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Post-Activation Performance Enhancement in Pull-Up Exercise with Elastic Resistance Training in Tactical Personnel

Mejora del rendimiento posterior a la activación en ejercicios de dominadas con entrenamiento contra resistencia elástica en personal táctico

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Abstract. The Pull-up (PU) is a multi-joint upper body exercise that is included in the physical fitness assessments for tactical occupations such as police, firefighters, and military personnel. This study aimed to evaluate the post-activation performance enhancement (PAPE) in the PU exercise using elastic resistance training (ERT) and traditional resistance training (RT). A total of 18 resistance-trained male firefighters (28.3 [5.6] years; 178.1 [6.8] cm; 78.1 [8.2] kilograms; 24.6 [2.4] kg·m^{-2}) participated in the study and performed four PAPE protocols in a cross-over fashion. Two protocols consisted of three sets of 3 repetitions at 75 and 85% of the maximum repetition (RM) in the lat pull down (LPD-M and LPD-H, respectively). The other two protocols consisted of three sets of 3 repetitions using elastic bands for vertical traction (VTEB) at "moderate" (VTEB- M) and "hard" intensity (VTEB-H), based on the Thera Band perceived exertion scale. Repetitions until failure in the PU exercise were measured before and after the application of the four protocols, with an 8-minute pause before and after the PAPE. Results showed a significant increase on repetitions until exhaustion after all PAPE protocols: LPD-M (P=0.007, d=0.19), LPD-H (P=0.023, d=0.17), VTEB-M (P=0.01, d=0.13) and VTEB-H (P=0.001, d=0.28). The use of ERT and traditional RT at moderate and high intensities represent a proper stimulus for the generation of PAPE in the PU.
Keywords: Physical performance, conditioning activity, warm-up exercise, muscle power

Resumen. El Pull-up (PU) es un ejercicio de la parte superior del cuerpo de múltiples articulaciones que forma parte de las evaluaciones de aptitud física para ocupaciones tácticas (p. ej., policía, bomberos y personal militar). Este estudio tuvo como objetivo evaluar la mejora del rendimiento posterior a la activación (PAPE) en el ejercicio PU utilizando entrenamiento de resistencia elástica (ERT) y entrenamiento de resistencia tradicional (RT). Un total de 18 bomberos varones entrenados en resistencia (28,3 [5,6] años; 178,1 [6,8] cm; 78,1 [8,2] kilogramos; 24,6 [2,4] kg·m-2) participaron en este estudio y realizaron cuatro protocolos PAPE de forma cruzada. Dos protocolos consistieron en tres series de 3 repeticiones al 75 y 85% de la repetición máxima (RM) en el jalón lateral (LPD-M y LPD-H, respectivamente). Los otros dos protocolos consistieron en tres series de 3 repeticiones sobre tracción vertical utilizando bandas elásticas (VTEB) en intensidad "moderada" (VTEB-M) y "dura" (VTEB-H), según la escala de esfuerzo percibido Thera Band. Se midieron repeticiones hasta el fallo en PU antes y después de la aplicación de los cuatro protocolos con una pausa de 8 minutos antes y después de la PAPE. Hubo un aumento significativo de repeticiones hasta el agotamiento después de todos los protocolos PAPE: LPD-M (P=0,007, d=0,19), LPD-H (P=0,023, d=0,17), VTEB-M (P=0,01, d=0,13) y VTEB-H (P=0,001, d=0,28). El uso de ERT y RT tradicional a intensidades moderadas y altas representan un estímulo adecuado para la generación de PAPE en la UP.
Palabras clave: rendimiento físico, actividad de acondicionamiento, ejercicio de calentamiento, potencia muscular

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Introduction

The Pull-up (PU) is a multi-joint upper body exercise that not only increases strength in the muscles involved in the pulling pattern (e.g., latissimus dorsi, biceps) but also improves shoulder girdle stability (Harman, 2010; Sanchez-Moreno et al., 2016). It has been a part of the physical fitness assessment for admission into state security forces in different international institutions. For example, military infantry units in Poland (Tomczak et al., 2012), Croatia (Sporis et al., 2012), Sweden, (Larsson et al., 2012), Finland (Kinnunen et al., 2012) and Canada (Carlson & Jaenen, 2012). Moreover, the PU is used in physical battery test for the recruitment of the USA Navy www.navy.mil, Fire Department (McGill et al., 2013), and Task Forces such as the Federal Bureau of Investigation (FBI) (Knapik et al., 2011). It is also utilized to assess strength in boys and adult men attending military service academies in the USA (Youdas et al., 2010). During these assessments, the number of PU repetitions is scored on a scale, where a minimum threshold must be reached, and the highest score is achieved when the number of repetitions surpasses a pre-established maximum. The testing procedures are usually conducted under various conditions, including room temperature and social pressure, with a high number of applicants and limited time available for each individual's assessment. Generally, applicants are given only two attempts with minimal recovery time between them. Every single repetition can greatly impact the total score obtained and potentially determine success or failure.

