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Effect of Post-Activation Potentiation Enhancement Induced Using Elastic Resistance Bands on Female Track and Field Jumpers

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Abstract

Elastic Resistance Bands (ERB) are widely used by athletes separately and in conjunction with heavy loads to activate muscles and improve various athletic abilities. The study aimed to assess the effect of ERB training while warm-up among female track and field jumpers. In the randomized between-group parallel design, 14 athletes were separated into ERB (age: 21±2.16 years, height: 165.6±8.24 cm, body mass: 57.97±4.28 kg) and control (CON) (age: 21.42±2.29 years, height: 164.57±8.54 cm, body mass: 56.57±5.18 kg) groups. A baseline test for CMJ was performed after a general warm-up. Upon completion, both groups performed similar specific pre-competition warm-up drills, with the ERB group performing the exercises using an elastic resistance band. Both groups were tested for follow-up measurements. Significant time x group interaction was observed for jump height ($p=0.024$, $\eta p2=0.36$) and take-off force ($p=0.039$, $\eta p2=0.30$). Significant differences in baseline and follow-up measurements were found in ERB groups for all the dependent variables except peak speed (jump height $p=0.006$, $g=0.48$; take-off force $p=0.009$, $g=0.99$; take-off speed $p=0.046$, $g=0.55$, and max. concentric force $p=0.005$, $g=0.87$). The results suggest that performing running drills with ERB may have the potential to enhance lower limb force generation capacity, as indicated by improvements in CMJ height and take-off force in this study. While these findings are promising, they should be interpreted with caution due to the small subsample size. ERB could be considered as a potential component of warm-up routines for track and field athletes, particularly in situations of low logistical availability. However, further research involving larger sample sizes is necessary to confirm these preliminary findings regarding the efficacy of ERB in warm-up protocol.

Keywords: *resistance bands, counter movement jump, strength and conditioning, take-off force, jumpers, warm-up protocols*

Introduction

Post-activation performance enhancement (PAPE) is a phenomenon characterized by improved muscular power after a "conditioning" contractile activity. Blazevich and Babault (2019) suggested that the mechanism underpinning PAPE may be attributed to increases in neural drive muscle temperature, blood flow cellular water, and muscle-tendon stiffness, although the specific mechanisms require further empirical investigations. The increased force output caused by contractile history has been known to improve sprint ability, acceleration, change of direction speed (COD), and jump performance (Katushabe & Kramer; Turner, Bellhouse, Kilduff, & Russell, 2015; Wallace, Winchester, & McGuigan, 2006; Wyland, Van Dorin, & Reyes, 2015).

Evidential practices causing PAPE include methods such as maximum voluntary isometric contraction (MVIC)

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(Lima et al., 2014; Tsoukos, Bogdanis, Terzis, & Veligekas, 2016), heavy resistance loading (>80% of 1RM) (Linder et al., 2010; Mitchell & Sale, 2011), and loaded and unloaded plyometrics (Aloui et al., 2020; de Villarreal, Izquierdo, & Gonzalez-Badillo, 2011), among soccer, handball, track and field power athletes, and sprinters. Heavy and maximum resistance loading before performance induces PAPE, but as argued by Lum and Chen (2020), it is neither viable to carry heavy weights all the time nor feasible during competitions. Another limitation of heavy resistance is the lack of sports-specific movements (Aandahl, Von Heimburg, & Van den Tillaar, 2018), which are not biomechanically similar to the movements performed, and impede the involvement of muscles for a specific movement. As Turner et al. (2015) emphasized, maximizing the movement velocity results in greater fast-twitch muscle fibre recruitment inducing PAPE. Smith et al. (2014) examined the effects of sledge resistance sprints, utilizing loads ranging from 0% to 30% of body mass as the PAP warm-up protocol. Findings revealed a significant main effect, demonstrating subsequent sprint performance improvement. Chattong (2008) investigated the effect of the weighted vest with 5-20% of the subject's body weight with box jump on vertical jump performance; findings reveal significant post-test results, but no significant difference in jump height between groups was found. Thus, plyometric exercises could be an effective way of performance enhancement other than conventional weight loading and MVIC, inducing less fatigue, shortening the recovery time, and providing movement velocity (de Villarreal et al., 2011; Seitz & Haff, 2016).

