THE INFLUENCES OF SHANK MASS AND INERTIA MANIPULATION ON SPRINT KINETICS

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The purpose of this study was to investigate the kinetics changes caused by the lower extremities mass and inertia, explore the mechanics of this training method and provide theoretical instruction for sprinting training. 18 male sprinters were recruited and required to sprint with different lower extremities loading conditions (0%, 10%, 15% of the shank mass). The data was collected using high speed infrared motion capture system and force plates. 15% of the shank mass loading made the joints torque and power decrease significantly, while the torque of knee significantly increased at the toe-off moment. In addition, the ankle absorbed more energy during the stance phase as well as the knee generated more energy during the swing phase. The result showed that changes of the joints torque and power attribute to the location of the loadings.

KEY WORDS: sprinting, kinetics, biomechanics, energy contribution

INTRODUCTION: In 2015, the 15th World Championship in Beijing, Chinese team has won the silver in male 100 meter × 4 relay, which was a big step in Chinese sprinting history. However, there are still large gaps between Chinese sprinters and world top sprinters in techniques and physical quality. Therefore, it is crucial to find out a better sprinting training method. Numerous methods have been advocated and employed by coaches to effectively develop athletes’ speed. Among so many different methods, the resisted sprint training modality of additional mass training has become more and more popular (Corn, 2003; Lockie, 2003). There are a number of research has already found that resisted sprinting training is an effective way to improve athletes’ speed (Hrysomallis, 2012; Engelen, 2013). However, research on resisted sprint training methods has mainly dealt with towing weighted sleds, weighted vests, and parachutes (Cross, 2014). Plus, most of the research on lower limb additional mass were about the energy consuming and other variables during walking (Lenoir, 2005). However, it is still unknown that how this training method will change the kinetics variables of lower limbs. To sum up, the purpose of this study was to examine the impact and effects of lower extremity mass and inertia manipulation on key lower extremity kinetic parameters of the sprint cycle and to examine the impact of shank added mass training on subsequent sprint performance.

METHODS: 18 young male sprinters, free of lower extremity musculoskeletal injuries for at least 6 months before the study, were recruited. Detailed descriptions of the subjects are given in Table 1. The sprinting trial took place on an indoor synthetic 60-m running track in the gymnasium. Vicon system (200Hz) and 3 Kistler force platforms (1000Hz) were used to collect the kinematic and kinetic data. The additional mass was a bag which was filled with tiny metal balls and can be adjusted (the additional loads were attached at the center of rotation of the shank, we ensured that the loads wouldn’t move before each trail). Subjects
were requested to sprint with the additional mass of 0%, 10% and 15% shank mass in sequence. The kinematic and kinetic data was smoothed with a 13 and 72 Hz low-pass filter separately. Using Visual3D to compute all the kinematic and kinetic data. The stance phase was stated from touchdown (TD) to toe-off (TO) of left foot. The swing phase was delimited from toe-off to touchdown. The joint energy contribution was computed using equation in Darren’s research (Darren, 1998). Using SPSS to conduct one way ANOVA with repeated measure to compare all the variables under different conditions. Significant differences were determined by a LSD post hoc test. Statistical significance was set at p < 0.05.

### Tab 1. Anthropometric characteristics of subjects (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>20.7±8.7</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>67.2±5.5</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.77±0.1</td>
</tr>
<tr>
<td>Best 100m performance (s)</td>
<td>10.9±0.3</td>
</tr>
</tbody>
</table>

### RESULTS: The COM speed decreased significantly with additional mass. The stride length and frequency significantly decreased under 10% shank mass condition. The stance time became longer and the difference was significant under 15% shank mass condition.

### Tab 2. Spatial temporal parameters of the subjects under three loading conditions

<table>
<thead>
<tr>
<th></th>
<th>0% shank mass</th>
<th>10% shank mass</th>
<th>15% shank mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM speed (m/s)</td>
<td>9.41±0.109bc</td>
<td>9.25±0.11a</td>
<td>9.19±0.12a</td>
</tr>
<tr>
<td>Stride length (m)</td>
<td>2.24±0.29b</td>
<td>2.23±0.23a</td>
<td>2.23±0.27</td>
</tr>
<tr>
<td>Stride frequency (Hz)</td>
<td>2.13±0.12b</td>
<td>2.08±0.10a</td>
<td>2.08±0.13</td>
</tr>
<tr>
<td>Stance time (s)</td>
<td>0.10±0.01c</td>
<td>0.11±0.01</td>
<td>0.11±0.01a</td>
</tr>
<tr>
<td>Swing time (s)</td>
<td>0.37±0.02</td>
<td>0.37±0.02</td>
<td>0.37±0.02</td>
</tr>
</tbody>
</table>

a, b, c stand for the variable under this condition has significant difference with it is under 0%, 10%, 15% shank mass condition separately. All the significance were 0.05 level.

