive devices during ambulation has been documented[1], elucidation of superior shoulder joint reaction force should illustrate more accurately the potential for impingement and damage of subacromial shoulder structures. The purpose of this study was twofold: 1) to compare the vertical shoulder joint reaction forces during crutch (CR) vs. walker (WKR) ambulation and investigate the influence of lower extremity (LE) isometric strength on these forces, and 2) compare stride characteristics (including velocity, cadence and stride length) during CR vs. WKR ambulation in persons with incomplete (SCI).

Statement of Clinical Significance: In order to maximize functional mobility and prevent deterioration of the shoulder complex in persons with incomplete SCI, clinicians need to consider the interaction of LE strength and vertical shoulder joint forces, in addition to gait characteristics and environmental constraints, when prescribing an appropriate ambulatory aid.

Methodology: Six persons with incomplete SCI participated (3 tetraplegia, 3 paraplegia). Subjects were > 1 year post SCI, able to walk a minimum of 50 feet, and asymptomatic for UE pain. Subjects ambulated at a self-selected free velocity using forearm CR and a front-wheeled WKR instrumented with 3D load cells that recorded forces applied to the assistive device during ambulation. Bilateral UE kinematics were measured with a VICON motion analysis system. Stride characteristics were measured using compression closing switches taped to the bottom of both shoes. Lower extremity isometric torque was measured bilaterally at the ankle, knee and hip using a LIDO dynamometer and ring tensiometer. An inverse dynamics approach was used to calculate the UE moments and forces. The vertical component of the shoulder joint reaction force was determined for the UE contralateral to the weaker LE. Peak vertical shoulder joint reaction force, walking velocity, cadence and stride length were compared between the 2 assistive devices using a paired t-test. Stepwise regression analysis was used to determine the association between LE isometric torque and the peak vertical shoulder force.

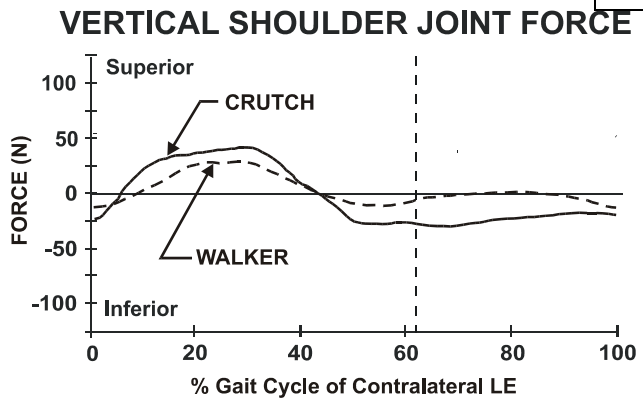
Results: Mean self-selected walking velocity was similar during ambulation with CR and the WKR. Stride length was 4% greater during CR walking however cadence was 5% reduced compared with that recorded during the WKR trial. (Table). Peak vertical shoulder joint force during ambulation with the CR was 50% greater than peak force with the WKR (Figure). Statistical power analysis revealed an effect size of 0.52 for the difference in vertical shoulder

joint force and determined that 31 subjects would be necessary to achieve significance (80% power). Mean LE torque ranged from 24% of normal (plantar flexion) to 43% of normal (dorsiflexion). Stepwise regression analysis revealed that combined contralateral hip abductor and knee extensor torque was a significant predictor of vertical shoulder joint forces during ambulation with a WKR (r = -.88). The strongest predictor of vertical shoulder joint force during CR ambulation was contralateral hip and knee extensor torque (r = -.69).

Table. Mean and Standard Deviation Gait Characteristics (% of normal) and Peak Superior Shoulder Joint Forces in Newtons (N)

	Crutches	Walker	p value
Velocity	39.7% +/- 18.0	40.1% +/- 17.9	0.88
Stride Length	62.9% +/- 13.4	60.7% +/- 12.5	0.36
Cadence	59.9% +/- 20.5	63.1% +/- 20.9	0.13
Joint Force	45 N +/- 40	31 N +/- 29	0.16

Figure. Superior Shoulder Joint Forces in Newtons (N)



Discussion: Increased UE demand for functional mobility following SCI contributes to a high incidence of shoulder pathology. In this study, CR and WKR walking velocity was not significantly different. CR walking, however, produced a greater peak vertical shoulder joint reaction force, although not statistically significant with these preliminary data. During ambulation with a WKR, reduced strength of the contralateral hip abductors, along with the knee extensors, was associated with increased vertical shoulder joint force. For the CR walking condition, the critical muscle groups were the contralateral hip extensors and knee extensors. To minimize the risk for impingement of subacromial structures, the impact of LE strength on shoulder joint forces and the ability of the UE to meet these imposed demands should be considered when selecting an assistive device.

References:

1. Waters RL et al., *Arch Phys Med Rehabil*. 1994; 75:756-760.
2. Gellman H et al., *Clin Orthop Rel Res*. 1988; 233:132-135.
3. Sie et al., *Arch Phys Med Rehabil* 1992; 73:44-48.

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