Previously used for injury rehabilitation, elastic resistance bands (ERB) are found to be a potential alternative to resistance loading, eliciting explosive performance in athletes; ERB offers Variable resistance (VR) at the range of motion and could substitute conventional weights (dumbbells) offering similar muscle activation (in deltoid and trapezius) (Bergquist, Iversen, Mork, & Fimland, 2018). ERB is also found to be effective when used in conjunction with external resistance, Mina et al. (2019) investigated the potentiating effect of the ERB training (35% load from ERB) against FWR (85% of 1RM) and revealed a significant increase in 1RM Squat in the ERB group (mean=7.7%, $p<0.01$). Dundass (2013) compared the ERB (70% free-weight resistance + 30% ERB) group with the CON group (100% free-weight resistance) on the lower-body power (max. vertical jump) and strength output (1RM) and found significant improvement in both groups, but no significant difference was recorded in the between-group assessment. ERB, in conjunction with contrast strength training (Hammami et al., 2022) and free-weight resistance (FWR) exercises (Wallace et al., 2006), produces PAPE, which substantially improved 30m sprint, CMJ, and peak force, peak power, respectively. However, PAPE-induced performance improvement using ERB with plyometrics is still an area of investigation.

As per the researcher's knowledge and literature review, only a few studies assessed ERB training without free-weight intervention. Aandahl et al. (2018) assessed the efficacy of warm-up with ERB on roundhouse kicking performance in trained martial arts practitioners. 3D motion capture technology and electromyography recorded a 3.3% increase in kicking velocity against the CON group ($p=0.009$, $\eta=0.32$) and 35% and 44% more muscle activation in the vastus-medialis (prime movers) and rectus femoris, respectively, signifying the use of ERB in warm-up can be substantial for kicking performance. However, the study did not record the effect of ERB training on the vertical jump performance of athletes and other performance variables. Another investigation by Lum and Chen (2020) on male national athletes compared unloaded and ERB-loaded CMJ with different resistance levels. Findings revealed a significant increase in peak power, peak velocity, and reduced time to peak torque in the ERB condition. However, no significant change in jump height was recorded between conditions.

Despite the positive effect of ERB-loaded CMJ on subsequent CMJ performance, it is currently not known if the inclusion of ERB when performing running drills would also potentiate lower limb force development capability. As these drills are commonly performed by track and field athletes, such knowledge would have great practical implications for track and field jumpers. Therefore, the study aimed to assess the effect of ERB training with a dynamic warm-up on track and field female athletes. Based on the available literature, the researcher hypothesized that ERB training with dynamic warm-up would induce PAPE to elevate athletes' jump height, take-off force, take-off speed, maximum concentric force, and peak speed.

Material and Methods

Experimental approach to the problem

A between-group parallel experimental design was used to investigate the potentiation effect caused by the elastic resistance band (ERB) during warm-up. The protocol included general and specific warm-ups. After following a similar general warm-up, jumpers were randomly assigned to the ERB or control (CON) group. In the specific warm-up, the ERB group performed plyometrics and jumping movements with resistance bands, whereas the CON group performed identical movements without resistance bands. Pre- and post-testing before and after specific warm-up measured jump height, take-off force, take-off speed, maximum concentric force and peak speed.

Subjects

Female track and field jumpers (long, high, and triple jumpers) with at least university or national participation who suffered no injury in the past six months were admissible for the study. Fulfilling the above criteria, a total of 14 track and field jumpers (6 high, 5 long, and 3 triple jumpers), with a minimum of 1.5 years of competitive experience and past exposure to resistance training, were allocated into ERB (age: 21±2.16 years, height: 165.6±8.24 cm, body mass: 57.97±4.28 kg) and CON group (age: 21.42±2.29 years, height: 164.57±8.54 cm, body mass: 56.57±5.18 kg) as shown in Table 1. Being from the same university and residing on the campus, all the participants had similar conditioning regimes and followed a similar daily routine. Before signing the consent form, participants were well-informed about the associated details, procedure, risks, and benefits. The study adhered to the ethical standards of the Declaration of Helsinki (2013) and was approved by the Departmental Research Committee of Lakshmibai National Institute of Physical Education, Gwalior, India. LNIPE/DRC/MPE/2021-22/816.

