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PLYOMETRIC WEIGHT TRAINING CAN INCREASE HIP AND ANKLE JOINT STRENTH SIGNIFICANTLY

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The purposes of this study were to (1) investigate the changes in muscle strength and power at each joint of lower extremity, kinetics and stiffness of hip, knee, and ankle joints during counter-movement jump with different weights before and after plyometric weight training (PWT); (2) compare each of the joint contributions during plyometric exercises with different weights. Sixteen basketball players were asked to perform the PWT, i.e. 3 groups continued CMJ with the weight of 30% 1RM for 8-weeks with incremental-loads. Before and after the 8-week training program, kinematics and kinetics of the lower-limb were collected during CMJ performance. Joint moment, joint power, joint stiffness, and joint contirbution were then determined. The results indicated that an 8-week plyometric weight training program could significantly increase jump height, peak GRFv, and power output. The results also revealed that muscle strength and power of hip were dominantly developed during PWT and the enhanced kinetics (moment and stiffness) of hip turned out to be a major factor responsible for the improved jump performance.

KEY WORDS: plyometric weight training, joint kinetics, joint contribution, vertical jump.

INTRODUCTION:

Plyometric weight training (PWT) combining the advantage of weight training and plyometric training can significantly increase the strength and power of lower extremity which are vital for performance of running and jumping in athletics. The movements of running, jumping and throwing are ballistic and commonly multi-joint exercises, which involve a process of stretch-shortening cycle (SSC). Relative contributions of each joint reflected the distribution of mechanical demand differently across the joints of the lower extremity during jump movements (Flanagan et al. 2006).

Plyometric weight training (PWT) was often used as a functional training program in jump events. Currently, much of the work on the relationship between PWT and performance has mainly focused on evaluating the change of strength and power production, but has not further evaluated why this change occurs and where (at which joint) this change occurs. Meanwhile, there is still a lack of normative reference data in research of the role of joint dynamics related to PWT (Jing, et al. 2010).

Based on the above observations, the purposes of this study were to (1) investigate the changes in muscle strength and power at each joint of lower extremity, kinetics and stiffness of hip, knee, and ankle joints during counter-movement jump (CMJ) with different weights before and after PWT; (2) compare each of the joint contributions during plyometric exercises with different weights.

METHODS:

Subjects: Sixteen basketball players (age: 17.3±1.0 yrs, height: 192.3±5.2 cm, weight: 89.9±8.8 kg, years played: 5 yrs above) were served as subject.

Experimental Protocol and Instruments: All subjects were asked to perform the PWT, i.e. 3 groups continued CMJ with the weight of 30% 1RM for 8-weeks with incremental-loads (Dugan, et al. 2004). The subjects performed plyometric exercise (3 trials of counter-movement jump) with 0%, 10%, 20%, 30%, 40%, 50%, and 60% 1RM weights determined by squat jump. Before and after an 8-week training program, CMJ performance of each player was also tested by using the motion analysis system and the force plate for collecting kinematics and kinetics data. A VICON motion analysis system (120Hz) and a force plate (Kistler, 1200Hz) were used to collect kinematics and kinetics data simultaneously.

Inverse Dynamics: Inverse dynamics technique was utilized to calculate the net joint moment (NJM) at hip, knee, and ankle, respectively. Joint stiffness (k_{joint}) was defined as the change in joint moment divided by the change in joint angle. The joint contribution (JC) was determined from NJM with the following equation: JC = (average NJM) / (average support moment). Where the average support moment is the sum of average NJM across all three joints.
Data analysis: Other main variables discussed in this study for performance were jump height, peak vertical GRF, and peak power, while for lower extremity's kinetics were peak joint moment, peak joint power, joint work, and joint stiffness.
Statistics: A one-way ANOVA was used to determine the differences between various weights. Tukey's HAD tests were performed to analyze the differences between three joints. Paired t-test was used to determine the differences between pre- and post-test. The level for significance was set at $\alpha=0.05$.

