Secondary Gait Compensations in Normal Adults with an Imposed Unilateral Ankle Equinus Constraint

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Introduction

Treatment of gait disorders requires that primary and secondary deviations be delineated, so that only primary deviations are treated. While voluntary bilateral toe walking by normal individuals has been investigated as to its compensatory effects at other joints [1,3], none have previously investigated similar compensations of unilateral toe walking, nor with a biomechanically imposed constraint. The purpose of this study was to determine what compensatory gait deviations occur as a result of an imposed unilateral ankle equinus constraint.

Statement of Clinical Significance

Persons with spastic hemiplegia can present with a multitude of gait deviations involving the hip, knee, and/or the ankle, all of which can be the focus of separate soft tissue lengthening or transfer procedures aimed at facilitating a more normal gait pattern. While it is understood intuitively that impairments at one joint can lead to effects at others, these relationships have not necessarily been well defined. One impairment generally occurring in even mild cases of hemiplegia is a gastrocsoleus contracture on the involved side. Defining and quantifying those gait deviations which occur at the hip and knee secondary to this single, common impairment may aid in our understanding of hemiplegic gait.

Method

Twelve normal adult subjects without history of orthopaedic or neurological impairments, acute lower extremity injury, or recent lower extremity surgery participated in this study (8 females, 4 males; mean age = 23.7 years; normal lower extremity PROM). Using a unique taping method, one ankle, randomly selected, was constrained in significant equinus (Mean dorsiflexion PROM = -24°). Subjects were then asked to walk a 10-meter walkway at a self-selected, comfortable speed, first with the constraint intact (experimental condition), then with it cut to allow the resumption of normal ankle motion (control). A 3-D motion analysis system (6-camera Vicon 370 system with a 13-marker set) was used to record kinematic data over several trials in each condition. Temporal-distance measures and a variety of kinematic variables were assessed.

Results

In addition to the primary imposed deviations at the ankle, several significant alterations in normal, ipsilateral hip and knee motion were also observed (Table 1). No significant differences were seen in the contralateral ankle, knee, or hip kinematic variables between the two conditions, although one-third of the subjects demonstrated an absent first ankle rocker contralateral to the taped equinus. Velocity, stride length, step length, and cadence were all reduced in the experimental condition.

Table 1. Temporal-distance parameters and select kinematic variables. *Indicates a significant difference ($p < 0.05$). +Primary imposed deviations.

Dependent Variables	Experimental Condition (Constraint Intact)	Control Condition (Constraint Cut)	
Velocity (cm/s)	111 (13.8)	133 (13.0)	*
Stride Length (cm)	123 (10.6)	141 (11.9)	*
Ipsilateral Step Length (cm)	65 (5.4)	73 (5.5)	*
Cadence (steps/min)	109 (10.2)	113 (9.0)	*
+Ankle Dorsiflexion, initial contact (deg)	-28 (6.0)	-1 (4.9)	*
+Peak ankle dorsiflexion, stance (deg)	-7 (7.8)	15 (6.9)	*
+Peak ankle dorsiflexion, swing (deg)	-20 (6.5)	3 (3.8)	*
Knee extension, initial contact (deg)	-26 (7.8)	-8 (3.7)	*
Peak knee extension, stance (deg)	-22 (9.5)	-4 (5.1)	*
Peak knee flexion, swing (deg)	62 (3.9)	61 (3.9)	
Timing to peak knee flexion (% of swing)	30 (4.3)	28 (3.2)	
Peak hip extension, stance (deg)	-6 (7.2)	5 (7.8)	*
Peak hip flexion, swing (deg)	49 (7.0)	40 (5.5)	*

Discussion

The current study suggests that a unilateral equinus constraint alone can lead to significant limitations of knee extension at initial contact and in mid stance, as well as a significant limitation of hip extension in terminal stance. Therefore, it is important to determine if deviations displayed at the hip and knee in a Type IV pattern as described by Gage [2] are primary (caused by contractures) or secondary (compensatory to restricted ankle dorsiflexion) before proceeding with soft tissue treatment at the hip and knee. In addition, if contractures of the hamstrings and hip flexors are present, one may want to consider whether these could have developed over time as a result of a long-term compensatory pattern in which the hamstrings and hip flexors are not elongated normally during gait. In contrast to previous studies of bilateral voluntary toe walking [1, 3], subjects in this study demonstrated significant reduction in knee extension at initial contact and mid stance, as well as the retention of normal knee flexion magnitude in swing. The two major differences in our protocol were a unilateral limitation in ankle dorsiflexion and a mechanical block of this motion. The current method of taping was believed to more closely mimic a true equinus contracture. Evidence of this is a higher peak stance phase dorsiflexion value, demonstrating the tendency of our subjects to load the mechanical constraint passively rather than to maintain increased plantarflexion via active calf muscle contraction alone [1, 3]. The clinical significance of this study is to suggest that limitations in ipsilateral hip and knee extension in the gait of persons with hemiplegia may occur as a result of a unilateral plantarflexion contracture alone.

References

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