Table 1. Demographic, anthropometric and training characteristics of the CON and ERB group

Variables	Mean ± SD		p
	CON Group (n=7)	ERB Group (n=7)	
Age (years)	21.42 ± 2.29	21 ± 2.16	0.72
Training age (years)	6.15 ± 1.57	7.71 ± 1.6	0.09
Height (cm)	164.57 ± 8.54	165.57 ± 8.24	0.82
Body mass (kg)	56.57 ± 5.18	57.97 ± 4.28	0.59

Procedure

After two mandatory weekly familiarization sessions with ERB exercises and CMJ protocols, all the participants were randomly divided into CON and ERB groups. To avoid learning effects during the data collection, familiarization was strictly adhered to and made sure athletes were reaching their best scores. One day before the data collection procedure, basic demographic information and anthropometric measurements (standing height, body mass, fat percentage) were recorded. Athletes were asked to avoid any arduous activity 48 hours before the assessment and refrain from any energy/supplement drinks 4 hours before testing (caffeine, creatine, and other stimulants), which may alter their performance. After 15-minutes of performing the general warm-up, the pre-test measurement and randomization for ERB and CON were done.

Warm-up Protocol

Before commencing the testing procedure, both the CON and ERB groups followed a 15-minute general warm-up consisting of 7-minutes of self-paced joggings, followed by 5 dynamic stretches of 8 repetitions each: knee to chest hugs, butt kicks, lateral lunges, forward deep lunges, and squats, with 3 repetitions of 10-meter sprints. After the general warm-ups and before commencing the specific warm-up, Pre-testing of CMJ was done. After 2-minutes of Pre-testing, athletes went for specific warm-up exercises, 5-7 repetitions each, including High-knee marching, A-skips, straight lead leg-skips, split lunges jump, one leg complete cycle (both legs), single-leg swing and cycle (both legs), piston action, and ABC drills. The ERB group performed the exercises/drills using spiral elastic resistance bands circumscribed on thighs and knees while performing the drills, whereas, in the case of single leg movements, the resistance bands were hooked to the stationary points to perform the exercises, as shown in Figure 1. The colour determined the intensity of resistance bands: yellow, green, red, blue, and black. All the athletes used blue-coloured resistance bands. This induced approximately 12-14 kg of force upon 100% elongation (as per the manual GoFit Pro Power), ensuring an ERB load of at least 10% of body weight (Burkett, Phillips, & Ziuraitis, 2005; Lum & Chen, 2020; Mina et al., 2019).

