EFFECTS OF PLYOMTRIC TRAINING ON MUSCLE FATIGUE AND MAXIMAL RATE OF FORCE DEVELOPMENT OF LOWER-LIMB

Kuo-Chuan Lin[1], Chi-Yao Chang[1], Chin-Shan Ho[1], Chun-Hao Chang [1] and Ke-Chou Chen[2]
Graduate Institute of Sports Science, National Taiwan Sport University, Taoyuan, Taiwan[1]
Physical Education Office, Chung Yuan Christian University, Taoyuan, Taiwan[2]

The purpose of this study was to examine the effects of plyometric training on muscle fatigue and maximal rate of force development in volleyball players. Ten college volleyball players volunteered to participate in this study and underwent a 6-week plyometric training. The BTS free EMG and force-plate were used to evaluate the median frequency (MDF) of the rectus femoris (RF), anterior tibialis (AT), lateral gastrocnemius (LG), biceps femoris (BF) and maximum rate of force development (mRFD). The results revealed that the plyometric training significantly improves the MDF of RF and AT and mRFD. This study demonstrated that by using plyometric training could facilitate the mRFD and postpone muscle fatigue for trained volleyball players.

KEY WORDS: median frequency, force-plate, mRDF

INTRODUCTION: In volleyball, the athletes were required to react the ball, opponent, or teammate in short interval with high-intensity. During the competitions, the well-developed physical capability is needed for the players to perform spike, set, block, serve and defense. Considering the physiological assessment of volleyball players, the exercise could be characterized by quick and short displacements and vertical jump in defensive or offensive maneuvers. The various sprints, dives, jumps occurred repeatedly which altered on the neuromuscular function with fatigue (Lepers et al., 2000) and reduced the jump performance. Thus, the outstanding strength and "explosive" muscle strength are two of the fundamental factors for the players. The explosive muscle strength also could be defined the maximal rate of force development (mRFD) which represent the slope of the force-time curve during muscle contraction (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002). A large proportion of literature revealed that the plyometric exercises are used as periodized strength-training program to improve maximal power output and jumping ability (Markovic, 2007; Potteiger, et al., 1999). The benefits of plyometric training are resulting from the storage of elastic energy during muscle stretch (eccentric and contraction), the stretch-shortening cycle (SSC) (Makaruk, & Sacewicz, 2010). The improvements usually contain with changes in muscle activities and neuromuscular adaptations. By using long-term strength and power training, the cross-sectional area of type II fibers, motor unit recruitment and firing rate could be synchronously improved (Markovic, 2007). Although plyometric training has been reported to increase performance variables, little scientific information is available to determine if that improve muscle fatigue. Therefore, the purpose of this study was to investigate the effects of plyometric training on muscle fatigue and mRFD in volleyball players.

METHODS: A total of ten male college volleyball players, free from injuries (age= 20.5 ±1.5 years, weight= 78.5±4.7 kg, and height= 185.5±.1 cm), volunteered to participated in this study. A 6-week plyometric training program was applied to the subjects twice per week (Makaruk & Sacewicz, 2010). In this study, the blocking agility test (BAT) using a blocking agility test system including visual stimuli (Ho, et al, 2015) was applied to examine the effects of muscle fatigue. In the BAT, fourteen block jump with 90% jump height incorporated in a trial of activity that are separated by 8 seconds and three trials of the test were performed with three minutes rest interval. The BTS free EMG and force-plate (Kislter 9287, kislterLtd., Switzerland) were used to evaluate the median frequency (MDF) and mRFD (Gathercole, Sporer, Stellingwerff, & Sleivert, 2014) during the BATs. The mRFD was the largest force increase during each block jump within 30-ms epoch. Athletes attended the same experimental procedures at both pre-test and post-test. Self-designed MATLAB programs (Version 7.6.0.324, The MathWorks Inc., USA) were used to calculate the MDF of the rectus femoris (RF), anterior tibialis (AT), lateral gastrocnemius (LG), biceps femoris (BF) and mRFD for each jump. The mRFD was divided by the body weight (BW) of the subjects for normalization. SPSS 20.0 software for Windows was used for statistical analysis and for identifying significant differences. Five 2 X 3 ANOVAs were used to examine the interaction effect between tests (pre-test vs. post-test) and trials. The repeated measures ANOVA examined the differences across trial (trial effect) while estimates examined the differences between tests. The significant level was set atα =.05

