INTRODUCTION

Alterations in trunk flexion are associated with aging, spinal pathologies, and neuromuscular disorders [1]. For example, the pathology known as flatback causes a forward inclination of the trunk (referred to as positive sagittal spine balance) due to abnormal reductions in lumbar lordosis [2] and may induce crouch gait (i.e., excessive hip and knee flexion during stance) [3]. While these compensations may be necessary to maintain the body center-of-mass (COM) within the base of support [4] for upright balance, they place high demand on muscles and increase energy expenditure [5]. The unique joint configuration resulting from sustained trunk flexion and the increase in metabolic cost of crouch gait suggests changes in joint kinetics compared to normal posture.

Although the effect of varying levels of sustained trunk flexion on lower limb kinematics has been described [4], little is known of the effects on joint kinetics. Therefore, the purpose of this study was to investigate the effect of sustained trunk flexion on lower limb kinetics of able-bodied gait. We hypothesized that sustained trunk flexion and consequential adoption of crouch gait would increase hip extensor moments to support the trunk and reduce knee flexor moments resulting from sustained knee flexion. These results may serve as a model for developing insight into the joint kinetics and muscular demands of pathological populations that suffer from similar postural adaptations.

METHODS

Subjects without known musculoskeletal or neurological disorders were asked to walk at their self-selected normal walking speed under three trunk flexion conditions: 1) self-selected upright (UP), 2) 25 ± 7° trunk flexion (INT), and 3) 50 ± 7° trunk flexion (MAX). Participants were asked to bend from the hips to achieve their target trunk flexion as opposed to rounding at the lower or upper back. The Biofeedtrak feature in EVa RealTime software (Motion Analysis Corporation (MAC), Santa Rosa, CA) was used to provide auditory feedback to subjects while walking to assist them in maintaining the trunk flexion angle within the specified range during the INT and MAX conditions. The order of trunk flexion conditions was randomized to eliminate task order effects.

Retro-reflective markers were attached to subjects according to the Helen Hayes Marker Set [19], with an additional marker on the C7 spinous process. Sagittal plane trunk flexion was defined as the angle between the global vertical axis and a line connecting the sacral and C7 markers. Kinematic and kinetic data were collected with a digital motion capture system (MAC) at 120 Hz and six embedded forceplates (AMTI, Watertown, MA) at 960 Hz, respectively. Kinematic data were low-pass filtered with a 6 Hz cutoff frequency. Joint kinetics were estimated using inverse dynamics with OrthoTrak software (MAC). Joint work as an estimate of mechanical energy absorption or generation during stance was calculated by integrating joint power with respect to time. For each condition, data were averaged over at least three trials.

RESULTS AND DISCUSSION

Data were collected from 14 able-bodied subjects (7 male, 26±3 years, 174.2±9.9 cm, 72.3±12.1 kg). Trunk flexion resulted in noticeable changes in lower limb joint moments and powers (Figure 1). Increased trunk flexion systematically decreased the peak plantar flexor ankle moment, but
systematically increased the plantar flexor moment at 25% of the gait cycle. Most noticeably, increasing trunk flexion systematically decreased the magnitude of the knee flexor moment in terminal stance and caused it to occur earlier in gait; at 46%, 42%, and 32% of the gait cycle for UP, INT and MAX conditions, respectively. This was expected, as sustained knee flexion would theoretically require less flexor moment for active flexion during mid stance. Furthermore, as the ground reaction force would remain posterior to the knee joint longer in stance as knee flexion increases, earlier extensor moments would be necessary to maintain this posture. Peak extensor moment at the hip increased systematically with trunk flexion and this was expected as subjects were requested to produce sustained trunk flexion at the hip.

As seen in Table 1, progressive trunk flexion produced a systematic increase in energy absorption at the ankle joint, as well as increased energy generation and decreased absorption at the hip joint. No consistent changes were observed at the knee, however, this joint acted to produce a net energy generation throughout stance for all conditions.

![figure1](image.png)

**Figure 1:** Joint moments (a) and powers (b). Solid=UP; dashed=INT; dotted=MAX. Arrows denote moments of interest.

<table>
<thead>
<tr>
<th>Joint</th>
<th>Mean ± SD (J/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UP</td>
</tr>
<tr>
<td>Ankle</td>
<td>13.2 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>-19.2 ± 4.4</td>
</tr>
<tr>
<td>Knee</td>
<td>11.8 ± 3.6</td>
</tr>
<tr>
<td></td>
<td>-5.4 ± 2.5</td>
</tr>
<tr>
<td>Hip</td>
<td>11.5 ± 3.7</td>
</tr>
<tr>
<td></td>
<td>-9.2 ± 4.5</td>
</tr>
</tbody>
</table>

Importantly, whereas in normal posture (UP) hip moments transition into flexor toward the end of mid stance then gradually increase through terminal stance to aid in forward progression, sustained trunk flexion calls for increased and prolonged extensor moments to maintain this posture. Consequently, the mechanical energy generation demands on the hip increased systematically, suggesting a considerable increase in metabolic cost.

**CONCLUSIONS**

Walking with increasing trunk flexion places significant demand on the hip extensors to support the anteriorly displaced trunk COM and forces the knee joint to generate extensor moments earlier in stance. Importantly, the direct relationship between trunk flexion and energy absorption and generation at the ankle and hip joints, respectively, would suggest overall increased muscular demand during gait. These results support clinical observations that individuals with positive sagittal spine balance as a result of spinal pathology are susceptible to increased metabolic energy expenditure and premature muscular fatigue [6].

**REFERENCES**