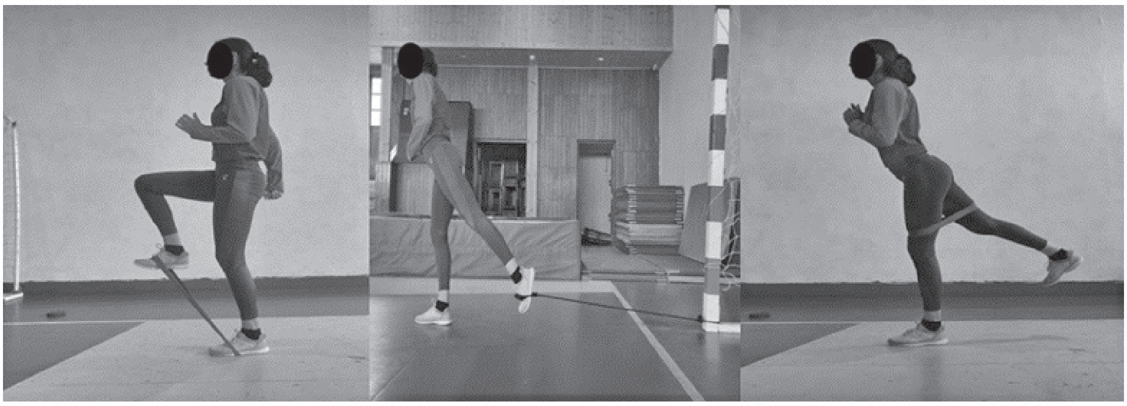

FIGURE 1. Demonstration of exercises performed by the ERB group

Counter Movement Jump

To assess jump height, maximum height, take-off force, take-off speed, maximum concentric force, and peak speed. Countermovement jump performance with arm swing (CMJA) was performed using an inertial moment sensor (BTS G-walk, Italy). The sensor was positioned at the fifth lumbar vertebrae, providing a belt in the centre of the device. Participants were asked to stand with feet slightly apart and were instructed to swing their arms and perform a countermovement to a self-selected depth before taking off and landing with both legs (Domire & Challis, 2007). Knee flexion was not permitted during the flight phase of the jump. The athletes of both groups were consistently motivated throughout the assessment protocols (pre-post attempts) to maximize their CMJ performance. Three trials were performed with 30-40 seconds of rest between jumps, and the best trial was selected for analysis (Rixon, Lamont, & Bemben, 2007). The ICC for test-retest was 0.92–0.96, and CV=11.44-12.52%.

Statistical Analysis

Descriptive analyses were presented as mean and Standard Deviation (SD) for demographic and performance variables. The homoscedasticity was tested using Leven's test of equality of variance followed by an independent (between-group) t-test to compare baseline measurements. Further, the normality assumption for all the data was met using the Shapiro-Wilk test. 2x2 mixed ANOVAs with post hoc analyses using Bonferroni adjustments were used to compare the time, i.e., pre-test and post-test vs. ERB and CON groups. Partial ETA squared was used to calculate the effect size of time and between group testing, and Hegde's g was calculated between baseline and follow-up testing in each group. The magnitude of the intervention was estimated to be classified as trivial (<0.20), small (0.2–0.6), or moderate (>0.60–1.2) based on established criteria (Hopkins, 2007). The magnitude of effects for η2p was interpreted as small (0.6–1.2), large (>1.2–2.0), very large (>2.0–4.0), and extremely large (>4.0) (Hopkins, 2007; Pereira, Horwitz, & Ioannidis, 2012). Statistical significance was set at p≤0.05. All the analyses were done using IBM SPSS version 25.0 (IBM, New York, USA).

Results

Records of demographic, anthropometric, and training differences for both groups are summarized in Table 1. Further, no statistical baseline differences (p=0.44-0.90) were found between CON and ERB groups when tested for dependent variables, supporting similar physical characteristics. The results comparing the ERB and CON warm-up effect on various CMJ constructs are presented as mean±SD.

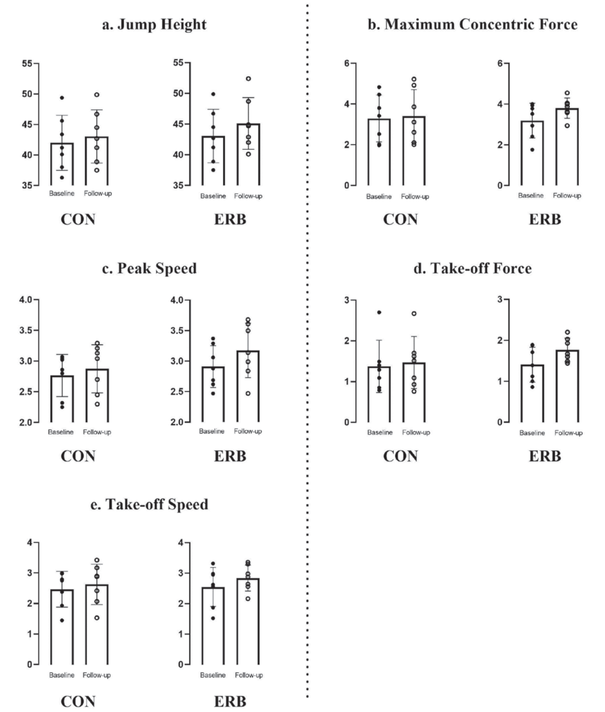

FIGURE 2. Mean (column) and SD for ERB (right) and non-ERB (left) with baseline and follow-up measurements for (a) jump height, (b) maximum concentric force, (c) peak speed, (d) take-off force and (e) take-off speed.