RESULTS AND DISCUSSION:

The jump height, peak vertical GRF, and peak power in the post-test condition were significant greater than those in the pre-test ($p < 0.05$, Table 1).

Table 1: Strength performance between pre- and post- PWT during CMJ. Values are mean±SD.

PWT Program	Jump Height (m)	Peak GRFv (BW)	Peak Power (W/kg)
Pre-	0.45±0.02	2.24±0.63	49.15±7.22
Post-	0.53±0.02*	2.73±0.79*	53.32±8.60*

* indicate a significant difference compared with pre- condition, p<0.05 (the same below).

The 8-week plyometric weight training program also significantly improved peak joint moments, peak power and work for both hip and ankle joints ($p < 0.05$, Table 2).

Table 2: Peak moment, peak power and work for three joints between pre- and post- PWT during CMJ.

PWT	Peak Moment (N·m/kg)			Peak Power (W/kg)			Work (J/kg)		
	Hip	Knee	Ankle	Hip	Knee	Ankle	Hip	Knee	Ankle
Pre-	1.6±1.0	2.0±0.6	1.3±0.9	1.3±0.9	13.0±0.7	11.6±3.1	1.3±0.9	2.5±0.1	1.1±1.0
Post-	2.3±1.0*	2.0±0.7	1.9±0.7*	1.9±0.7*	12.5±1.0	14.6±2.3*	1.9±0.7*	2.2±0.8	1.5±0.7*

However, there were no changes in peak joint moments, peak power, and work of knee. The joint moment and power time curves from beginning of movement (t=0) to take-off (t=100) during CMJ were showed in Figure 1 and 2. There was an evident increase of moment and power for hip and ankle in the post-test condition but with no changes found at knee.

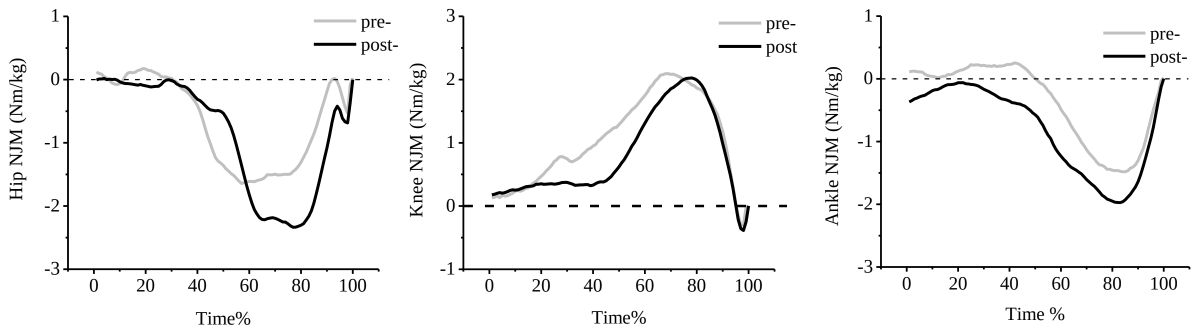

Figure 1: Comparison of pre- and post- 30% PWT on net joint moment during CMJ.

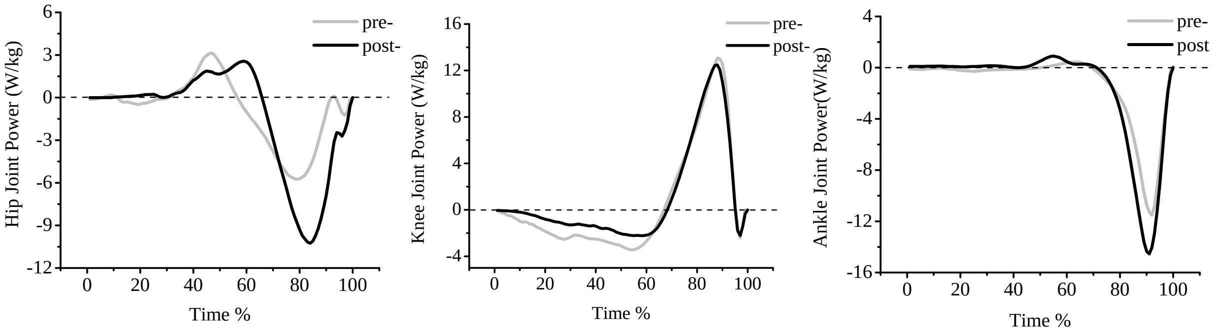

Figure 2: Comparison of pre- and post- 30% PWT on joint power during CMJ.