Therefore, incorporating a prior activation work that can enhance performance and consequently increase the number of repetitions performed may be an effective

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strategy. In this regard, Post Activation Performance Enhancement (PAPE) emerges as a suitable performance optimization strategy (Blazevich & Babault, 2019). Various underlying physiological mechanisms have been proposed to explain this phenomenon, as highlighted in a recent review (Blazevich & Babault, 2019); a) changes in myosin light chain phosphorylation; b) increased muscle temperature; c) changes in muscle pH; d) alterations in muscle blood flow and/or fluid content; e) increased neural drive/muscle activation; and f) enhanced muscle-tendon stiffness. Furthermore, initiating a maximal o near-maximal muscular action before the test, such as the PU, may increase the probability of triggering an action potential, resulting in higher postsynaptic potentials that can generate greater force output (Wilson et al., 2013). This increased excitability favors subsequent activities, mainly those requiring strength-speed or power. It has been demonstrated that high loads, typically exceeding 80% of maximum repetition (1RM), are required for optimal PAPE generation (Dobbs et al., 2019; Tillin & Bishop, 2009); however, not all studies have yielded consistent results (Carbone et al., 2020). Traditionally, the 1RM test is employed to determine the required intensity and make relevant calculations; however, implementing this methodology for elastic resistance training (ERT) can be challenging (Newsam et al., 2005).

The PAPE phenomenon has been observed in various types of actions, such as jumping (Gouvea et al., 2013; Kobal et al., 2019; Vargas-Molina et al., 2021), sprinting (Carbone et al., 2020; Dello Iacono & Seitz, 2018), and even long-distance running (Boullosa et al., 2018). However, the majority of research on PAPE has focused on the lower body, with limited investigations conducted on the upper body (Esformes et al., 2011; Kilduff et al., 2007; Markovic et al., 2008; Sarramian et al., 2015; Ulrich & Parstorfer, 2017). Implementing a PAPE protocol requires access to equipment capable of generating high loads, which may not always be feasible. On the other hand, ERT equipment is not only convenient to handle and transport but also it has shown similar strength benefits compared to conventional weight lifting equipment (Lopes et al., 2019). Variable or accommodated resistance training (RT) protocols have been applied with positive results, as observed in the case of ERT (Mina et al., 2019; Peng et al., 2020; Wyland et al., 2015). It has been reported that ERT can serve as a variation of the conventional lat pull-down (LPD) exercise (Iversen et al., 2017), and given the kinetic similarities and correlation found between the PU and the LPD exercises (r=0.62, P<0.01) (Sanchez-Moreno et al., 2016), it can be suggested that they are interchangeable exercises/movements for various goals, including triggering PAPE. To the best of our knowledge, the effects of prior muscular activity using ERT on the generation of PAPE in PU exercise has not been investigated yet.

The aim of this study was double; i) to investigate if the generation of PAPE can improve the number of repetitions in the PU exercise, and ii) to compare the effects on PAPE of a protocol based on traditional LPD exercise at moderate (LPD-M) and high intensity (LPD-H) with two protocols utilizing vertical traction elastic bands (VTEB) at "moderate" (VTEB-M) and "hard" intensity (VTEB-H) based on the Thera-Band® perceived exertion scale (Thera Band RPE). We hypothesized that applying PAPE through VTEB or LPD would yield positive results in the PU exercise, with no differences observed between the protocols.

Material and methods

Experimental Approach to the Problem

During the initial two visits to the laboratory, the participants underwent a familiarization session, a 1RM test in the LPD exercise, and the anthropometric measurements were taken. To quantify the intensity during the ERT protocols, the Thera Band RPE was used for the VTEB (Colado et al., 2014), recording subjective ratings of "hard" and "moderate". Since there is no available scientific basis to establish a correlation between the Thera Band RPE and the percentage of 1RM, the "moderate" and "hard" values were used as subjective perceived exertion levels, similar to those achieved with 75 and 85% of the 1RM, respectively. Bands were added incrementally until the participants could perform the three repetitions according to the prescribed effort scale.

During the second laboratory visit, the participants were randomly assigned to one of four groups (www.randomizer.org). The third, fourth, fifth, and sixth sessions involved inducing PAPE in the VTEB-M, VTEB-H, LPD-M and LPD-H groups, respectively. The overall methodology was similar for all groups, with participants crossing over to different protocols. All laboratory visits were conducted at the same time of day and monitored by the same group of researchers (Figure 1). Additionally, the participants were instructed to maintain their regular nutritional habits and level of physical activity throughout with the study to prevent fluctuations in total body mass. As the PU exercise is related to relative strength and body mass (Pate et al., 1993), sudden changes in body mass can affect the results. Therefore, total body mass was assessed before each session, and changes exceeding 300 g between sessions were not allowed.

