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Verbal Feedback Cues for Altering Vertical Ground Reaction Forces Patterns in Gait Re-Education Training

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Introduction

Dynamic feedback has been advocated for helping individuals with pathology re-learn symmetrical load distribution in gait (1,2). Real-time visual feedback of vertical ground reaction forces during steady state walking on treadmills has been used to alter the gait of amputees (1). Amputees were able to reduce gait asymmetries for the force variable displayed but other gait asymmetries increased. It was suggested that the walking patterns were altered to decrease one asymmetry by increasing others. The phase of the force curve a subject attends to, or the verbal feedback cues given are important considerations. We propose to use real-time feedback of vertical forces to alter asymmetric gait of individuals with arthritis. To investigate the role of verbal cues, instructions to normal individuals that encouraged asymmetric limping strategies similar to individuals with hip arthritis were given, to investigate changes in bilateral vertical force curves. With this "reverse feedback" paradigm, the effect of verbal cues on specific phases of vertical force curves could be identified.

Methodology

Four healthy experienced treadmill walkers were given specific verbal cues to mimic asymmetric limping strategies similar to the gait of individuals with unilateral degenerative hip disease. The instructions were: 1) Shorten your step on the affected limb and swing the other limb through faster; 2) Shift your trunk over the affected limb when you step; 3) Land gently on the affected limb, without bending your knee initially. The subjects practice walking overground and on the treadmill (10-15 minutes) until the movements were consistent with the verbal cues. Trials of 30 s were collected for normal gait, and for each of the altered gaits while the subject walked at 1.8 mph on a treadmill housing two force plates (Kistler Instrument Corp.). Vertical foot-ground reaction force records were A-D converted (500 Hz) and low-passed filtered (100 Hz). Six to eight steps were averaged. Symmetry indices (3) for stance time (ST), vertical force impulse (F_{imp}), peak load acceptance (F_1), mid-stance (F_2) and push-off (F_3) forces were determined for each condition.

Results and Discussion

Consistent with reported results (3), all subject had bilateral symmetry indices (SI) within 5% for their normal gait trials. Verbal cues 1 and 3 resulted in the greatest SI change (average 37% for F_{imp}). The reduced impulse is due to a decrease in stance time and the magnitude of the force peak F_3 in terminal stance (Fig. 1). These changes would appear to be related to a shortening of the affected limb stance (Cue 1) and a lack of knee flexion through terminal stance (Cue 3). Feedback cues 1 and 3 also resulted in increased SI values (F_1) during load acceptance (average 18.1%), primarily resulting from increases in F_1 on the "unaffected limb" side above normal values; the rate of rise of loading force also appeared to be greater (Fig. 1). Feedback cues 1 and 3 resulted in changes in vertical forces that are most like those reported for patients with unilateral hip arthritis (4). Shifting of the trunk over the "affected side" (Cue 2) did not result in increase SI values for any of the dependent measures. By itself, the trunk shift characteristic of arthritic gait has little effect on the magnitude of vertical forces or stance time. Force during mid-stance F_2 was not affected by any of the three commands and is probably more related to walking speed. Based on the results of the present study, feedback trials with individuals having unilateral joint arthritis will be undertaken in which the importance of achieving knee flexion early in stance and lower limb extension through terminal stance will be emphasized in the form of verbal cues with visual real-time force feedback.

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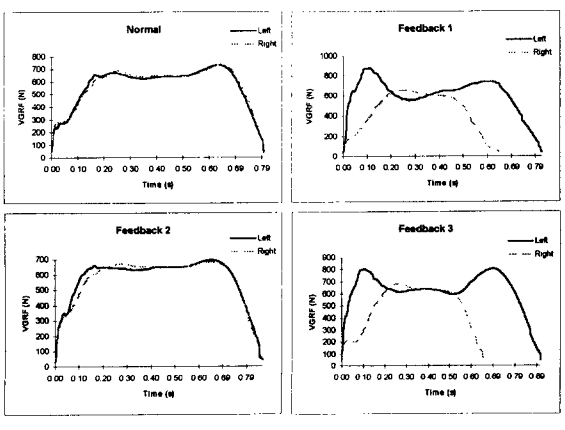

Figure 1: Vertical force curves for different feedback cues. One subject, four trials averaged in real-time mimicking right affected limb.

Relation of Vertical Ground Reaction Forces to Walking Speed

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Introduction

Vertical foot-ground reaction force (VGRF) curves are often used to analyze differences between normal and pathological gait (1,2). Since force is related to walking speed, speed effects must be accounted for when comparing differences. Little has been published relating VGRF to walking speed (3,4). To our knowledge, normal data with equations relating selected vertical force magnitudes and stance time to walking speed has not been established. This data would be useful for differentiating pathological changes from speed related changes in ground reaction force. In the present study, regression equations relating stance time and selected force magnitudes to walking speeds are reported.

Methodology

Twenty healthy college age subjects (10 males and 10 females) consented to volunteer for the study. Each subject walked at variable speeds from 1 mph (0.45 m/s) to 6 mph (2.7 m/s) on a treadmill housing two force plates (Kistler Instrument Corp.). A period of familiarization was followed by 20 s data collection trials at incremental speeds. VGRFs were A-D converted (500 Hz) and low-passed filtered (100 Hz). Six sequential steps were analyzed. Stance time (ST), peak load acceptance F_1, mid-stance F_2 and peak push-off (roll-off) F_3 forces were determined for each individual, averaged across strides, and normalized to body mass. Walking speeds were normalized by subject height. Regression analyses relating dependent measures to walking speed were determined for first through third order polynomials. An ANOR was used to test for statistical significance.

Results and Discussion

Magnitude of the three peak forces, and the stance time were significantly related to walking speed changes (Fig. 1). Variability estimates from correlation coefficients (R^2) and regression equations accompany figures. Stance time decreases non-linearly ($p<.001$) with walking speed. Peak forces during loading response F_1 increase with walking speed. All polynomials 1 through 3 were significant (<.001). An increase in F_1 represents increased demand on lower limb muscles as they work eccentrically to reverse downward momentum after initial foot contact. During mid-stance F_2 decreases linearly with increasing speed. In this phase the vertical lift to the center of gravity decelerates more at higher walking speed and reflects greater vertical oscillations of the subject's center of mass as they walk faster. F_3 did not increase with walking speed. A second order polynomial, concave down was significant ($p<.001$) but only 25% of the variability was explained by the regression equation. These are the first results showing vertical "push-up" force decreases at higher walking speeds. This finding may be peculiar to treadmill gait since others have shown that F_3 increases with faster gait overground (3,5). The present data suggests less active concentric work is done through "push-off" and a more passive "roll-off" occurs in treadmill gait.

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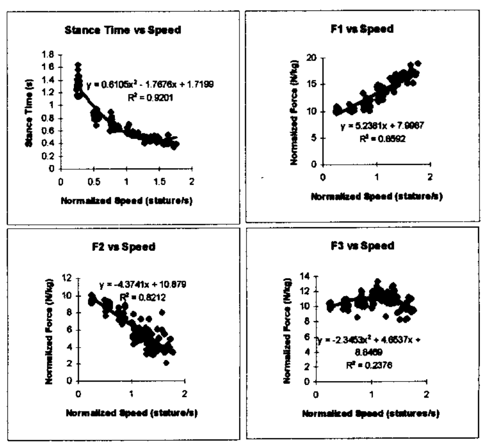

Figure 1: Regression equations for vertical ground reaction force measures as a function of walking speed.