### Table 3. Lower extremity kinetics variables of three loading conditions

<table>
<thead>
<tr>
<th></th>
<th>0% shank mass</th>
<th>10% shank mass</th>
<th>15% shank mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip torque at TD (Nm/kg)</td>
<td>-2.24±1.50</td>
<td>-2.45±1.37</td>
<td>-1.68±1.69</td>
</tr>
<tr>
<td>Max hip flexion torque (Nm/kg)</td>
<td>-5.45±1.03</td>
<td>-5.16±1.24</td>
<td>-5.36±1.01</td>
</tr>
<tr>
<td>Hip torque at TO (Nm/kg)</td>
<td>2.67±0.71c</td>
<td>2.49±0.59</td>
<td>2.37±0.62a</td>
</tr>
<tr>
<td>Max hip power (W/kg)</td>
<td>43.56±10.28c</td>
<td>41.59±8.46</td>
<td>39.15±9.52a</td>
</tr>
<tr>
<td>Knee torque at TO (Nm/kg)</td>
<td>-0.22±0.16bc</td>
<td>-0.28±0.16a</td>
<td>-0.29±0.15a</td>
</tr>
<tr>
<td>Max knee power (W/kg)</td>
<td>19.61±5.50</td>
<td>18.66±6.20</td>
<td>18.51±5.13</td>
</tr>
<tr>
<td>Ankle torque at TD (Nm/kg)</td>
<td>-1.55±1.01bc</td>
<td>-0.87±0.69a</td>
<td>-1.15±1.03a</td>
</tr>
<tr>
<td>Max ankle power (W/kg)</td>
<td>25.59±5.84</td>
<td>26.84±6.70c</td>
<td>25.01±6.67b</td>
</tr>
</tbody>
</table>

Ankle torque at TD decreased significantly with additional mass. Meanwhile, Hip torque at TO decreased significantly with additional mass. As for the power variables, max hip power decreased under 15% condition, the max ankle power was decreased under 15% condition. At the stance phase (Fig 1.), energy absorbed contribution in hip decreased significantly as a result of shank additional mass, while it increased in ankle; as for the generated contribution, it decreased as the shank mass increased initially and increased a little bit afterwards, but in general, it decreased. At swing phase (Fig 2.), the energy generated contribution of hip and
knee changed significantly. Both of them increased significantly as the shank mass increased.

![Energy Absorbed and Generated Contribution](image1)

**Fig 1. Stance phase relative energy absorbed and generated contribution under three loading conditions**

![Energy Absorbed and Generated Contribution](image2)

**Fig 2. Swing phase relative energy absorbed and generated contribution under three loading conditions**

**DISCUSSION:** The results of this study showed that the stride length, frequency and speed decreased when the load is added to sprinters’ shank (Tab. 2). The COM speed has significantly decreased as the shank mass increased, which was a result of the decrease of stride length and the increase of stance time. As far as we know, no other published studies in the field of added mass training have sought to examine the impact and effects of such a load configuration on sprint kinetics. In addition, we computed the joint energy contribution to the energy changes of this method. The kinetic results showed that, the ankle torque at TD, the hip torque at TO and the max hip power have decreased significantly (Tab 3), which might be related to the decrease of COM speed. It is similar to the finding in Li’s study (Xiaolin, 2014). The knee flexion torque at TO has increased as the shank mass increased. Apparently, that was to deal with the additional mass of the shank and tried to flex the knee as normal at initial swing phase. The joint energy contribution provided us the location and ratio of the energy absorbed and generated (Myer, 2007). It can
suggest the muscle strength demand around one joint in one specific training method, and the
biggest one would be the target muscle of this training method (Flanagan, 2006). The joint
energy contribution results suggested that the biggest change of lower limb at stance phase
was ankle. The contribution of ankle (stance phase) and knee (swing phase) increased as the
shank mass increased, which suggested the additional shank mass training can improve the
knee strength at swing phase and the ankle strength at stance phase. It is obvious that it was
the location of the additional mass leads to these results. If we changed the location of the
loading, different kinetic effects might happen.

CONCLUSION: The result of our study would suggest that 15% shank mass loading made
the lower limb joints torque and power decreased significantly, while the knee torque at toe-
off moment increased. The energy generated at knee during swing phase and at ankle during
stance phase got increased. These kinetic changes were related to the location of the added
loading, different loading location might change the torque and power of different joints as
well as the training targets. This training method concentrated more on the sprint-specific
muscle strength comparing with other resisted training method. But based on the results of
our study, change of loading location might result in different training effects. Thus, coaches
and athletes need to decide the loading location according to their training purposes.

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