EFFECT OF POST-ACTIVATION POTENTIATION ON KINEMATICS AND KICKING PERFORMANCE IN A ROUNDHOUSE KICK WITH TRAINED MARTIAL ARTS PRACTITIONERS

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The purpose of this study was to examine if kicking with elastic resistance (ER) during warming up could initiate Post-Activation Potentiation (PAP), and increase kinematics and performance on subsequent explosive kicking. Five woman and eleven men (n=16) with a background in kickboxing and/or TaeKwonDo performed two warming up strategies with subsequent testing. Kicking performance, defined as kicking velocity with the foot was measured 3D. In addition, muscle activity of the prime movers was measured. Kicking velocity of the foot increased by 3.3% after performing a warming-up strategy including kicking with ER (p=0.009). Increases were also recorded in muscle activity in m. vastus medialis (35.2%, p=0.05), rectus femoris (43.9%, p=0.04). The study show a positive effect on kicking performance after performing a warmup strategy including kicking with ER.

KEY WORDS: Warmup, explosive, PAP, elastic, resistance, ballistic.

INTRODUCTION: Warming up before a performance is used to prepare and enhance the upcoming performance. A mechanism that is associated with warming up and has positive effect upon performance in explosive movements is Post-Activation Potentiation (PAP) (Mitchell & Sale, 2011; Bergmann, et al., 2013; Miarka, et al., 2011). The muscles' ability to develop force is dependent on what has happened earlier within the muscle and improvements in performance that follow a submaximal or a maximal contraction has been referred to as PAP (Baudry & Duchateau, 2007). These improvements could come from changes in pennation angle (Tillin & Bishop, 2009), physiological improvements (Paasuke, et al., 1996; Rassier & Macintosh, 2000; Sale, 2002; Hodgson, et al., 2005) or neurological improvements (Chiu, et al., 2003; Güllich & Schmidtbleicher, 1996; Aagard, 2003; Aagard, et al., 2002).
Previous studies presented inconsistent findings of PAP and improvements in performance. Some studies have shown improvements in performance (Chiu, et al., 2003; Mitchell & Sale, 2011; Batista, et al., 2007; Rixon, et al., 2007), while other studies have not been able to measure an effect of PAP (Behm, et al., 2004). Some studies have used maximal voluntary contractions (MVC) (Behm, et al., 2004; Batista, et al., 2007), while other studies have used heavy resistance weightlifting exercises (Chiu, et al., 2003; Mangus, et al., 2006; Rixon, et al., 2007; Mitchell & Sale, 2011) with the intention to initiate PAP. Even so, for many sports there is a lack of specificity in using such exercises to initiate a short-term positive effect on performance.
Only a few studies have applied more specific exercises to initiate PAP to enhance performance. Smith et al. (2014) applied sprinting with resistance in form of a sleigh with the intention of initiating PAP, which is more biomechanically similar and specific to the following sprinting exercise. Kicking with elastic resistance (ER) has previously shown to chronically increase kicking performance in terms of velocity (Jakubiak & Saunders, 2008). However, using elastic resistance as an exercise to initiate a short-term positive effect (PAP) on performance is not studied yet.
Therefore, the purpose of this study was to examine if kicking with ER could initiate PAP, increase kinematics and thereby performance on subsequent explosive kicking. It was hypothesized that kicking with elastic resistance at the end of a warming up protocol will improve short-term kicking kinematics and performance of the trained martial arts practitioners.

Furthermore, that this was caused by the increase muscle activity in the kicking legs' knee extensors due to PAP.