RESULTS: The means and standard deviations of the results on pre-test and post-test are provided in table 1. The results revealed that a significant interaction between tests and trials were found with respect to RF ($F_{1, 18}$ = 6.231, p = .022) and AT ($F_{1, 18}$ = 30.118, p < .001). However, no significant difference were observed in LG ($F_{1, 18}$ = 0.469, p = .502) and BF ($F_{1, 18}$ = 0.001, p = .979). The repeated measures ANOVA revealed significant differences between pre-test and post-test a) trial 2 ($F_{1, 9}$ = 14.409, p = .004) and trial 3 ($F_{1, 9}$ = 9.956, p = .012) for the RF b) trial 3 ($F_{1, 9}$ = 66.306, p < .001) for the AT. No significant interaction between tests and trials was found with respect to mRFD ($F_{1, 18}$ = 0.425, p = .523). Further, the main effect was significant between tests ($F_{1, 18}$ = 14.926, p = .001) in mRFD.

Table 1

Means and SDs across Pre-test and Post-test with MDF

Items		RF (Hz)	AT (Hz)	LG (Hz)	BF (Hz)	mRFD (BW/s)
	T1	98.24±7.97	136.32±7.75	100.39±7.08	139.06±9.65	23.33±2.92

Pre-test	T2	93.16±10.33	133.91±6.65	98.63±13.19	140.28±12.70	23.07±3.58
	T3	87.89±7.95	127.54±6.04	96.56±9.24	136.57±10.13	22.94±2.71
	T1	99.02±6.71	137.50±5.84	103.32±10.39	141.40±8.62	27.21±3.64
Post-test	T2	95.58±11.14	135.94±7.66	98.39±5.25	142.19±8.59	26.82±2.05
	T3	92.77±9.03	134.96±7.33	95.70±8.28	139.06±8.57	27.27±2.58

DISCUSSION: The results of this study indicated that a six-week plyometric training program significantly improves the MDF of RF and AT and mRFD. The greatest effect of PT was on the MDF of RF and BF and mRFD; i.e., the MDF of RF and AT increased by 1.28% and 1.73% respectively and mRFD by 17.29%, whereas the MDF of LG and BF did not change significantly after training. In present study, the subjects were required to perform forty-two block jumps with both left and right lateral-direction changes which demanded high-intensity loads of neuromuscular system. By this event, the concentration of the lactates changes in intracellular pH. The pH and muscle fiber conduction velocity decrease simultaneously which result in decrease of MDF (De Luca, 1983). Wulf, Dufek, Lozano and Pettigrew (2010) reported that the RF, AT, LG and BF were the main prime movers during jumping and an external focus enhances the effectiveness of movement patterns. Because plyometric training involved muscle actions similar to the subjects used in the block jumps which could improve the muscle potentiation (mRFD) via SSC. During the high-intensity dynamic protocol, the athletes were required to perform fast limb movements and block jump. The mRFD is major determinant of the maximal force and velocity which is importance for athletes performing an explosive type of muscle action (Aagaard et al., 2002). The mRFD may be effected by various elements, i.e., the level of neural activation, muscle size, and fiber-type (MHC isoform) composition (Harridge, 1996). Consequently, an elevated mRFD induced by plyometric training allows increase of neuromuscular potentiation and which may improve the jumping ability in the same time.

CONCLUSION: In this present study, the results demonstrated that by using plyometric training could facilitate the mRFD and postpone muscle fatigue for trained volleyball players. Further research is needed to see whether different training frequency and sessions have an additive effect in volleyball athletes.

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