THE EFFECTS OF EXTERNAL LOAD ON LOWER EXTREMITY ELECTROMYOGRAPHY AMPLITUDE DURING COUNTERMOVEMENT JUMP

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The purpose of this study was to investigate the effects of different loads on the mean electromyography (EMG) amplitude of the gluteus maximus, biceps femoris, vastus medialis, gastrocnemius, soleus, and tibialis anterior during the deceleration phase and the acceleration phase of the countermovement jumps (CMJ). Ten male physical education students performed different CMJs with and without an external load (0, 2.5, 5.0, 7.5, or 10.0 kg hold in arms). The results showed the amplitude of the gluteus maximus with load of 7.5 kg was higher than with load of 2.5 kg during the deceleration phase ($p < .05$), and the amplitude of the soleus with load of 10.0 kg was higher than with load of 2.5 kg during the acceleration phase ($p < .05$). It indicated that the activities of lower limb muscles were not influenced by the relative lower of external loading during CMJ.

KEY WORDS: vertical jump, stretch shortening cycle, EMG

INTRODUCTION: It is generally daily work to load the extra weight to movement, for example, the student carrying the school bag to go to school, the construction worker carrying heavy loads to walk, or the fireman or the marine bearing the equipment to execute task. Therefore, it is an important issue that necessary to investigate the behavior of loading activities. The past studies that concerned with the analysis of external load in cycling, running upstairs, vertical jump, or squat jump, these indicated the power output increased with external loading (Buttelli et al., 1996; Caiozzo & Kyle, 1980). Driss, Vandewalle, Quievre, Miller and Monod (2001) studied the effects of external loading on the squat jump, and indicated the peak power was increased and the velocity was decreased with external loading at the peak instantaneous power.

In order to understand the muscle activation of squat jump that was seen as the pure form of concentric action under the condition of various external loads, Giroux, Guilhem, Couturier, and Rabita (2015) analyzed the EMG activity of lower limb muscles and power output in the loading conditions of 0 to 60% of maximal repetition squat during ballistic squat jumps. They found the amplitude of muscle activity and the sequence of muscle action were not affected by loading condition during squat jump. However, in addition to the forms of concentric, eccentric, or isometric actions, there is also the form of stretch shortening cycle (SSC) that combination of the concentric action following the eccentric action. The mechanism of countermovement that muscle to perform shortening following lengthening action is a kind of the natural pattern. Pazin, Berjan, Nedeljkovic, Markovic and Jaric (2013) used a pulley system to reduce or increase the body weight by 10-30% to an individual. They found the individual optimum load for the peak power output did not differ among the groups of various activity profiles. It has become the topic of concern in this study that the change of EMG amplitude with the increased external load. The aim of this study was to determine the effects of external loading on the EMG amplitude during deceleration phase and the acceleration phase of CMJs.

METHODS: Ten male physical education students (age = 23.0 ± 3.1 y; height = 172.2 ± 6.8 cm; body mass = 74.2 ± 8.2 kg) performed different CMJs with and without an external load (0, 2.5, 5.0, 7.5, or 10.0 kg held in arms) randomly. The external loads consisted of flat steel weights of 2.5, 5.0, and 10.0 kg. The participants jumped with arms cross on chest with or without external loads. They performed three CMJs at each load, and the best jump of each load was used to analysis the EMG amplitude.

A Kistler force plate (9260AA6, 1500 Hz), a Noraxon TeleMyo DTS EMG system (1500 Hz), and a Noraxon MyoMotion system (200 Hz) were synchronized to acquire the ground reaction force, EMG activities, and kinematical data during CMJ respectively. Surface EMG activity was recorded during CMJs with Noraxon wireless sensors from 6 muscles of right lower limbs (gluteus maximus [GM], biceps femoris [BF], vastus medialis [VM], gastrocnemius [GAS], soleus [SOL], and tibialis anterior [TA]). The joints kinematical data was recorded by Noraxon Myomotion system with 7 inertial sensors to identify the deceleration phase and acceleration phase for right hip, knee, and ankle joint during jump. Jump height and squat depth were obtained by time integration of the instantaneous velocity; that is, the time integration of the instantaneous acceleration. The acceleration-time curve is the force exerted on the ground reaction force minus body and external load weight divided by body and external flat steel mass. The reliability of jump height and squat depth were calculated across the three jump trials at each load, providing intra-class correlation coefficients (ICC) ranging from .967 to .993 for jump height and .933 to .985 for squat depth.

All raw EMG data were processed in band pass filtered (50-400 Hz), rectified, and root mean square (RMS) envelope (50 ms moving rectangular window). The average RMS amplitude was quantified the deceleration phase and acceleration phase of jump for each muscle. The results were analysed in repeated measures one way analysis of variance and Tukey's post-hoc. The alpha level was .05. All statistical tests were processed using SPSS 20.0.