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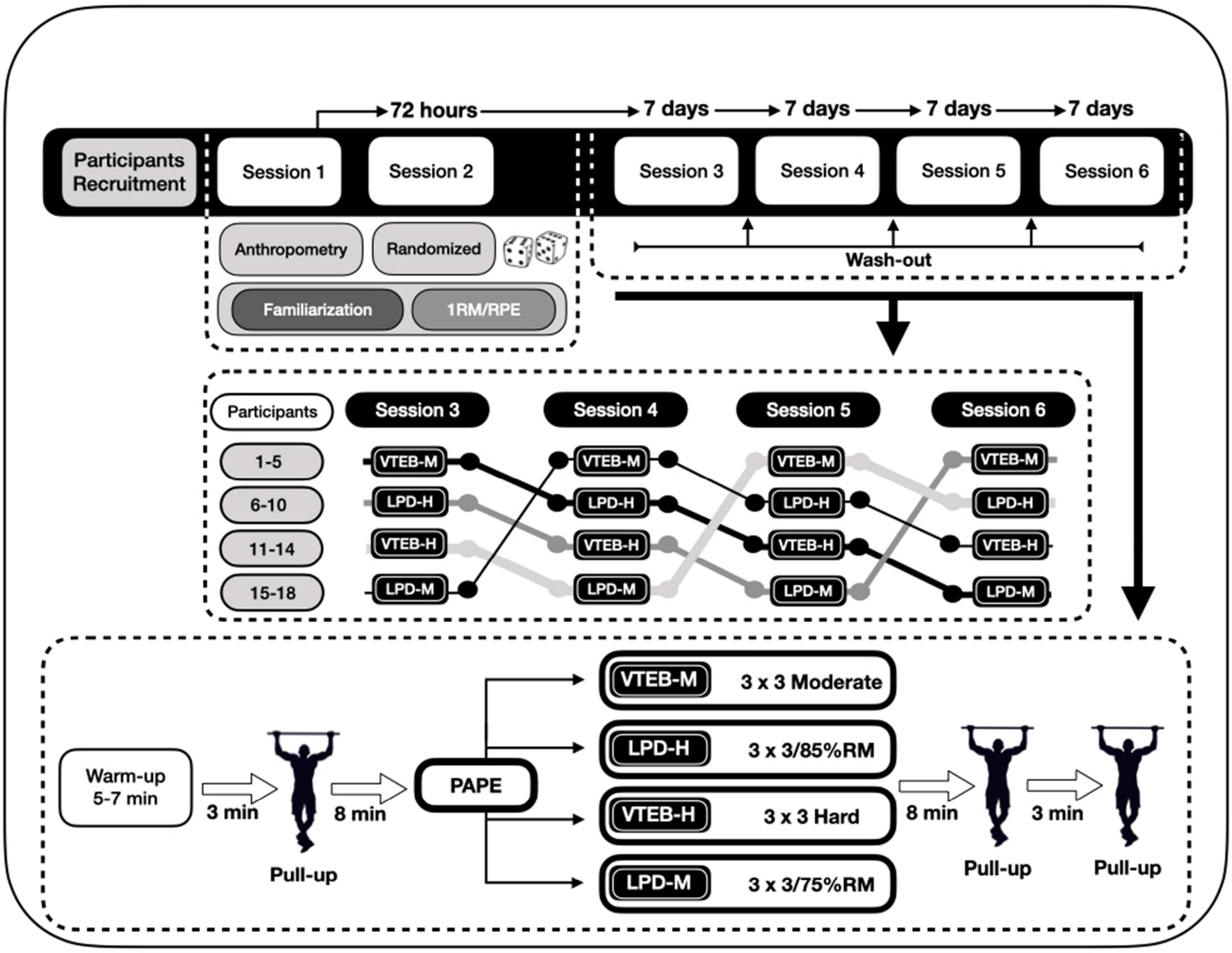

Figure 1. Representation of the study design.

Participants

A total of 18 healthy resistance-trained men (28.3 [5.6] years; 178.1 [6.8] cm; 78.1 [8.2] kilograms; 24.6 [2.4] kg·m^{-2}, ≥2 years of experience in RT) participated in this study. All participants were informed about the experimental procedures and potential risks, and they signed an informed consent form. The study procedures adhered to the Declaration of Helsinki (WMA, 2013), and the research protocol was approved by the Ethics Committee of the EADE- University of Wales Trinity Saint David (EADECAFYD2020-5).