Similarly, the joint stiffness of hip and ankle in the post-test were significantly higher than that in the pre-test ($p < 0.05$, Figure 3). However, no significant differences were observed in the joint stiffness of knee between pre- and post conditions.

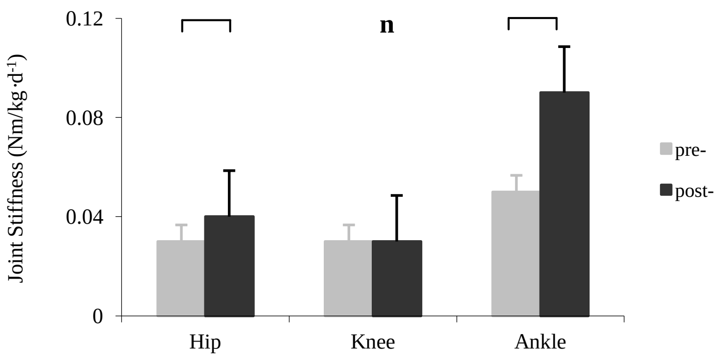

Figure 3: Comparison of pre- and post- 30% of 1RM PWT on joint stiffness during CMJ.

Why the plyometric weight training can significantly improve joint moment and joint power at both hip and ankle but not at knee? This could be explained by the parameter of joint contribution (JC). Under the condition of zero loads, knee joint was the dominant contributor (order: knee, hip, and ankle). During plyometric exercise with the increase of weights, the contribution of hip increased and became dominant (Figure 4, order: hip, ankle, and knee).

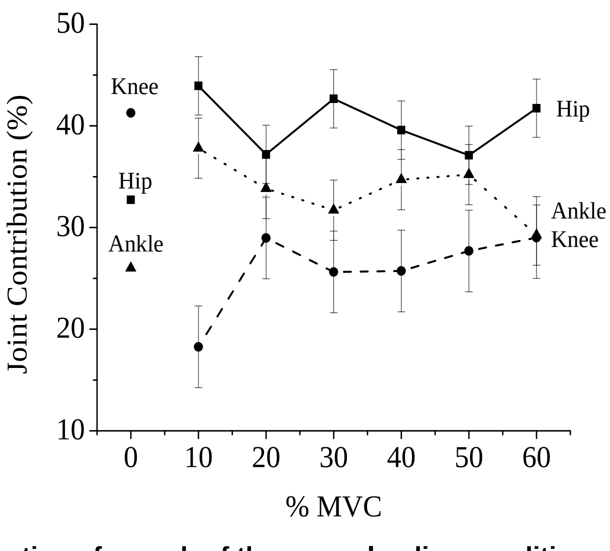

Figure 4: Joint contributions for each of the seven loading conditions during weighted CMJ.

Compare to hip joint, knee is weaker in terms of joint muscle strength. In order to avoid huge load on knee joint with increased weight, the posture of human body during plyometric weight training was regulated by putting the hip backwards, so that the vertical projection of weight passed nearby the knee joint and the load on hip joint muscle, or the demand on hip joint was increased. These may explain why the training effects of PWT on the kinetics of hip joint (also ankle) are significantly improved, but not on knee kinetics.

CONCLUSIONS:

The results indicated that an 8-week plyometric weight training program could significantly increase jump height, peak GRFv, and power output. The results also revealed that muscle strength and power of hip were dominantly developed during PWT and the enhanced kinetics (moment and stiffness) of hip turned out to be a major factor responsible for the improved jump performance.

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