UPPER EXTREMITY BIOMECHANICS OF ASSISTED MOBILITY DEVICE USAGE IN PEDIATRIC ORTHOPAEDIC DISABILITIES

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INTRODUCTION

According to the latest NIDRR Mobility device report there are an estimated 1.7 million wheelchair or scooter users and 6.1 million users of walkers, crutches, canes, or other devices [1]. Walker use has been reported by 1.8 million persons, while 1.5 million persons use manual wheelchairs and 566,000 persons use crutches [1]. A growing population of pediatric individuals is included within this population. Severe cerebral palsy (CP), spinal cord injury (SCI), myelomeningocele (MM), and osteogenesis imperfecta (OI) are associated with these leading causes of assistive mobility device usage in children and adolescents.

While the number of pediatric individuals using assistive devices is significant, there is limited information on joint dynamics. The relationship between joint forces, assistive devices and the transition effects to adulthood has not been studied. We propose methods for characterizing three-dimensional (3-D) upper extremity (UE) joint forces and moments during assisted mobility (wheelchair mobility, crutch and walker assisted-gait).

High joint forces during assistive device usage have been shown to lead to joint pain and approach levels of injury [2-4]. Quadrapedal gait, as occurs with crutch and walker usage requires high, unnatural demands on the upper extremity. Literature has shown that peak joint forces at the shoulder are directly correlated to device usage. These forces are also anticipated to be of concern at the wrist and elbow. Quantification of 3-D inverse dynamics and correlation among assistive device usage and pathology is essential for improved care of children with severe orthopedic disabilities. The investigation of the joint demands placed on the UE may have significant impact on rehabilitation protocols and transitional care.

METHODS

Advanced mobility modeling techniques using 3-D inverse dynamics methods are proposed. The UE inverse dynamics model computes wrist, elbow and shoulder complex kinematics and kinetics [5].

The model includes the kinetically instrumented assistive device segment(s) of interest (i.e., wheelchair, crutches, or walker) and defines the thorax, shoulder complex, upper arm, forearm and hand. Computed joint motions include the thorax, shoulder complex, elbow and wrist. The model follows ISB recommendations [6].

Wheelchair mobility is one of the three activities of interest. Three subjects with SCI (17 year-old) propelled their manual wheelchair along a 15-meter path at a self-selected propulsion pattern and speed (Figure 1). Kinematic data was collected using a 14 camera Vicon MX motion capture system (120 Hz). 3-D forces and moments were acquired simultaneously (240 Hz) from a SmartWheel (OutFront, Mesa, AZ) on the subjects’ dominant side.

Figure 1: Manual wheelchair user (MWU) with UE model marker set.
RESULTS

Ten stroke cycles of each subject were analyzed using our custom pediatric inverse dynamics model. Average joint forces for three subjects’ dominant side are presented in Figure 2. Mean shoulder, elbow, and wrist joint forces were computed triaxially.

DISCUSSION

The custom pediatric UE biomechanical model successfully characterized joint dynamics in MWUs with SCI. Subjects displayed similar, yet different morphologies, suggesting the need for subject specific analysis and further characterization of orthopaedic pathologies. Joint forces during crutch and walker assisted gait are proving to be substantially higher than wheelchair mobility, causing even greater concern. The implications for pain and overuse pathology are significant.

CONCLUSIONS

Improved biomechanical understanding of assistive device usage will provide insight for children as they mature. Transition to adulthood will bring about new challenges to be addressed biomechanically. This work provides quantitative framework to support training paradigms, alternative mobility patterns or redesigned assistive devices to reduce joint loading. Future work involves determining correlations among joint dynamics, pain and functional outcomes, as well as to determine the underlying tissue level effects through musculoskeletal modeling of pathology.

REFERENCES


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