THE KINETIC ANALYSIS OF CONTINUOUS JUMP WITH BENT LEGS

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The purpose of this study was to investigate the effects of fatigue on lower extremity dynamics during 60s continuous jump with bent legs (CJBL). Twelve college students served as subjects in this study. A Kistler force plate (500Hz) was used to collect vertical ground reaction force. Dependent t-test was used to test the difference between pre-fatigue and post-fatigue (α = .05). There were significantly differences on instantaneous force, peak force before take-off phase, and average concentric power between pre-fatigue and post-fatigue during CJBL ($p<0.05$). There were significant differences in contact time, and jump height between pre-fatigue and post-fatigue during CJBL ($p<0.05$).

KEY WORDS: continuous jump with bent legs, kinetic, fatigue.

INTRODUCTION: The vertical jump is one of the basic skills in many sports and the performance of this skill depends on the player's ability. The appropriate power output must be associated with speed and strength. In the execution of the vertical jump in the landing phase, the muscles of the lower extremity lengthen (muscle elongated), the muscle-tendon system store elastic energy then the lower extremity shorten muscle (muscle shortening) in the push-off phase. Then elastic energy would be released throughly. This phenomenon of the elasticity of muscle and the stretch reflex, increases the force of muscle contraction, which then leads to larger levels of explosive power (Komi,1984). It shows spontaneously the muscle action of SSC in the braking phase such as during running and jumping, in order to modulate leg stiffness, absorb a greater impact force and store energy in the muscle-tendon complexes (Komi,1984; Horita, 2000). Butler et al. (2003) suggested that high leg stiffness will cause bone injury and lower levels of leg stiffness are related to soft tissue injury.
In previous studies, different variables are used to evaluate the effects of fatigue and these include; less knee flexion, reduced vertical jump height, and increased EMG activity of quadriceps and hamstrings (Chappell, Yu, Kirkendall & Garrett, 2002; Rodacki, Fowler & Bennett, 2002; Greig & Walker-Johnson,2007). The purpose of this study was to investigate the effects of fatigue on lower extremity dynamics during 60s CJBL.

METHODS: Twelve recreational male college students (height: 173.57 ±6.04 cm, age: 20.17 ±1.70 years, weight: 72.58 ±13.67 kg) served as participants in this study. All the data were collected by a portable single axis force plate (Quattro Jump, Kistler, Winterhur, Switzerland) with a sample rate of 500Hz and the vertical direction of the vertical ground reaction force was recorded.
All subjects signed an informed consent document. Before the experiment, the subjects performed a15-min warm-up and practiced the CJBL 3 times. We asked the subjects to jump in place with their hands on their hips as the performance of the legs could be isolated. The subject started from an upright standing position on the force plate for 1-2 seconds. The subjects were then asked to continuously jump with bent legs. During the landing phase of the CJBL subjects had to bend their knees to 90 degrees.
The fatigue protocol was modified from previous research by Bosco (1999). Average mechanical power and average height during multiple jumps tests of 30-60s are very sensible parameters that permit the evaluation of lactic anaerobic capacity, mechanical power and resistance to fatigue (Bosco ,1999).
Force at the transition from eccentric to concentric contraction was defined as instantaneous force . Peak force was the maximum vertical ground reaction force in the takeoff phase. Squat position was the lowest height of center of gravity. Jump height was the flight height of

rise of center of gravity. Jump height difference was the height from jump start of center of gravity to squat (ecc/con transition) of center of gravity. Contact time was the time from foot landing to take-off. The leg stiffness was the ratio of maximum vertical ground reaction force and the center of gravity to the lowest point of the vertical displacement, respectively of the leg stiffness on shortening phase (instantaneous force / jump height difference) was the ratio of instantaneous force and jump height difference; the leg stiffness on stretch phase(peak force / jump height difference) was the ratio of peak force and jump height difference. Average concentric power was the average power from the time when velocity of center of mass becomes positive until takeoff. The first (jumps 1-8) and last (last 8 jumps) of CJBL were selected for analysis, and kinetic data were averaged from jumps. The first of CJBL was defined as the pre-fatigue conditon while the last of CJBL was defined as the post-fatigue condition. The comparison between pre-fatigue and post-fatigue was made by using the depedent t-test. Statistical significance was set with α level of .05.

