Acute effect of Complex Training protocol on grenade throwing velocity on military pentathletes

Álvaro C. Huerta Ojeda[1,2,3,6], Luis J. Chirosa Ríos[2,3], Rafael Guisado Barrilao[3,4], Ignacio J. Chirosa Ríos[2,3], Pablo A. Cáceres Serrano[5]

[1]Facultad de Educación, Universidad de las Américas sede Viña del Mar, Chile. [2]Departamento de Educación Física y Deporte, Universidad de Granada. [3]Grupo de Investigación y Desarrollo en Actividad Física, Salud y Deporte CTS 642, Universidad de Granada. [4]Departamento de Enfermería, Universidad de Granada. [5]Departamento de Psicología, Pontificia Universidad Católica de Valparaíso, Chile. [6]Centro de Capacitación e Investigación Deportiva Alpha Sports, Chile.

Received: 11.12.2015
Accepted: 02.03.2016

Summary

Introduction: Complex Training (CT) has been used to achieve Post-activation Potentiation (PAP) of physical capabilities and, in doing so, improve athletes' sports performance, however few studies have taking into account an activation with intensities in power zones.
Objective: To determine the acute effect of Complex Training on bench press on grenade throwing velocity on military pentathletes.
Method: Nineteen military pentathletes were part of the study. The study had a quasi-experimental intra-subject design. The Complex Training protocol consisted of 4 sets of 5 repetitions at 30% one Repetition Maximum (1RM) + 4 repetitions at 60% 1RM + 3 grenade throws with a 15-second rest. The measured variables were: maximum velocity and grenade throw average through a Radar Gun, peak power and bench press average through a lineal encoder and post-effort Lactate [La]. For the statistical analysis repeated measures of ANOVA was used, and for the size of the effect an Eta-squared test was used.
Results: The maximum velocity, average velocity and peak power did not show significant modifications between the control series and the 4 experimental series ($p = 0.90$; $p = 0.94$; $p = 0.06$). However, the average power of bench press and [La] showed a significant fall ($p = 0.002$: $p = 0.001$).
Conclusions: The results of the study did not show effects in Complex Training on maximum and average velocity of grenade throwing in military pentathletes; hence, Post Activation Potentiation was not reached in the muscles involved in the projectile throwing. General and local fatigue was also observed during the application of the protocol. It is recommended to continue researching on activation loads, performing changes in the intensity and pauses of each load.

Key words:
Complex Training.
Post activation potentiation.
Explosive strength.
Grenade throwing.

Efecto agudo de un protocolo de *Complex Training* sobre la velocidad del lanzamiento de la granada en pentatletas militares

Resumen

Introducción: El *Complex Training* se ha utilizado para lograr la potenciación post-activación (PAP) de las capacidades físicas y, al hacerlo, mejorar el rendimiento deportivo de los atletas. Sin embargo pocos estudios han considerado una activación con intensidades en zonas de potencia.
Objetivo: Determinar el efecto agudo de un protocolo de *Complex Training* en *press banca* sobre la velocidad del lanzamiento de la granada en pentatletas militares.
Método: Diecinueve pentatletas militares fueron parte del estudio. El estudio tuvo un diseño cuasi experimental intrasujeto. El protocolo de *Complex Training* consistió en: 4 series de 5 repeticiones al 30% de 1RM + 4 repeticiones al 60% de 1RM + 3 lanzamientos de granada separada por 15 segundos. Las variables medidas fueron: velocidad máxima (Vmax) y promedio (Vpro) del lanzamiento de la granada a través de un Radar Gun, las potencias máximas (Pmax) y promedio (V pro) en *press banca* a través de un encoder lineal y concentraciones de lactato [La] post esfuerzo. Para el análisis estadístico se utilizó *ANOVA de medias repetidas* y para el tamaño del efecto la prueba *Eta Cuadro Parcial.*
Resultados: La Vmax, Vpro y Pmax no presentaron modificaciones significativas entre la serie control y las cuatro series experimentales ($p = 0{,}90$; $p = 0{,}94$; $p = 0{,}06$). Sin embargo las Ppro de *press banca* y las [La] sufrieron un descenso significativo ($p = 0{,}002$; $p = 0{,}001$).
Conclusiones: Los resultados del estudio no mostraron efectos positivos del protocolo de *Complex Training* sobre las velocidades de lanzamiento de la granada en pentatletas militares, por lo tanto no se consiguió PAP en la musculatura involucrada en el lanzamiento del proyectil. También se observó fatiga general y local durante la aplicación del protocolo. Se sugiere seguir indagando las cargas de activación realizando cambios en la intensidad y pausas de las cargas.

Palabras clave:
Complex Training.
Potenciación post activación.
Fuerza explosiva.
Lanzamiento de la granada.