Significant outcomes for the main time effect were concluded for take-off force (p=0.002, ηp2=0.572); take-off speed (p=0.015, ηp2=0.404); maximum concentric force (p=0.02, ηp2=0.374); and peak speed (p=0.003, ηp2=0.528). However, no significant main time differences were found in jump height (p>0.05). Group-by-time interaction effect was found with a substantial increase in jump height of 4.54% (p=0.024, ηp2=0.359) and take-off force of 20.45% (p=0.039, ηp2=0.309) amongst the ERB

Table 2. Counter Movement Jump Variables

Variable	CON (Mean±SD.)				ERB (Mean±SD.)				Main Time Effect	Time x Group	Between-group
	Baseline	Follow-up	(p)	% Δ [g]	Baseline	Follow-up	(p)	% Δ [g]	p-value [ηp2]	p-value [ηp2]	p-value [ηp2]
Jump Height (cm)	42 ± 4.51	42.25 ± 5.01	0.61	0.60 % 0.052	43.05 ± 4.35	45.1 ± 4.2	0.006#	4.54% 0.48	0.06 (0.482)	0.024** (0.359)	0.432 (0.052)
Take off force (N)	1.37 ± 0.64	1.46 ± 0.63	0.17	6.56 % 0.14	1.40 ± 0.42	1.76 ± 0.28	0.009#	20.45% 0.99	0.002* (0.572)	0.039** (0.309)	0.55 (0.039)
Take-off Speed	2.46 ± 0.58	2.62 ± 0.66	0.38	6.50 % 0.25	2.54 ± 0.64	2.84 ± 0.42	0.046#	11.81% 0.55	0.015* (0.404)	0.41 (0.057)	0.64 (0.019)
Max. Concentric Force	3.29 ± 1.15	3.40 ± 1.29	0.22	3.34 % 0.09	3.19 ± 0.85	3.80 ± 0.49	0.005#	19.12% 0.87	0.020* (0.374)	0.90 (221)	0.77 (0.07)
Peak Speed.	2.76 ± 0.34	2.87 ± 0.39	0.12	3.99 % 0.30	2.91 ± 0.34	3.17 ± 0.44	0.068	8.93% 0.66	0.003* (0.528)	0.152 (0.163)	0.282 (0.09)

Note- abbreviations used; % Δ: percentage difference in baseline and follow-up records, [g]: Hedges' g, ηp2: partial eta squared; SD: standard deviation, #: significant baseline and follow-up measure (with-in group), *: significant main time effect between baseline and follow-up measure; **: significant time by group interaction group when compared to CON. Post-hoc analysis showed a significant increase in peak concentric force in CON but no other CMJ measures. In contrast, all CMJ measures except peak speed increased post-warm-up in the ERB group (p=0.005-0.046).

Discussion

The purpose of the current study was to investigate the effectiveness of including ERB during running drills on the potentiating lower limb force development capability of female track and field jumpers. Our hypothesis was supported by the current results, as CMJ height, take-off, and max concentric force were significantly improved in the ERB group.