The exclusion criteria for participant selection were as follows: a) age outside the range of 18 to 35 years; b) less than two years of experience in high-intensity RT, specifically with PU and LPD variation exercises; c) use of doping agents (e.g., androgenic anabolic steroids) within the previous two years; d) recent traumatic injury to the neuromuscular or musculoskeletal structures of the upper limb (e.g., shoulder or elbow) within the past six months to the study. Participants were instructed not to engage in exercise or consume stimulant substances (e.g., caffeine-containing drinks) prior to the tests. A summary of the participant demographics is shown in Table 1.

Table 1.
Participants baseline characteristics.

Variable	Mean	SD
Age (years)	28.39	5.60
Stature (cm)	178.05	6.84
BM (kg)	78.19	8.29
BMI (kg·m^{-2})	24.69	2.44
FM (%)	12.46	4.50
VTEB-M (repetitions)	14.11	3.62
VTEB-H (repetitions)	13.39	3.56
LPD-M (repetitions)	13.89	3.35
LPD-H (repetitions)	13.72	3.51
RM (kg)	90.56	11.23
Relative strength	1.16	0.12

BM: body mass; BMI: body mass index; FM: fat mass; VTEB-M: vertical traction at moderate intensity; VTEB-H: vertical traction at hard intensity; LPD-M: lat pull down at moderate intensity; LPD-H: lat pull down at high intensity.

Procedure

Participants were informed about the use of the Thera Band RPE scale. Anthropometric data were obtained, including stature using a SECA 220 stadiometer (Hamburg, Germany), and body mass using a Tanita RD-545 digital scale (Tokyo, Japan). The 1RM was tested for the LPD exercise was assessed during the initial visit, and the 75% and 85% of 1RM were calculated. In the second session, participants were randomly allocated either in the LPD-H, LPD-M, VTEB-H, or VTEB-M protocols for the third, fourth, fifth, and sixth sessions. All measurements were carried out at the laboratory of the EADE-University of Wales Trinity Saint David.

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Measures

Maximum repetition test of Lat Pulldown

The 75% and 85% of the 1RM for the LPD were calculated using equipment from Gervasport (Gervasport, Madrid, Spain). A warm-up protocol was implemented following the laboratory methods described by (Vargas-Molina et al., 2020). It included a low-intensity stationary bicycle warm-up (BH fitness, Bilbao, Spain) for 7-10 minutes, followed by a specific warm-up consisting of 12-15 repetitions at 40% of the perceived 1RM. Subsequently, participants performed two or three sets of two to three repetitions at 60-80% of 1RM, followed by sets of one repetition until they achieved their 1RM, with 3-5 minutes of rest interval between each attempt.

During the exercise, participants were seated, and the machine's support was adjusted on their thighs to stabilize the lower limb. They were instructed to use a closed pronation grip, approximately 1.5 times their biacromial width, and the distance of the grip was measured in centimeters from the ends of the handle to the little fingers to ensure consistency in the technique, as changes in grip width can impact muscle activation patterns (Andersen et al., 2014). The lifting motion started with the elbows fully extended above the head and ended when the bar touched the sternum. Participants were instructed not to extend their trunk beyond 135°, and were encouraged verbally to perform the pull in a vertically downward direction with maximum intended speed while maintaining proper technique.

Perceived exertion

Once the participants were familiarized with the proper exercise technique, the Thera Band RPE scale for resistance exercise with elastic bands (Colado et al., 2014) was used to determine exercise intensity. The elastic bands were attached to a specially designed structure that was 2.35 meters tall. Participants were positioned 20 cm away from a mark on the floor, aligned with the point where the band was attached. The exercise was performed in a standing position with knees semi-flexed and maintaining a neutral spine. The procedure began with the red or yellow band and a wide grip width. Participants were instructed to perform 8-10 repetitions at a lower effort perception on the scale ("easy" and "low") to establish a baseline. After the first set, the intensity gradually increased until reaching a "moderate" effort perception. This was achieved by either adding bands of different colors (blue, silver, black, or gold) (Colado et al., 2014), or by shortening the grip length (Calatayud et al., 2015). The decision on band color and grip length was made by the supervising researcher based on the morphological characteristics of the bands. The same procedure was used to locate the "hard" effort perception. During the exercise, participants began with their elbows fully extended above their head and hands in a neutral position. The pulling motion involved keeping the elbows close to the body between approximately 0 and 45°, and at the end of the movement, the hands should be in a pronated position. Only repetitions performed throughout the full range of motion (ROM) were considered valid.