Table 1
The Performance of CMJs and the Results of ANOVA

Variable	0 kg[a]	2.5 kg[b]	5.0 kg[c]	7.5 kg[d]	10.0 kg[e]	F(4, 36)	p	η^2	power	Tukey's post-hoc
Jump height (cm)						23.80	< .001	.726	1.00	a > c
M	53.6	52.0	50.3	47.9	47.3					> d, e;
SD	8.2	8.7	7.8	7.2	6.8					b > d, e
Squat depth (cm)						1.17	.341	.115	.33	
M	35.6	36.0	36.9	37.0	37.0					
SD	7.6	6.6	7.1	6.1	6.5					

Table 2
EMGs Amplitude of GM, BF, VM, GAS, SOL, and TA at 2.5 kg, 5.0 kg, 7.5 kg, and 10.0 kg Time to CMJ without External Load (0 kg) during Deceleration Phase and the Results of ANOVA

Variable	2.5 kg[b]	5.0 kg[c]	7.5 kg[d]	10.0 kg[e]	F(3, 27)	p	η^2	power	Tukey's post-hoc
GM					3.42	.032	.275	.70	d > b
M	1.11	1.33	1.43	1.38					
SD	0.53	0.55	0.43	0.50					
BF					1.88	.157	.173	.43	
M	1.05	1.10	1.19	1.24					
SD	0.31	0.36	0.31	0.35					
VM					1.03	.394	.103	.25	
M	1.11	1.14	1.22	1.30					
SD	0.46	0.40	0.29	0.43					
GAS					0.42	.617	.450	.10	
M	0.92	0.88	1.00	1.06					
SD	0.52	0.56	0.43	0.62					
SOL					0.13	.942	.014	.07	
M	1.25	1.15	1.25	1.22					
SD	1.10	0.67	1.02	0.50					
TA					2.37	.092	.209	.53	
M	0.89	1.00	1.04	1.16					
SD	0.31	0.37	0.29	0.33					

RESULTS AND DISCUSSION: Values of jump height and squat depth in the different loading conditions were showed in Table 1. The effect of load was significant for jump height, $F(4, 36) = 23.80$, $p < .001$, partial $\eta^2 = .726$. The jump height at 0 kg was higher than at 5.0, 7.5, and 10.0 kg significantly, and the jump height at 2.5 and 5.0 kg were higher than at 7.5 and 10.0 kg. The differences in squat depth were not significant among loading conditions, $F(4, 36) = 1.17$, $p = .341$, partial $\eta^2 = .115$. The one way analysis of variance showed that the GM at 7.5 kg was higher significantly than at 2.5 kg during deceleration phase (Table 2). Only the SOL at 10.0 kg was higher significantly than at 2.5 kg during acceleration phase (Table 3).
The external loads in this study were moderate for the participants. The jump height of CMJ was affect at the load of the above 5.0 kg, and the jump height appeared decrease more above the load of 7.5 kg. Similarly, Driss et al. (2001) indicated that the external load over 5.0 kg would cause the performance of squat jump decrease by the velocity corresponding to peak instantaneous power decreased with external loading. On the muscle activation point of view, the sequence of activation and the amplitude of muscle activity of action muscle were not affected by the moderate loads. The increase in external load in this study showed the soleus that is plantar flexor was active more at higher load during the push-off phase. The higher amplitude of gluteus maximus showed the action of deceleration at higher load during the eccentric action, but it was not affected the concentric action during the push-off phase.

Table 3
EMGs Amplitude of GM, BF, VM, GAS, SOL, and TA at 2.5 kg, 5.0 kg, 7.5 kg, and 10.0 kg Time to CMJ without External Load (0 kg) during acceleration Phase and the Results of ANOVA

Variable		2.5 kg[b]	5.0 kg[c]	7.5 kg[d]	10.0 kg[e]	F(3, 27)	p	η^2	power	Tukey's post-hoc
GM						0.64	.599	.066	.17	
	M	1.03	0.93	1.01	0.97					
	SD	0.20	0.22	0.21	0.22					
BF						1.38	.272	.133	.32	
	M	0.97	1.05	1.10	1.02					
	SD	0.13	0.18	0.21	0.18					
VM						1.50	.238	.143	.35	
	M	1.04	1.00	0.99	1.09					
	SD	0.18	0.13	0.09	0.13					
GAS						0.10	.958	.011	.07	
	M	1.06	1.09	1.07	1.09					
	SD	0.21	0.20	0.24	0.15					
SOL						3.18	.04	.261	.67	e > b
	M	0.94	0.96	1.04	1.05					
	SD	0.18	0.19	0.25	0.24					
TA						1.07	.357	.106	.19	
	M	1.21	1.29	1.00	1.31					
	SD	0.83	0.74	0.28	0.59					

CONCLUSION: The jump height was decrease under the condition of higher external load. But the activities of lower limb muscles were not influenced by the relative lower of external loading during CMJ.

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