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THE EFFECT OF LOAD ON MOVEMENT COORDINATION DURING SLED TOWING

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INTRODUCTION

Towing sleds while walking is a popular resistance exercise for the healthy athlete. One reason for the popularity of sled towing is that it is widely believed to be a 'functional' exercise. Preliminary research suggests towing while walking can increases lower extremity moment impulses; however whether towing a sled utilizes the same coordination patterns as un-resisted walking is unknown. While altered patterns may not be as relevant to a healthy athlete, sled towing is also sometimes used in the rehabilitation of athletes who sustained a lower extremity injury (anterior cruciate ligament rupture) with the goal of regaining movement symmetry. The addition of resistance to walking may induce a shift to a coordination patterns not consistent with normal gait and may not aid in the retraining of normal gait movement patterns.

Dynamic systems theory (DST) provides a framework for analyzing optimal coordination patterns and how patterns of functional movement are produced [1]. Segmental relations may be analyzed as a measurement of coordination and can be measured utilizing continuous relative phase angles (CRP). CRP uses a segment's angular position and angular velocity compressed into lower-order variables to assess coordination patterns and variability. Too much variation deteriorates the stability of the system and may lead to injury or undesired adaptations while too little does not allow for adaptation to perturbations [2]. Determining differences in attractor states can be done by assessing mean absolute continuous relative phase (MARP) while variability of movement can be measured by calculating deviation phase (DP), which is the mean standard deviation of the relative phase angle [3].

The goal of this study is to determine if towing sleds at two different loads (20 and 50% body weight (BW)) produce different lower extremity coordinative movement patterns and if those patterns are more or less variable than normal walking.

METHODS

13 healthy, uninjured subjects (9 males; 4 females), aged 21.0±1.9 years, were recruited for this study. Lower extremity motion during stance phase of gait was tracked using a cluster marker set.

Subjects completed 5 conditions: normal walking and sled towing with two loads (20 and 50% BW) with attachment at the waist and the shoulder. After walking, the order of towing conditions was randomized. For the purposes of this study only the attachment site at the waist was analyzed. Walking speed was set at 1.3 m/s for all conditions and was controlled using a Brower laser timing device [4]. Trials were collected bilaterally, but for this investigation only the dominant side was analyzed. Dominance was determined as the foot used to kick a ball; every subject was right limb dominant. Five stance phases of each condition were analyzed. Sleds were towed over an indoor rubber track (Super X, All Sports Enterprises). Kinematic data were collected with 8 Oqus Series-3 cameras (Qualisys AB, Gothenburg, Sweden) set at 60Hz. Visual 3D (C-motion, Germantown, MD) was used to apply a Butterworth filter with a cutoff of 6Hz to kinematic data.

Global sagittal segmental angles for the right foot, thigh, and shank were calculated in Visual3D, differentiated to obtain velocities, and both measures were normalized to stance. Phase plots were developed by plotting angular velocity verses angular position and phase angles were calculated according to the method of Stergiou et al [5]. Relative phase angles were then calculated between adjacent segments and MARP and DP were then calculated as described by Stergiou [3].

Two one-way ANOVAs with multiple comparisons (one for each segment pairing) were then performed using MATLAB 2011b (MathWorks, Natick, MA).

RESULTS AND DISCUSSION

MARP between the shank and thigh was significantly different ($p = 0.002$), with the 50% BW load being different than either normal walking or the 20% BW load. The difference in MARP indicates the movement pattern between the shank and thigh was altered when towing with the 50% BW load. MARP during normal walking and the 20% BW load were not significantly different. The DP was not significantly different for any comparisons, meaning there was not an increase or decrease in variability between loads, even when a new coordination pattern emerged. This study suggests that a large load (50% of BW) is required to alter inter-limb coordination patterns when the load is attached near the center of mass, such as attachment at the waist.

These results also suggest that the movement pattern between the shank and thigh is the first to be altered by the addition of resistance. Further investigations on the CRP of other movements is needed to determine if this pattern holds true for most movements or if movement pattern alteration is more specific upon load placement.

CONCLUSIONS

Towing sleds with a 20% BW load did not produce movement patterns that were different than normal walking. Therefore using a 20% BW load with a waist attachment may be an appropriate scenario to provide resistance to the lower limbs and still utilize a movement pattern consistent with normal walking.

Future studies should investigate differences seen using a finer load gradient to determine a more precise load threshold as well as between limbs comparisons. Future research should also investigate more dynamic resisted moments such as sprinting while towing sleds, towing a parachute, or wearing a weight vest to determine if a more dynamic movement is more easily changed to a different coordinative movement pattern. Although such movements have been previously investigated, conclusions were generally drawn using more traditional gait parameters, such as lower limb angles at specific gait events [6]. It may be that a high order analysis such as the comparison of continuous relative phase angles could provide more informative results.

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