Pull Up Exercise Protocol

The PU was performed with the participant hanging vertically from a bar with a diameter of 2.5 cm, following the recommendation of (Halet et al., 2009). A pronation grip was used, with a grip width close to 1.5 times the biacromial width. To standardize the grip distance, measurements were taken from the bar's corners to the little finger and marked with tape, and this measurement was recorded to maintain consistency in subsequent sessions. The movement started with the elbows fully extended and the trunk in a neutral position. Only repetitions where the chin exceeded the bar were counted (Halet et al., 2009; Youdas et al., 2010). Verbal cues were provided to the participants, such as "keep the chest high", "squeeze the shoulder blades down, back and in", and "pull the arms and elbows to the hips". No metronome was used to control the rhythm; instead, participants were instructed to choose their own execution speed. Interestingly, a study by (Lachance & Hortobagyi, 1994) found that participants who performed repetitions at their own pace completed 96% more repetitions in the PU and did so in 16% less time compared to those following controlled speeds.

Relative Strength

To calculate the relative force, the maximum weight obtained in the lat pulldown (1RM) was divided by the body mass (kg).

Experimental Intervention

PAPE Induction

In the third, fourth, fifth, and sixth sessions, the protocols were implemented in a randomized fashion. Similar to sessions one and two, a warm-up was conducted. Three minutes after completing the warm-up, the participants performed as many PUs as they could under the supervision of the researcher, with the condition that only full ROM repetitions would be counted.

Following the PU test, an eight-minute break was then taken to implement the PAPE protocols. The LPD protocol followed the same technical indications as in the familiarization phase, except that the trunk was kept at approximately 135º from to the hip during each repetition. Both protocols consisted of three sets of three repetitions, with a three-minute rest between sets, based on previous research (Evetovich et al., 2015; Kilduff et al., 2007; Kilduff et al., 2008). The intensity for the LPD group was between 75 - 85% 1RM, while the VTEB-H and VTEB-M protocols were performed with the loads established in the familiarization phase. Thera-Band elastic bands (Hygenic Corporation, Akron, OH, USA) in various colors (red, blue, black, silver, and gold) were used for this purpose. After completing the third set of the PAPE protocols, another eight-minute rest period took place. Subsequent-

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ly, two sets of PUs were performed, with a three-minute pause between them, until technical failure was reached. The difference in the number of repetitions before and after the PAPE protocols were recorded. A research assistant collected the data in an Excel spreadsheet according to the provided instructions.

Analysis

Results are expressed as mean, standard deviation, and 95% confidence intervals for the mean (95% CI). The normality of the data was assessed using the Shapiro-Wilk test. Baseline variables were compared using the Friedman test for intra-subject analysis, with exact unilateral significance values, considering the time factor of the three measurements obtained from each protocol (Pre, Set 1, Set 2). To determine significant differences between each pair of measurement time points, a Wilcoxon test with the Bonferroni correction (α=0.0083) was performed, as recommended by (Pallant, 2007). Inter-subject comparisons for the different protocols were made using the Kruskal-Wallis test. The effect size (ES) was calculated using Cohen's d test for intra-group interactions, (pre-post effect). The ESs were categorized as follows: trivial (ES <0.20); small (0.20 ≤ ES < 0.49); moderate (0.50 ≤ ES < 0.79); large (0.80 ≤ ES < 1.19), and huge (ES > 1.19).

Correlations between the variables of interest were calculated using the Pearson's r and the Spearman's Rho (ρ), the latter being more appropriate for measurements taken from ordinal scales. A significance level of <0.05 was assumed for all statistical tests. The analyses were performed using SPSS software (Version, 25, SPSS, IBM corporation, Armonk, New York, USA) and the graphs were created using GraphPad Software version 6 (GraphPad Software, California, USA).

Results

The values obtained in each intervention were; i) VTEB-M [$\chi^2(2)=32,37$; P<0.001] showed statistically significant differences in all pairs, Pre-set1 (P= 0.010; d= 0.13), Pre-set2 (p<0.001; d=1.77) and set1-set2 (P<0.001; d=1.95); ii) VTEB-H [χ^2 (2) = 34.353; P<0.001], differences in pairs Pre-set1 (P<0.001; d=0.28), Pre-set2 (P<0.001; d=1.49) and set1 - set2 (P<0.001; d=1.73); iii) LPD-M [$\chi^2(2)=31,433$; P<0.001] also showed differences in all pair comparisons, Pre-set1 (P<0.001; d=0.19), Pre-set2 (P<0.001; d=1.88) and set1-set2 (P<0.001; d=2.04); iv) finally, the LPD-H protocol [$\chi^2(2)=32.516$; P<0.001] showed significant differences between Pre-set1 (P=0.023; d=0.17), Pre-set2 (P<0.001; d=1.84) and set1-set2 (P<0.001; d=2.02). In all protocols, significant differences are seen in the three measurements of PU; however, between pre-set 1 and set 1-set 2 pairs a significantly decrease in the number of PU until failure was detected (Table 2).

