Kinematic Contribution of the Trunk to Vertical Barbell Displacement in Back Squat

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Summary

The majority of biomechanics studies of the back squat modeled the human trunk as a single rigid-body segment, ignoring its joint mobility. This study used a trunk model with six rigid-body segments and quantitatively compared spine movements during the back squat with varying load weights. In addition, the percentage contribution of each joint movement to the barbell between different load conditions was also calculated.

Introduction

The squat is recognized as a fundamental exercise for strength training of the lower limbs [1]. Research focusing on the trunk during squats has become increasingly active in recent years [2, 3, 4, 5]. As the load increases, thoracolumbar rounding occurs [5]; however, its contribution to vertical displacement during the ascent phase remains unclear. The present study aims to quantify the percentage contribution of individual segments to vertical barbell displacement as thoracolumbar rounding increases with load weights.

Methods

Eleven healthy young males participated in this study, performing back squats with varying load weights (60, 70, 80, 90%1RM: one repetition maximum). A three-dimensional optical motion capture system (VICON MX) with 12 cameras was utilized for the experiment. Twenty-seven reflective markers were attached to landmarks on the participants' bodies; six markers were located on the tips of specific spinous processes, thus creating a two-dimensional trunk model with six rigid body segments in the sagittal plane. The percentage contribution of each joint movement to the barbell velocity was calculated and compared between different load conditions. A one-way repeated measure analysis of variance (ANOVA) was performed to detect differences in the kinematic contributions due to differences in load weight. Bonferroni's multiple comparison analyses were employed to measure differences in the kinematic contributions between load weights.

Results and Discussion

The results of the kinematic contribution of the trunk and lower limb is shown in Figure 1. For the positive contribution, significant differences were observed in the pelvis ($P<0.01$), L3 ($P<0.01$), and T12 ($P<0.01$). Subsequent post-hoc tests showed that the pelvis contributed significantly more at 90%1RM than at 60%1RM and 70%1RM ($P<0.05$). However, L3 and T12 showed smaller contributions at higher loads ($P<0.05$). No significant differences were found in other segments. For the negative contribution, significant differences were observed in S1 ($P<0.05$), L3 ($P<0.01$), T12 ($P<0.01$), and T6 ($P<0.05$). S1 contributed more at 90%1RM than at 70%1RM ($P<0.05$), while L3, T12, and T6 showed greater contributions at higher loads ($P<0.05$). No significant differences were found in other segments.

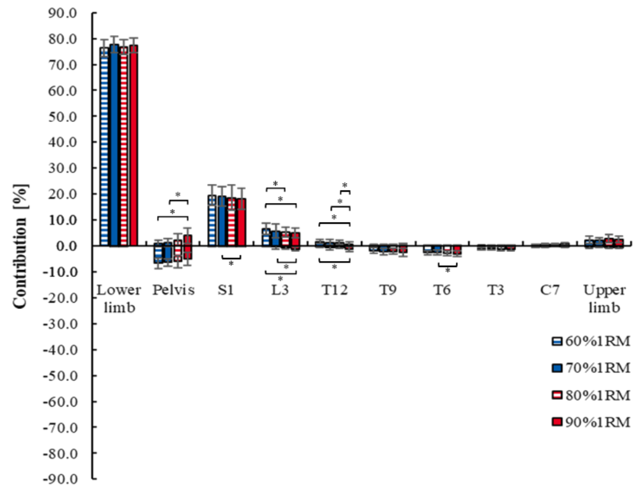

Figure 1 Kinematics contribution of the trunk.

The results indicate that the kinematic contribution of the lower limbs remains constant with increasing load weight while the pelvis increases and the upper lumbar spine (T12 and L3) decreases. These findings suggest that the lifting strategy varies depending on the load used.

Conclusions

Concerning the kinematic contribution of the trunk to vertical barbell displacement in the back squat, the following conclusions can be drawn: first, the shaft displacement distance gained at the pelvis increases with increasing load, while it decreases at the lower back; and second, the lifting strategy may differ depending on the weight used.

References

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