EFFECTS OF TOWING A WEIGHTED SLED WITH DIFFERENT LOADS AND ATTACHMENT POINTS ON LOWER LIMB MOMENTS

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INTRODUCTION

The strength and conditioning community uses resisted running and walking to increase lower extremity strength while simulating an athletic task. Several different methods are used to add resistance to the body during gait, including parachutes and weighted clothing. Towing a sled is a popular method since the resistance can be readily altered and used for both running and walking. While positive adaptations to running while towing a sled have been observed [1-2], the lower-extremity kinetics of walking while towing a heavily weighted sled are unknown.

Sprinting while pulling a sled with relatively light weights [13-16% of body weight (BW)] may provide an adequate stimulus without compromising sprint mechanics [3], with 20% BW being the greatest load tested [4]. Whether walking while towing a sled at relatively light and heavy loads alters walking kinetics differently is of interest. The addition of a greater load would in theory produce similar benefits as progressing loads during resistance exercise, such as muscular recruitment and strength.

The two most common methods of attaching the sled to the person while walking are with straps held over the shoulder and with a belt or strap attached at the waist. It is conceivable that the placement of the sled attachment may alter resultant joint moments. A load that is much larger than optimal may completely alter mechanics[4]. However, the alterations in mechanics found in these studies may be due to the decrease in velocity which occurred at greater loads, not the loads themselves. Determining the magnitude of joint moment differences while pulling sleds of different weights while controlling for gait speed will eliminate the effects of gait velocity.

The purposes of this study are to determine how lower extremity biomechanics differ: 1) when different percentages of body weight are towed for each condition and 2) when the sled is attached at the waist compared to the shoulder. Peak knee flexion (PKF) was chosen as the time point of interest due to the aberrant joint moments seen at this time in subjects after anterior cruciate ligament rupture[5] and reconstruction[6].

Five conditions were compared: 20% body weight load (BWL) attached at the shoulder (S20); 50% BWL attached at the shoulder (S50); 20% BWL attached at the waist (W20); 50% BWL attached at the waist (W50); and normal walking (0%BWL due to no sled). We hypothesized that hip, knee, and ankle moments at PKF will be greater in the conditions with heavier loads than those with lighter loads. We also hypothesized that the hip moment at PKF will be greater during conditions in which the sled is attached at the shoulder than when attached to the waist.

METHODS

12 healthy, uninjured subjects (8 males; 4 females), aged 21.5±2.1 years, were recruited for this study. Lower extremity motion during stance phase of gait was tracked using a cluster marker set.

Subjects completed the 5 conditions: normal walking; S20; S50; W20; and W50. After walking, the order of towing conditions was randomized. Walking speed was set at 1.3 m/s for all conditions and was controlled using a Brower laser timing device [7]. 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 and the mean joint moments at PKF were calculated. Sleds were towed over an indoor rubber track (Super X, All Sports Enterprises). Kinematic data were collected with 8 Qualisys Oqus Series-3 cameras set at 60Hz and kinetic data were collected by two AMTI BP400600 force plates (Watertown, MA) at 2400Hz. Visual 3D (C-motion, Germantown, MD) was used to apply a Butterworth filter with a cutoff of 6Hz to kinematic data and analog data was filtered with a Butterworth filter with cutoff of 50Hz, as determined by retaining 95% of signal power through a fast Fourier transformation. Inverse dynamics were used to calculate external joint moments at the PKF angle during the stance phase of gait which were normalized to body mass.

A repeated measures ANOVA was used to answer the first hypothesis (joint moment differences against load) with post-hoc paired t-tests calculated if a significant difference was found. For the second hypothesis, paired t-tests were used to determine whether hip moments were greater at the shoulder vs. waist attachment. Statistical analysis was performed using SYSTAT 11 (SYSTAT, Chicago, IL) (alpha=0.05).

RESULTS AND DISCUSSION

Joint moments per condition are given in Table 1. Only knee flexion moments at the shoulder towing condition significantly increased as load increased. Knee flexion moments during waist towing showed a similar pattern with insignificant results.

Our second hypothesis was supported. Greater hip extension moments were found with attachment at the shoulder conditions for the light (S20 vs. W20: p<0.001) and heavy (S50 vs. W50: p<0.001) conditions.

Even though attachment at the shoulder produced a greater hip extension moment than attachment at the waist, normal walking produced a moment similar to the greatest moment produced by any sled condition. This is surprising as it was expected that greater moments would be required to counteract the heavier loads. Furthermore, moments at the hip and ankle decreased or remained the same as load increased when pulling a sled. It may be that gait is altered by sled towing to an extent that PKF is not a valid point of comparison. Through visual inspection of the data, the PKF instance appears to be occurring earlier in the stance phase when towing a sled. Therefore future studies should compare moment impulse or peak moments rather than moments at a specific kinematic point.

| Table 1: External Joint Moments (Nm/kg) at peak knee flexion angle |
|---------------------------|---------------------------|---------------------------|
| Hip ( Ext - )             | Knee ( Ext + )            | Ankle ( Plantar flexion - ) |
| Walk                      | -0.11 ± 0.05              | -0.03 ± 0.01               | -0.95 ± 0.19 |
| S20                       | -0.13 ± 0.07              | -0.05 ± 0.01*              | -0.74 ± 0.20* |
| S50                       | -0.07 ± 0.05*             | -0.07 ± 0.01*             | -0.88 ± 0.21* |
| W20                       | -0.05 ± 0.08*             | -0.03 ± 0.01              | -0.68 ± 0.18* |
| W50                       | 0.04 ± 0.05*              | -0.05 ± 0.01*             | -0.52 ± 0.14* |

* significantly different than walking condition
† significantly different than 20%BWL

REFERENCES