Biomechanical Characteristics and EMG Activities of Weighted Countermovement Jump

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The purpose of this study was to investigate the biomechanical characteristics and EMG activities during a weighted countermovement jump (WCMJ) with 0%, 25% and 50% of body weight. Eight male college students participated this study. An AMTI force platform, Penny&Giles goniometer and Biovision EMG system were used synchronously to record the related parameters while subjects performed WCMJs. The results indicate that by increasing load, the eccentric mean force, the maximum force and concentric impulse increases significantly. With the load increase, the EMG activities of soleus and gastrocnemius did not changed significantly, while the eccentric mean EMG amplitude of rectus femoris got greater. This reveals that WCMJ has a marked influence on the lower extremity, especially on the rectus femoris.

KEY WORDS: Biomechanics, EMG, weight training, plyometrics, counter-movement jump.

INTRODUCTION: Strength and power training have been the primary topics concerned by many coaches and athletes, while they are critical foundation toward success. There are many methods to increase strength and power, such as traditional weight training and plyometric training. However, many studies have revealed that weight training (WT) can promote the development of maximum strength, but is insufficient to change the dynamic performance (Rutherford, Grig, Sargent & Johns, 1986; Bloomfield, Blanksby, Ackland & Allison, 1990; Fry & Kraemer, 1991). Meanwhile, plyometric training (PT) can effectively improve power, but is limited to develop maximum strength (Tsai, 1998). This study aims to combine the advantages of WT and PT, creating the development of plyometric weight training (PWT), which uses additional weights during PT. Weighted counter-movement jump (WCMJ) is one training style of PWT. The advantages of WCMJ are measured by biomechanical parameters and EMG activities. Furthermore, the purpose of this study was to investigate the characteristics of biomechanics and EMG activities during WCMJ using differing loads (CMJ with extra weight at 0%, 25% and 50% of body weight).

METHOD: Eight male college students voluntarily were participated this study. They can perform squat movement over 2.5 times of their body weight. The AMTI force platform, Penny&Giles electrogoniometer and Biovision EMG system were used synchronously to record the ground reaction force, knee angular displacement and the EMG activities of Rectus Femoris, Gastrocnemius lateral head and Soleus, respectively. All subjects stood on the force platform and performed CMJs with extra weighted barbells at 0%, 25% and 50% of their body weight, respectively. (Figure 1).

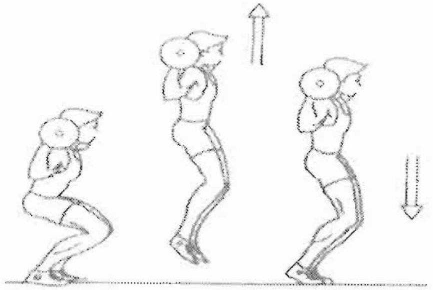

Figure 1: The experimental movement of Weighted Countermovement Jump.

The CMJ movement was divided into the eccentric and concentric phases, to achieve the related parameters. The standardized eccentric and concentric mean EMG was acquired by the eccentric and concentric mean EMG divided by the mean EMG of the Squat Jump, before takeoff 300 milliseconds. Differences among three groups were tested using one-way ANOVA.

RESULTS & DISCUSSION:

1) Biomechanical parameters.
The related parameters of biomechanics are shown in Table 1.

Table 1 One-way ANOVA statistics registering of biomechanical parameters during WCMJ.

Load	0%BW	25%BW	50%BW	F
Parameters	Mean±SD	Mean±SD	Mean±SD	
1. Eccentric time	0.681±0.151	0.687±0.113	0.751±0.190	0.06
2. Concentric time	0.336±0.024	0.401±0.023	0.409±0.041	1.73
3. Flight time	0.456±0.024	0.365±0.032	0.303±0.032	6.77**
4. Eccentric angular velocity	128.38±21.80	128.21±12.80	114.35±15.79	0.22
5. Concentric angular velocity	233.51±30.11	202.38±19.76	189.22±19.81	0.92
6. Eccentric mean force	0.974±0.034	1.182±0.158	1.486±0.034	7.29**
7. Concentric mean force	1.168±0.041	1.878±0.196	2.030±0.107	1.92
8. Maximum force	2.274±0.082	2.454±0.105	2.685±0.130	3.68*
9. Concentric impulse	5.474±0.292	7.377±0.758	9.123±0.699	8.70**
10. Peak power	44.91±5.422	46.34±3.952	44.93±6.971	0.02

*$p<0.05$, **$p<0.01$

Units: 1-3: ms, 4-5: deg/s, 6-8: N/body weight (bw). 9: N.s/bw. 10: watt/bw

Table 2 The Bonferroni post-comparison of kinetic parameters during WCMJ.

Parameters	Flight time	Eccentric mean force	Maximum force	Concentric impulse
0%BW	A	A	A	A
25%BW	B	B	B	B
50%BW	C	C	C	C

Same letter represents there is no significant difference between two groups.

According to table 1 and table 2, the eccentric mean force, the maximum force and concentric impulse augment significantly by increasing weight load. This conveys that WCMJ has a marked influence on the lower extremity, helping to increase strength development. However, they do not lead to improve the performance of flight time, resulting from the deceleration of angular velocity. Therefore, consideration of movement speed (a decisive factor of performance, especially in this case) is necessary during the increase of weight load, to acquire increasing concentric force and peak power.