METHODS: A randomised crossover study was conducted to examine differences in the trained martial arts practitioners (n=16) kicking performance subsequent to two warming up protocols. One warming up protocol included a standardized pre-competition warming up routine and ballistic hip movements. The second warmup protocol included the same standardized pre-competition warmup routine with an additional 10 kicks with ER (X-ERFIT FITNESS TUBE, high resistance, black colour) in three sets with 90 seconds pause, which was sufficient for maintaining maximal performance and complies with the theory of recovery of power (Rahimi, et al.,2009). Between the two protocols participants had a minimum 30 minutes break before starting the next warming up protocol to ensure that any effects of PAP had diminished. Three roundhouse kicks with maximal effort were conducted on a hanging heavy-bag 5-8 min after warming up. The three test kicks were measured by using six 3D cameras at 500 Hz. (Qualysis, Sävedalen, Sweden) with 15 markers fastened on the lower extremities (both troch. majors, both superior iliac crests, both lateral knees, both medial knees, both lateral malleolus, both medial malleolus, both lateral metatarsal-phalangeal joints and l. medial metatarsal-phalangeal joint).
Computation of maximal linear velocity of the kicking foots lateral markers (distal foot, ankle, knee and hip) together with the maximal angular velocity of joint movements (knee-, hip-extension and hip rotation) and their timing. All calculations were performed in Matlab 7.0 (The Mathworks Inc., MA, USA). Electromyography (Musclelab, Ergotest Technology AS, Langesund, Norway) was used to record muscle activity of m. vastus lateralis, m. vastus medialis and m. rectus femoris of the kicking leg during the kicks.
To examine the effect of warming up with and without ER a paired T-Test was used. The level of significance was accepted at $P<0.05$ and all data are expressed as mean ± SD. Statistical analysis was performed using SPSS 18.0 for windows (SPSS, inc., Chicago, IL).

RESULTS: A significant 3.3% higher velocity (p = 0.009) was found at the kicking foot's toe (Fig. 1) and knee marker when conducting the warming up with ER compared to the one without ER (table 1). In addition 2.5% higher linear velocity was found for the knee marker (p = 0.026), while only a trend was found for the linear velocities of the hip (p = 0.059) and ankle (p =0.092).

Table 1: Effect of kicking with elastic resistance on different parameters in kicking performance. *Significant difference without ER to with ER ($p<0.05$). Timing is displayed as impact - occurrence.

	Without ER		**With ER**	
Parameter	**Peak**	**Timing**	**Peak**	**Timing**
Hip marker (m/s)	3.29±0.55	0.647±0.29	3.47±0.69	0.706±0.37
Knee marker (m/s)	7.16±0.96	0.580±0.28	7.34±1.07*	0.628±036
Ankle marker (m/s)	13.29±1.34	0.495±0.28	13.51±1.63	0.546±0.37
Foot (m/s)	17.35±1.98	0.491±0.28	17.93±2.26*	0.541±0.37
Hip rotation (rad/s)	10.98±2.09	0.246±0.11	11.03±1.99	0.257±0.11
Hip extension (rad/s)	4.72±1.18	0.174±0.08	5.08±1.77	0.212±0.11
Knee extension (rad/s)	30.13±4.54	-0.011±0.01	30.86±5.47	-0.019±0.01

About the muscle activity only a significantly higher M-RMS was found in m. rectus femoris (without ER: 104.96 ± 80.13 M-RMS, with ER: 151.11 ± 131.26, p = 0.04). A trend was found in the increase of muscle activity in m. vastus medialis (without ER: 157.23 ± 66.76 M-RMS, with ER: 212.64 ± 151.59, $p = 0.05$), but there were no significant changes found in m. vastus lateralis ($p = 0.36$).

