Joint moments have greater impact on vertical jump height than joint angular velocities

Marvin Zedler[1,2], Jan-Peter Goldmann[1,2]
[1]Institute of Biomechanics, German Sport University Cologne, Cologne, Germany
[2]German Research Centre of Elite Sport Cologne, German Sport University Cologne, Cologne, Germany
Email: m.zedler@dshs-koeln.de

Summary

The differences in joint moments and joint angular velocities between good and poor performers of the countermovement jump (CMJ) were investigated ex-post-facto. Good performers showed sig. higher joint moments and joint angular velocities at the hip, knee, and ankle joint than poor performers (except for hip angular velocity). Since the effect sizes were greater in favor of joint moments, the authors suggest that it is more crucial to provoke high joint moments in athletic training rather than high angular velocities to improve the performance of ballistic movements such as the vertical jump.

Introduction

The ability to maximally accelerate one's body from rest or after a preceding countermovement is a critical limitation in athletic performance (e.g. vertical jumping). To accelerate the body's COM during a vertical jump, the hip, knee, and ankle joint must generate a high mechanical power. Since joint mechanical power is the product of joint moment and joint angular velocity, a given power output can be achieved by different relative contributions of those two components. Good performers of the vertical jump show higher mechanical power at the hip, knee, and ankle joint than poor performers [1]. Moreover, it is valuable knowledge for athletic coaches if there are differences in the joint moments and joint angular velocities between good and poor performers.

Methods

An ex-post-facto-experiment has been applied to the database of the German Research Centre of Elite Sport Cologne, which encompasses vertical jump performance diagnostics of young athletes in North-Rhine-Westphalia (10 infrared cameras, 120 Hz, Vicon Motion Systems, Oxford, UK; 2 force plates, 1080 Hz, Kistler Winterthur, Suisse; inverse two-dimensional model Alaska Dynamicus, Alaska, Chemnitz, Germany). For the analysis, the database was sorted by countermovement jump height resulting in a group of *good* (0.35 - 0.40 m jump height, n = 52, male, 17.4 ± 3.5 yrs., 70.2 ± 12 kg) and a group of *poor* (0.20 – 0.25 m jump height, n = 52, male, 14.4 ± 1.4 yrs., 60.0 ± 11.7 kg) performers. The group differences in the time series of hip, knee, and ankle joint moments and angular velocities were investigated by using statistical parametric mapping.

Results and Discussion

During the negative phase of the CMJ there is no difference in the angular velocities between *poor* and *good*, whereas during the positive phase, the *good* group shows sig. greater peak angular velocities at the knee (105.1 ± 12.3°/s, $p < 0.001$) and ankle joint (99.4 ± 14.9 °/s, $p < 0.01$) than the *poor* group (93.3 ± 13.6 °/s, 87.3 ± 17.6 °/s). Regarding the external joint flexion moments, a sig. difference between the two groups was found for all joints. The joint moments of the *good* group were sig. higher at the hip (1.9 ± 0.4 Nm/kg vs. 1.4 ± 0.3 Nm/kg, $p < 0.001$), knee (1.1 ± 0.2 Nm/kg vs. 0.9 ± 0.2 Nm/kg, $p < 0.001$) and ankle joint (1.5 ± 0.2 Nm/kg vs. 1.2 ± 0.1 Nm/kg, $p < 0.001$) than those of the *poor* group. Additionally, the effect sizes of the differences in joint moments were larger than the effect sizes of the differences in angular velocities (hip: d = 1.7 (0.3), knee: d = 1.0 (0.8), ankle: d = 2.1 (0.7)), which indicates that the ability to generate higher joint moments might be more crucial in the performance of vertically directed ballistic movements than joint angular velocities.

Table 1: Peak joint moments and angular velocities at the hip, knee and ankle joint during maximal CMJ (* sig. difference to low).

	Joint Moment [Nm/kg]		Angular Velocity [°/s]	
	poor	*good*	*poor*	*good*
Hip	1.4 ± 0.3	1.9 ± 0.4***	44.7 ± 8.8	47.3 ± 7.5
Knee	0.9 ± 0.2	1.1 ± 0.2***	93.3 ± 13.6	105.1 ± 12.3***
Ankle	1.2 ± 0.1	1.5 ± 0.2***	87.3 ± 17.6	99.4 ± 14.9**

The difference in hip moments was present for the longest time during the jump phase (58-94 %), which confirms the importance of this joint also found by [2]. Interestingly, the higher hip moments did not lead to a significant increase in hip angular velocity, which implies a proximal to distal energy transfer through biarticular muscles [3].

Conclusions

Theses findings suggest that athletic training should focus on provoking high joint moments rather than high angular velocities to improve vertical jump height.

References

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