RESULTS: For all the variables of CJBL analyzed, the mean values and the standard deviations were calculated (Table 1). There were significant differences for instantaneous force, peak force, jump height difference, contact time, jump height and average concentric power between pre-fatigue and post-fatigue ($p<0.05$) . However, instantaneous force, peak force, jump height difference, jump height and average concentric power were significantly lower in the post-fatigue than in pre-fatigue, contact time was significantly longer in the post-fatigue than in pre-fatigue. There were no significant differences on squat position, the leg stiffness on stretch phase and the leg stiffness on shortening phase between pre-fatigue and post-fatigue ($p>0.05$) .

Table 1: Comparison of temporal and kinetic parameters between fatigue levels.

parameter	Pre-fatigue		Post-fatigue		t
	M	SD	M	SD	
instantaneous force (BW)	1.09	0.31	0.78	0.27	3.778*
peak force (BW)	2.24	0.15	1.78	0.12	9.365*
jump height difference (m)	0.33	0.03	0.30	0.05	2.255*
squat position (m)	-0.25	0.03	-0.23	0.05	-1.079
contact time (ms)	530.06	48.18	744.52	225.53	-3.271*
leg stiffness on stretch phase (BW/m)	6.98	0.73	6.23	0.97	2.135
leg stiffness on shortening phase (BW/m)	3.38	1.00	2.78	1.22	1.812
jump height (m)	0.35	0.04	0.22	0.04	10.755*
average concentric power (W/kg)	22.25	3.08	12.93	2.50	11.245*

*p<0.05

DISCUSSION: The purpose of this study was to investigate determinants of the difference in the kinetic of leg during 60s CJBL between pre-fatigue and post-fatigue. The values of instantaneous force, peak force and average concentric power decreased with increasing time (Table 1, Figure. 1). We found that the degree of fatigue of the subjects increased with time, it will reduce the ability of lower extremity muscles to store and release elastic energy, thereby affecting the instantaneous force and forces of push-off. Bosco et al. (1996) have shown that the average concentric power between first (1-15 second) and last (45-60 second) were significantly different, and results indicated that the maximum amount of the short-term exercise was one of the factors that caused fatigue.