Table 2.
Intra-subject comparisons by PAPE protocol

Protocol	Sets	Mean (SD)	r_k	χ^2	*d-1*	*d-2*	*d-3*	*P*
VTEB-M	Pre	14.11 (3.62)	2.28	32.375	0.13	1.77	1.95	<0.001
	Set 1	14.61 (3.60)	2.72					
	Set 2	8.83 (2.12)	1					
VTEB-H	Pre	13.39 (3.56)	2.11	34.353	0.28	1.49	1.73	<0.001
	Set 1	14.44 (3.86)	2.89					
	Set 2	8.83 (2.43)	1					
LPD-M	Pre	13.89 (3.35)	2.25	31.433	0.19	1.88	2.04	<0.001
	Set 1	14.56 (3.53)	2.75					
	Set 2	8.72 (1.96)	1					
LPD-H	Pre	13.72 (3.51)	2.33	32.516	0.17	1.84	2.02	<0.001
	Set 1	14.33 (3.58)	2.67					
	Set 2	8.50 (1.94)	1					

VTEB-M: vertical traction with moderate intensity; VTEB-H: vertical traction with hard intensity; LPD-M: lat pull down with moderate intensity; LPD-H: lat pull down with high intensity; d = effect size of the differences between sets, where; Pre-Set 1=*d-1*; Pre-Set 2=*d-2*; Set 1-Set 2=*d-3*; r_k = Spearman's Rank Correlation Coefficient.

Based on the results of the Kruskal-Wallis test, there were no statistical differences between the four protocols: Pre [$\chi^2(3)=0.606$; P>0.05], set1 [$\chi^2(3)=0.181$; P>0.05], and set 2 [$\chi^2(3)=0.266$; P>0.05]. Figure 2 shows the number of repetitions by sets and by protocols. Complementary, body mass was negatively correlated in almost all the variables referring to the PU of the different protocols applied, with values of; VTEB-M Pre (ρ=-0.46, P<0.05), VTEB-M Set 1 (ρ=-0.479, P<0.05), VTEB-M Set 2 (ρ=-0.707, P<0.01), VTEB-H Pre (ρ=-0.463, P>0.05), VTEB-H Set 1 (ρ=-0.558, P<0.05), VTEB-H Set 2 (ρ=-0.550, P<0.05), LPD-M Pre (r=-0.547, P<0.05), LPD-M Set 1 (r=-0.554, P<0.05), LPD-M Set 2 (r=-0.483, P<0.05), LPD-H Pre (r=-0.471, P<0.05), LPD-H Set 1 (r=-0.512, P<0.05), LPD-H Set 2 (r=-0.699, P<0.01). These results indicate a moderate to large correlation between body mass (kg) and the PU-related variables, showing that individuals with higher body mass tend to perform fewer repetitions in the PU exercise (Table 3). In the lat pulldown, there were positive correlations between body mass and 1RM (r=0.566, P<0.05) and between relative strength and 1RM (r =0.566, P<0.01), meaning that higher body mass is associated with higher the 1RM values, and greater relative strength with higher 1RM values.

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Table 3.
Correlations between PU variables and Relative Strength

	VTEB-M (rho)			VTEB-H			LPD-M			LPD-H		
	Pre	Set 1	Set 2	Pre	Set 1	Set 2	Pre	Set 1	Set 2	Pre	Set 1	Set 2
Relative Strength	0.597**	0.618**	0.447	0.600**	0.735**	0.450	0.658**	0.646**	0.608**	0.631**	0.619**	0.086

VTEB-M: vertical traction at “moderate” intensity; VTEB-H: vertical traction at “hard” intensity; LPD-M: lat pull down at moderate intensity (75% 1RM); LPD-H: lat pull down at high intensity (85% 1RM). The correlation is significant at the level < 0.05 * and <0.01 **.