The peak power does not change significantly with additional weight load, but the value of power initially augments then eventually diminishes. It demonstrates the various weight loads' effect on power output, as power is the function of force and velocity. Without an additional weight load, movement speed is increased while strength output is decreased, and vice versa. Bloomfield et al.(1994) substantiates that the peak power performance occurs during 30~40% of the maximum movement speed. Therefore, failure to achieve optimum power output occurs with reduced movement speed. Fleck & Kraemer (1997) indicates that the achievement of optimum power occurs during the simultaneous increase of strength and movement speed. Power development is limited when merely emphasizing the increase of strength. This displays the functional relationship between force and velocity. In order to effectively improve power, it is best to choose an appropriate weight load and focusing in the development of maximum movement speed.

2) EMG parameters. The parameters of EMG are shown in Table 3:

Table 3 One-way ANOVA statistics of EMGs parameters during WCMJ.

Load	0%BW	25%BW	50%BW	F
EMG parameters	Mean±SD	Mean±SD	Mean±SD	
The standardized eccentric mean EMG:				
1. Rectus Femoris	0.277±0.116	0.339±0.099	0.784±0.203	3.56*
2. Gastrocnemius	0.144±0.070	0.154±0.090	0.187±0.105	0.06
3. Soleus	0.254±0.132	0.226±0.076	0.296±0.100	0.11
The standardized concentric mean EMG:				
1. Rectus Femoris	1.014±0.127	1.013±0.229	0.957±0.279	0.02
2. Gastrocnemius	0.968±0.075	0.829±0.141	0.860±0.197	0.25
3. Soleus	0.900±0.113	0.920±0.141	0.961±0.154	0.05

* $p<0.05$ ** $p<0.01$

Table 4 The Bonferroni post-comparison of the standardized eccentric mean EMG of Rectus Femoris.

Load	BSD Group
0%BW	A
25%BW	A
50%BW	B

During the eccentric phase, the mean EMG amplitude of Soleus and Gastrocnemius, excepting Rectus Femoris, did not differ significantly with a weight load increase. This conveys the obvious effects on the neuromuscular innervation of Rectus Femoris. During eccentric phase, the knee extensors of the thigh was emphasized more than the ankle extensors of the lower leg,.

During the concentric phase, the mean EMG amplitude of Soleus, Gastrocnemius and Rectus Femoris did not differ significantly. This was perhaps due to decreasing angular velocity with increased weight load. Fleck & Kraemer (1997) demonstrated that the level of EMG relates to load intensity, which is comprised of weight load and movement speed. Consequently, the concentric phase's EMG was stable during the simultaneous weight load increase and angular velocity decrease.

Besides, the eccentric mean EMG amplitude was obviously less than the concentric EMGs in this study, which parallels with Komi. (1992). He indicates that the EMG amplitude of concentric contraction is more intense than the eccentric contraction during certain muscle tension.

CONCLUSIONS & SUGGESTIONS: The eccentric mean force, maximum force, concentric impulse and the eccentric mean EMG on rectus femoris increase significantly by increasing weight load. This concludes that WCMJ has a marked influence on the lower extremity. However, movement speed is the decisive factor on jump performance. Therefore, it's necessary to emphasize on improve movement speed during the increase of weight load, to acquire increasing concentric force and peak power.

To effectively develop power, training must use the best combination of weight load and movement speed. Potentially, barbell implementation causes reduction of movement speed due to muscular self-protection. Furthermore, worry at barbell release eliminates power output potential during WCMJ. Thus, training apparatus utilizing hydraulic transmission with fixed track is more suitable. By preventing a premature barbell release, a risk of injury is avoided and power output is inspired. Further study suggests usage of the maximal strength with squat percentage, not the body weight percentage, as the extra load during WCMJ.

REFERENCES:

Bloomfield, J.; Ackland, T.R.; Elliott, B.C. (1994). Applied Anatomy and Biomechanics in Sport. pp.110~208. Blackwell Scientific Publications.

Bloodfield, J., Blanksby, B., Ackland,T., & Allison, G. (1990). The influence of strength training on overhand throwing velocity of elite water polo player. Australian Journal of Science and Medicine in Sport. 22, 63-67.

Komi, P. V. (1992). Stretch-Shortening Cycle. In P. V. Komi (eds.): Strength and Power in Sport, pp230-238. Oxford: Blackwell Scientific Publications.

Fleck, S. J., & Kraemer, W. J. (1997). Designing Resistance Training Programs (2nd ed). Champaign, IL: Human Kinetics.

Fry, A.C.; & Kraemer W.J.(1991). Physical performance characteristics of American collegiate football players. The Journal of Applied Sport Science Research, 5, 126-138.

Rutherford, O., Greig, C., Sargent, A. & Jones, D. (1986). Strength training and power output: Transference effects in the human Quadriceps muscle. Journal of Sport Science, 4, 101-107.

Tsai, F. J. (1998). The Study of Quantitative Control during Plyometrics. Unpublished master's thesis. Chinese Culture University, Taipei.

Wilson, G., Newton, R., Murphy, A. & Humphries, B. (1993). The optimal training load for the development of dynamic athletic performance. Medicine and Science in Sports and Exercise, 25, 1279-1286.