Correspondence: Álvaro C. Huerta Ojeda
E-mail: achuertao@yahoo.es

Introduction

Post Activation Potentiation (PAP) is a training method that allows for a natural increase in muscle strength[1]. PAP is achieved under two conditions: on the one hand, that the neural signal generated by the activation remains in the motor nerve for several instants and does not fade, whilst on the other hand, the muscle fatigue generated by the same activation is dissipated as quickly as possible[2]. If the activation load is sufficient and the break time is correct, the subject will have increased explosive strength capacity[3].

Various methods have been used to achieve PAP[4,5], and, aside from some exceptions[6-8], in the majority of the studies reviewed there are significant improvements in maximum strength and explosive strength. Therefore, it is key to further define the methods that allow athletes to efficiently achieve PAP.

Complex Training is a widely used method for PAP9; this kind of protocol uses variations in the work loads within a training session. This is how Complex Training can incorporate Variable Resistance works within the repetition (elastic bands or chains), or Intra-Series Variable Resistances (change of intensity within a series). In the majority of research studies consulted, loads close to 100% of physical 1MR were employed[10-15], but there is no conclusive evidence regarding the changes in the Explosive Strength, working in power areas (from 0.6 to 0.9 m/s of speed in the bench press bar). Nor is it sure of how this strength increases due to the PAP of the musculature involved in the grenade throw of military pentathletes. In parallel to this, establishing how power levels in the bench press are modified whilst work loads are applied is fundamental in achieving the objective of the study, as, by reducing the powers, the PAP would disappear.

The main aim of this study was to establish the acute effect of a protocol on the Complex Training bench press on the grenade throwing speed of military pentathletes. The secondary aim was to evaluate the local and general fatigue indicators in military pentathletes; these indicators were the maximum and average powers on bench press and the post-exertion blood lactate concentration.

Material and method

Experimental approximation to the study

19 male military pentathletes were the subjects of this study. The inclusion criterion was the number of years of experience in this sport. The subjects had a minimum of two years performing Military Pentathlons. For the application of the protocol, an almost experimental intra-subject design was used. In this study a control series and a Complex Training protocol were applied. There were 48 hours of separation between the control series and the Complex Training protocol. Before starting the study, all the subject had their weight, height and skinfolds measured. All the research participants were asked to avoid consuming any alcohol, medication or any substance that may increase the metabolism throughout the experiment.

Table 1. Sample characteristics (averages ± SD).

	Experimental group (n=19)
Age (years)	24.8 ± 5.3
Weight (Kg)	**66.2 ± 4.8**
Height (cm)	**172.4 ± 5.2**
BMI (Kg/m^2)	22.3 ± 1.2
Fat percentage	11.4 ± 2.5

BMI: Body Mass Index; SD: standard deviation.

Subjects

Nineteen military pentathletes belonging to the Chile Army (age: 24.8 ± 5.3 years; weight: 66.2 ± 4.8 Kg; height 172.4 ± 5.2 cm, Body Mass Index: 22.3 ± 1.2 Kg/m2; fat percentage: 11.4 ± 2.5%) (Table 1) were part of the study. All the athletes and trainers were informed about the study objective and the possible risks of the experiment, and they all signed an informed consent form before the protocols were applied. The informed consent and the study were approved by the Granada University Human Research Committee, Spain (registration number 933).

Instruments

For the characterisation of the sample, the weight and height were measured using the HEALTH O METER PROFESSIONAL® Scales and Height Rod. The skinfolds were measured using a F.A.G.A.® calliper. The skinfolds measured to establish the fat percentage were the Biceps, Triceps, Subscapularis and Supraspinal, using the Durnin & Womersley method (1974)[16].

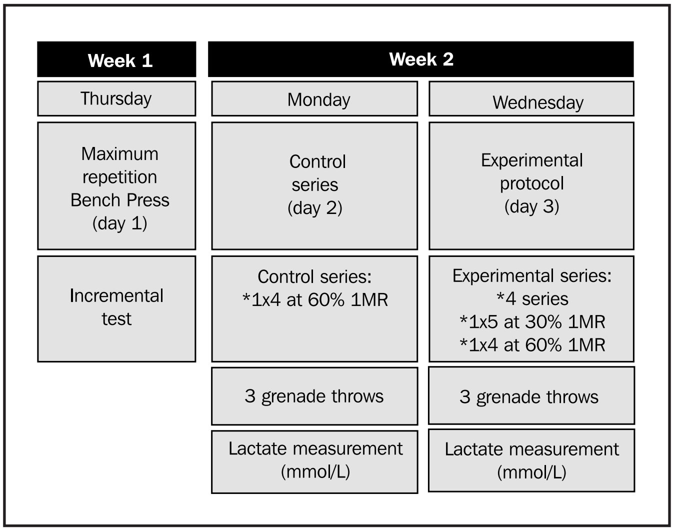
Standard warming up

To evaluate a Maximum Repetition (1MR), the control series and the Complex Training protocol, the standardised warm-up consisted of 10 minutes jogging, of which the first five minutes were free and the remaining five were with ballistic movements in the upper extremities (bending, stretching, shoulder adduction and abductions).