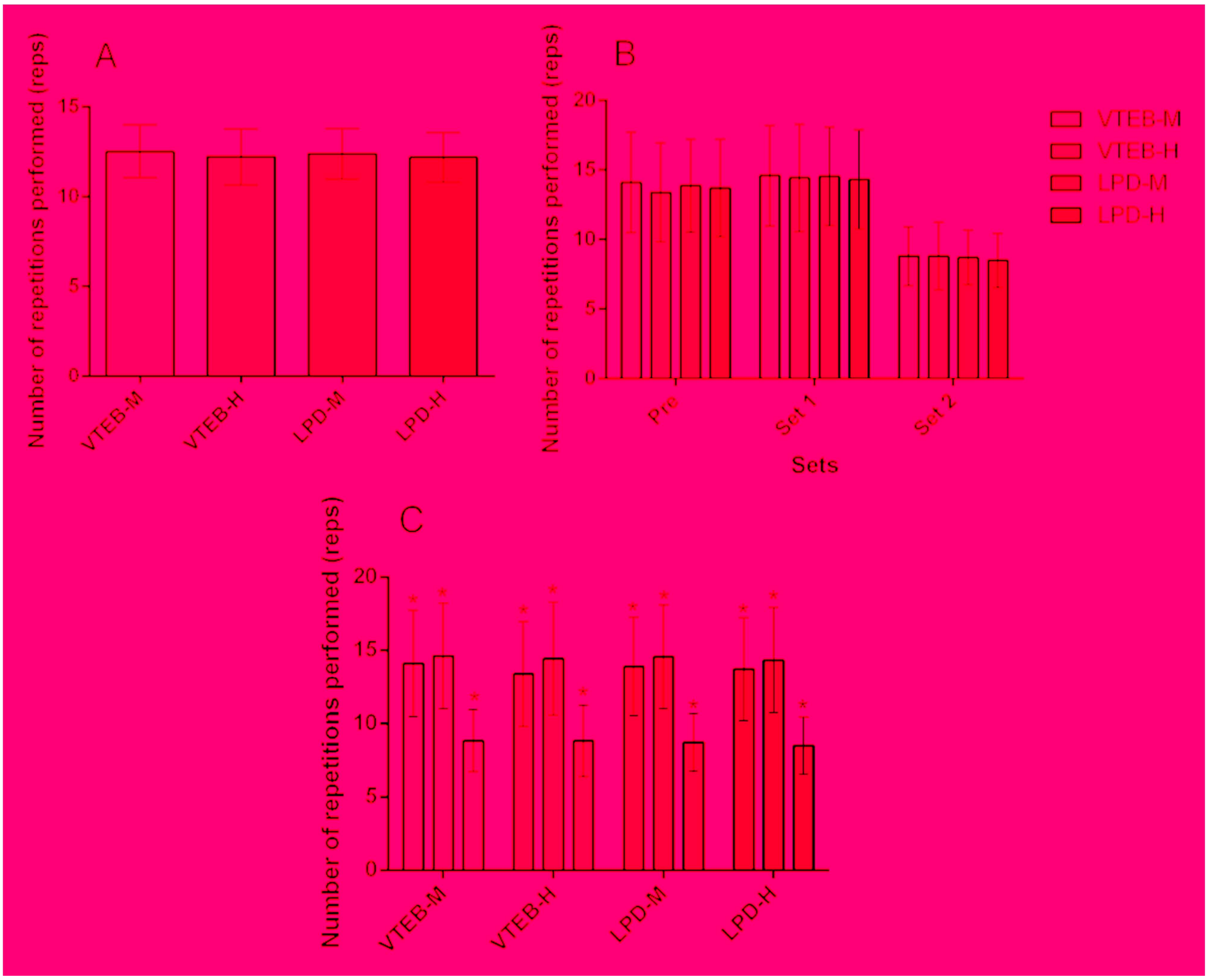

Figure 2. Number of repetitions per PAPE protocol.

Discussion

The research aimed to investigate whether the application of PAPE through ERT or LPD would increase the number of repetitions in the PU exercise in resistance-trained participants. Our research showed significant intra-subject effects in all protocols: VTEB-M (P<0.01, d=0.13), VTEB-H (P<0.001, d=0.28), LPD-M (P<0.007, d=0.19), and LPD-H (P<0.023, d=0.17). The effect of PAPE on the number of repetitions in PU has not previously been investigated, on the contrary, in other research (Sarramian et al., 2015), used this exercise as a means of activation on national level swimmers. The effects of PAPE have been reported on performance related variables such as the vertical and horizontal jump and the shot put distances or in the sprint times (Cuenca-Fernandez et al., 2018; Evetovich et al., 2015), sprint velocity (Cuenca-Fernandez et al., 2020) and also peak power, peak force and rate of force development (Esformes et al., 2011; Farup & Sorensen, 2010). However, few studies have tested the increase in the number of repetitions as an effect of PAPE. One study by (Sevilmis, 2019) found a significant difference in the bench press when PAPE was applied through eccentric loading, resulting in a favorable increase in the number of repetitions (17.25 [3.93] vs. 18.28 [4.11]). Our study yielded similar results in the inter-protocol comparison for the PU exercise (13.78 [3.45] vs. 14.49 [3.57]). The PU is a self-loading exercise where participant must lift their own body mass against gravity, primarily using the flexor muscles. Progression in this exercise becomes challenging once a certain number of repetitions is reached. Therefore, the increase in the performance of the PU exercise is typically limited to only 1 or 2 repetitions; However, even a single

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additional repetition can be crucial for determining eligibility in certain tactical forces.
On the other hand, most of the researchers have used traditional equipment such as bars, weights, or pulleys to generate PAPE. In contrast, our research utilized ERT, which has been reported to increase vertical jump power (Nickerson et al., 2019). Additionally, improvements were found in upper limb performance, specifically in Bench throw peak power, after the banded press bench was performed (Mason et al., 2017).