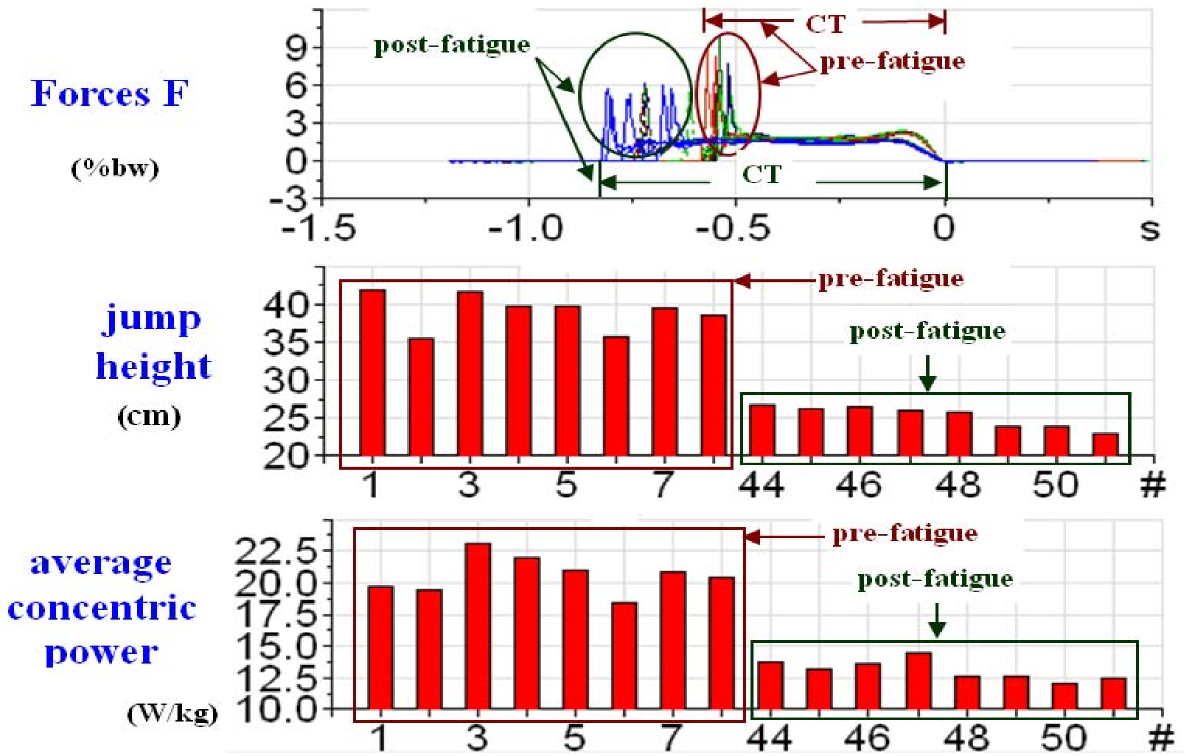

Figure 1: One of the subject's parameters in GRF, jump height **and average concentric power between fatigue level.**

The values of the jump height difference and jump height decreased with increasing time, and the values of the contact time increased with increasing time (Table 1). The results indicated that the subjects should reduce the center of gravity of displacement and jump height, and increase the landing time (Figure 1), instead of changing the center of gravity of the lowest point. Kuitunen et al. (2007) have shown that the results in contact time and squat position have the same as this study. Ronglan et al. (2005) indicated that because of continuous jumping for a long time period, the lower extremity flexion and jumped height of the subjects reduced. This is due to failure of bending the knees to 90 degrees caused by fatigue. The lack of skilled maneuver of subjects with power-trained and endurance-trained might affect the result. Bosco et al. (1982) have shown the effects of a 90 degree knee angular displacement, the subject reduced knee angular displacement 50 degree will increase 30% in mechanical efficiency.

In our study, there were no differences in the leg stiffness on stretch phase and the leg stiffness on shortening phase between pre-fatigue (Table 1). The subjects during CJBL remained at a constant value, the muscle-tendon system fixed lower leg stiffness, to store or output elastic energy (Kuitunen et al., 2007). Kuitunen et al. (2007) indicated that peak force reduction resulting in lower leg stiffness is smaller, similar to the SSC exercises. Kuitunen et al.(2007) also suggested that effective activities to modulate the triceps surae muscles of the lower extremity during the intensive fatigue SSC exercise may delay exhaustion and development of metabolic fatigue. During drop jumps, the execution of the SSC exercise due to fatigue changed in knee stiffness, and take-off velocity (Horita, Kimo, Nicol & Kyröläinen, 1996). Hobara et al. (2007) have shown that the execution of exercise reach fatigue to reduce leg stiffness. There were no significant differences found among the leg stiffness on stretch phase, the leg stiffness on shortening phase and squat position. The level of fatigue dosen't have an effect on the lower extremity joints, which suggests that it may not be the primary modulated mechanism of the lower extremity joints. Farley & Morgenroth (1999) and Arampatzis et al. (2001) indicated that lower leg stiffness depends on ankle stiffness as the ankle joint plays an important role in the modualtion of leg stiffness during continuous jumps.

CONCLUSION: During CJBL, it was shown that the post-fatigue values of instantaneous force, peak force, average concentric power, jump height difference, jump height were higher than pre-fatigue. Further, the post-fatigue value of contact time was less than pre-fatigue. The subjects recruited in this study were students who may get fatigued more easily than athletes. Therefore, we suggest that those engaging in vertical jump-related activities, should increase the endurance-trained and power-trained courses, to delay fatigue and increase in leg stiffness, and thus enhance vertical jump performance.

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