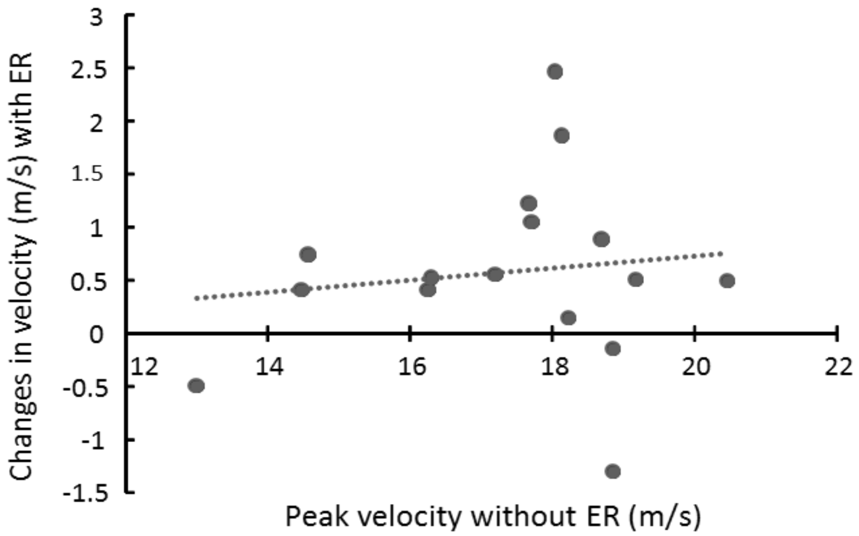

Figure 1: Effect of kicking with elastic resistance on kicking performance measured at the distal end point of foot in roundhouse kicks by the participants. The X-axis show peak velocity (m/s) recorded under testing after warmup without ER. The Y-axis show the difference in peak velocity (m/s) measured at toe marker from best test-kick after warmup without ER to best test-kick after warmup including ER.

DISCUSSION: The results in this study show that using a warming up protocol that includes kicking with elastic resistance positively affects kicking performance in the participating martial arts practitioners.

Even though there were not found any significant changes in terms of knee, hip extension and hip rotation, there were found two trends in terms of the hip ($p = 0.08$) and knee ($p = 0.06$) extensions timing. The overall results in timing indicates that the peak values of the kicking parameters occurred sooner after initiating the kick after including ER in the warming up protocol, thus leading to a better kicking performance.

The improvements in kicking performance were compliant with the theory of neural enhancements. Increased recruitment of higher order motor units (Chiu, et al., 2003; Güllich & Schmidtbleicher, 1996), a better synchronisation of the involved motor units and a reduced pre-synaptic inhibition (Aagard, et al., 2002; Aagard, 2003) could be the cause for a faster kick and reaching peak parameter values faster.

The increased kicking velocity could have been caused by physiological enhancements. The physiological enhancements involves a shorter path for myosin heads (Tillin & Bishop, 2009), increased supply of ATP (Hodgson, et al., 2005), heightened sensitivity for Ca^{2+} (Szczesna, et al., 2002), thus increasing the rate of cross-bridging and a greater muscular contraction velocity which could cause the increased kicking velocity. However, due to equipment limitation it was not possible to measure such physiological enhancements. Therefore we cannot conclude wether or not such physiological enhancements occurred or had an effect on the participant' kicking performance.

Changes in pennation angle is thought to provide a greater transmission of power from the muscle to the moving structure (Tillin & Bishop, 2009). The increased kicking velocity recorded in this study could have benefitted from a greater transmission of power from the muscle to the moving structure. The tensil strength of the muscle tendons could be decreased during a warmup and thusly counteract any increase gained from a greater transmission of power (Kubo, et al., 2001).

Advantages by including kicking with elastic resistance as part of a warming up strategy could be to increase short term performance in a competition environment for certain combat sports. Elastic tubing is very portable and including them as part of a warm up routine is very feasible. Even so, before this method of enhancing performance in a competition environment takes place, more research should be conducted.

CONCLUSION: This study shows that a warming up strategy that includes kicking with ER caused a positive effect in the kicking performance for trained martial arts practitioners. The forethought effects of PAP could have caused the 3.3% increase in the kicking-foot's distal velocity. The increased muscle activity indicates that the PAP effect could have been present after kicking with ER. Such effects are beneficially to include kicking with ER as part of a pre-competition warming up protocol.

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