All four protocols tested in our research demonstrated favorable activation alternatives without significant inter-protocol differences. However, the additional advantage of ERT lies in its portability and easy implementation in practical settings. ERT resulted in significant increases in both VTEB-H and VTEB-M protocols, with the VTEB-H protocol showing a larger effect size (d=0.28 vs d=0.13).

It should be noted that among the 18 participants in the VTEB-M protocol, eight of them were able to perform one additional repetition between the pre and post measurements, and one participant even achieved two more repetitions. This indicates that 50% of the participants experienced subsequent activation. In the VTEB-H protocol, nine obtained achieved one more repetition, and five achieved two more repetitions, resulting in 77% of activated participants, with 27% of them achieving two additional repetitions. Additionally, in the LPD protocol at 75% 1RM, 61% of the participants experienced an improvement in the PAPE effect, while in the protocol at 85% 1RM, the improvement was observed in 38% of the participants. Therefore, the use of elastic bands at different intensities provides beneficial effects to at least half of the participants.

Previous studies have suggested that athletes with higher levels of muscle strength may experience a greater magnitude of PAPE effect (Seitz & Haff, 2016). In our research, we calculated the relative strength of the participants and found a positive correlation between relative strength levels and the VTEB-H. This correlation suggests that athletes with higher levels of strength may require a higher intensity of previous activity to induce a greater PAPE effect. However, it is important to exercise caution in interpreting this finding, as there is a lack of previous data correlating relative strength and PAPE.

Limitations

The first notable limitation is the small sample size of the study, and furthermore, the sample was not specifically selected to assess the pull-up test as an admission criterion for certain task forces (e.g., fire service). Secondly, the electromyographic activity of the agonist muscles involved in the pull-up movement was not recorded, preventing the identification of which muscles generated the PAPE effect with greater emphasis. Thirdly, a body composition study was not conducted to determine fat-free mass or muscle mass. However, to mitigate this limitation, the study calculated the relative strength value. Finally, it should be acknowledged that the movement velocity during the exercise was not monitored, which could have provided additional insights into the results, considering the importance of this parameter for performance (Sanchez-Moreno et al., 2020).

Measuring training load accurately has been a challenge in the field of exercise training (Gonzalez-Badillo et al., 2017; Sanchez-Medina & Gonzalez-Badillo, 2011; Sanchez-Moreno et al., 2020). In recent years, measuring the velocity of the first repetition has emerged as a precise method to determine the training intensity since the percentage of 1-RM can vary from day to day (Baena-Marin et al., 2022). However, this study is limited in that it does not measure force through the velocity-load curve, which would be valuable to analyze in the future research, despite studies indicating the advantages of training PU under a movement velocity-based control (Sanchez-Moreno et al., 2020; Sanchez-Moreno et al., 2016).

Conclusions

Our findings indicate that utilizing ERT at “moderate” and “hard” intensities on the Thera Band RPE stress scale are effective options for inducing PAPE in the PU exercise, making them suitable for admission testing in task forces considering efficiency and portability.

Practical Applications

The utilization of VTEB-H, performed 8 minutes prior to a PU test, elicits a significant PAPE effect. These results suggest that employing a vertical pulling exercise with an elastic band is both effective and convenient. The ease of transportation coupled with the challenges of generating activation before tests using conventional materials such as pulleys, bars, or weights, offers an alternative for enhancing performance scores in task force admission assessments.

List of abbreviations

ERT: elastic resistance training
RT: resistance training
PAPE: Post Activation Performance Enhancement
BM: body mass
BMI: body mass index
FM: fat mass
VTEB-M: vertical traction at moderate intensity
VTEB-H: vertical traction at hard intensity
LPD-M: lat pull down at moderate intensity
LPD-H: lat pull down at high intensity.

Ethics approval and consent to participate

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and research

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protocol was reviewed and approved by the Ethics Committee of the EADE- University of Wales Trinity Saint David (EADECAFYD2020-5).

Availability of data and materials

The data that support the findings of this study are available upon request from the corresponding author.

Conflicts of Interest

S.V.-M receives honoraria for personalized training services and is manager of a physical fitness center. D.A.B. has conducted academic-sponsored research on resistance training and has received honoraria for selling linear position transducers and speaking about exercise sciences at international conferences and private courses. M.G-S. receives honoraria for rehabilitation services and is the current managing director of Eshmún Sport Clinic, a physiotherapy and exercise center. The other authors declare no conflict of interest.

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Authors' contributions

Conceptualization, S.V.M and M.G.S.; Methodology, S.V.M.; Investigation, I.C.M and L.C; Analysis and data interpretation: U.S, S.V.M. and D.A.B; Writing—original draft preparation, S.V.M and I.C.M.; Writing—review and editing, S.V.M, I.C.M., L.C., U.S., D.A.B., A.R-J. and M.G.

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