The current findings agreed with previous studies that have reported enhancing movement performance after including ERB in movement-specific warm-ups. Aandahl et al. (2018) examined the effect of roundhouse kicking velocity using ERBs during warm-up of trained martial arts practitioners, suggesting a 3.3% increase in linear kicking velocity and higher muscle activation (EMG activity) of associated muscles, confirming PAP. More such studies (Chua et al., 2021; Lum & Chen, 2020) reported that performing CMJ with ERB that provided a resistance level of 10% body mass or more resulted in improved CMJ height and reduced time to take-off. In a recent study, Chua et al. (2021) reported that performing ERB with a resistance level of 10% body mass could also enhance stretch-shortening cycle (SSC) ability. Lum (2019) in a study on judo players with upper and lower body PAP suggests that targeted explosive exercises with ERB can effectively improve peak power. Earlier studies indicated that engaging in ERB-resisted movements during warm-up could enhance subsequent non-resisted movements acutely, particularly when these movements are biomechanically similar, as demonstrated by the significant PAP effects observed in previous research (Baxter, 2014; Stevenson, Warpeha, Dietz, Giveans, & Erdman, 2010). However, the novelty of the current study was that the movement during the warm-up performed with ERB (running drills) was not similar to the movement used for the performance measure (CMJ). Despite that, the inclusion of ERB was still beneficial. The present findings further support a recent study (Singh, Singh, & Sharma, 2023) that highlights the beneficial effects of ERB-induced potentiation during warm-up on CMJ (power) when utilizing lighter loads (less than body weight). This stands in contrast to previous assertions that exercises involving lighter loads do not effectively induce PAP (Hanson, Leigh, & Mynark, 2007; Weber, Brown, Coburn, & Zinder, 2008).

A possible reason for the present observation could be that the inclusion of ERB leads to greater muscle activation during the warm-up due to the increased intensity. It further resulted in a reduction in the recruitment threshold for subsequent movement. Although electromyographic activity was not measured, this phenomenon is reflected in the increased take-off and maximum concentric force, which were observed concurrently with the improved jump height in the ERB group. Furthermore, the findings of this study align with previous research (Chua et al., 2021; Earp, Newton, Cormie, & Blazevich, 2014), indicating that a loaded warm-up can enhance the stiffness of the lower limb tendons. This increase in stiffness facilitates a greater force contribution from the change of direction (COD), which is crucial for improving both take-off force and maximum concentric force, as demonstrated in the current results. Another possible explanation for the significant improvement in the time x group interaction of take-off force can be assigned to the nature of drills performed during the warm-up with ERB and the nature of participants. As the track and field jumpers are conditioned to produce greater take-off force, this may have emulated the take-off mechanics of the female track and field jumpers (Yang, Tang, Liu, & Pandy, 2023). The ergogenic effect of including ERB in running drills has great practical implications for track and field athletes in the practical setting. As athletes are unlikely to have access to heavy resistance equipment during competition, using ERB to enhance their warm-up effect would significantly reduce the logistical requirement. Hence, track and field coaches and athletes may consider using ERB for their competition warm-up regime.

Several limitations should be considered while interpreting the current results. Firstly, important time variables for understanding the mechanism for improving jump performance (Bishop, Jarvis, Turner, & Balsalobre-Fernandez, 2022) were not measured due to limitations in the equipment used. Secondly, it was ensured that the ERB load is around 10% of body mass; however, this parameter was not consistently controlled across all jumpers. This lack of control may have resulted in a greater external load than anticipated. Lastly, the current study used CMJ to indicate lower limb performance. It did not specifically measure track and field-specific performance such as 100-meter sprint, long and high jump, etc. Hence, it is still unknown if running drills with ERB would also directly enhance track and field-specific performance. Future research should aim to explore the impact of ERB-induced PAP on specific track and field performance measures to establish an apparent connection between ERB and track and field performance.

Conclusion

In conclusion, the current study showed that performing running drills with ERB can enhance lower limb force generation capability, as indicated by improved CMJ height and force data. Hence, due to the low logistical requirement, track and field coaches and athletes may consider including ERB when performing running drills as part of their warm-up, specifically during competition settings.

Conflict of Interest
The authors have no relevant financial or non-financial interests to disclose.

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Ethics approval
This study was performed in line with the principles of the Declaration of Helsinki. The Ethics Committee of Lakshmibai National Institute of Physical Education, Gwalior, India. Approved the study. LNIPE/DRC/MPE/2021-22/816

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