Baseline

To assess the 1MR on the bench press, a CHRONO JUMP® Linear Encoder and the CHRONOJUMP® Version 1.4.6.0® software were used. The 1MR assessment was performed indirectly using the formula proposed by Sánchez-Medina *et al*. (2010)[17]. 24 hours after the 1MR assessment, a control series was assessed, consisting in four repetitions at 60% of 1MR on the bench press. The aim of the aforementioned was to check the vertical speed of the bar of each athlete, establishing the Maximum Powers (MaxP) and Average Powers (AveP) on the bench press[18]. Furthermore, and also as a baseline, a series of three grenade throws was assessed, separated by 15 s, used to analyse the maximum improvement speed of the three throws (maxS) and the average of the maximum speeds of the three throws of the series (aveS). The projectile

Figure 1. Experimental Complex Training protocol on the bench press.



1MR: 1 maximum repetition; mmol/L: millimoles per litre.

thrown is a metal sports implement that simulates a grenade, with a standard weight of 575 ± 25 grammes and is one of the five events in the Military Pentathlon19. To measure the speeds of the grenade throws, a Speedster III model Bushnell® RADAR GUN was used, with a measuring range of 16-177 kilometres per hour (Km/h) over 58 metres (m), with a 24,125 Giga Hertz radar transmitter (GHz) and a 916.68 Mega Hertz data transmitter (MHz). Both in the control series as well as the four experimental method series, each participant threw three projectiles at 15 s intervals, from a standard grenade throwing platform[19]. This platform is 2 m wide and 3 m long, and participants can use the area to gain momentum, whilst the assessment of the throwing speeds was performed from the rear end of this platform (3 m).

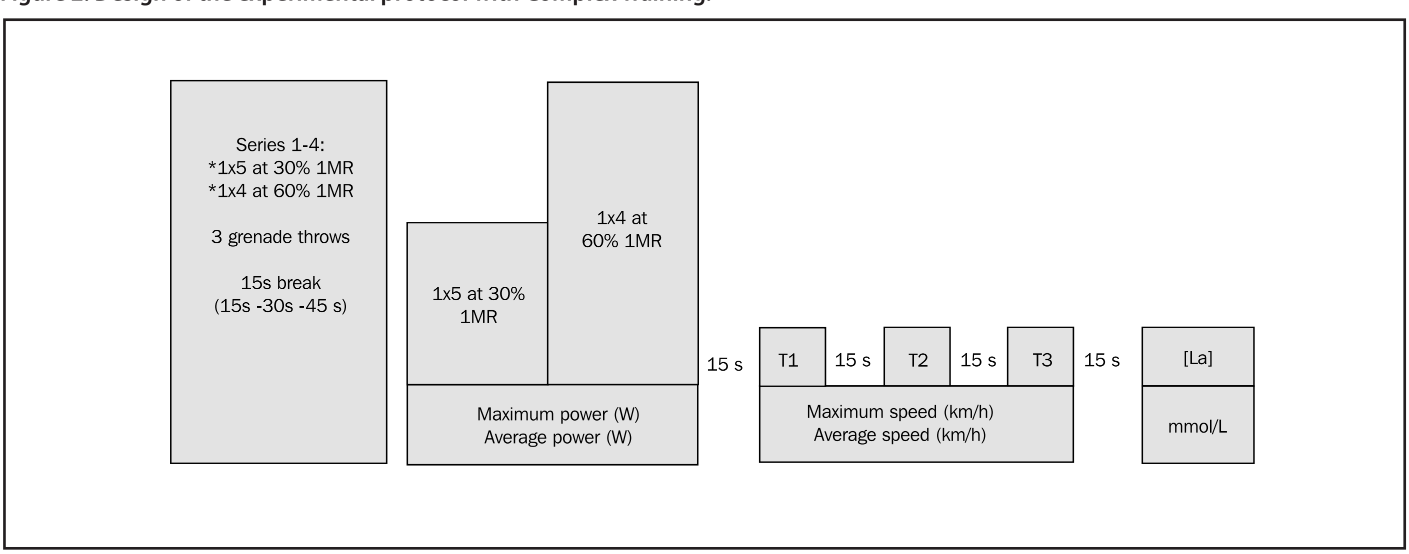
Finally, also as a baseline, lactate concentrations were assessed [La]. This measurement was performed 15 s after finishing the control series of three throws and the four experimental series. The [La] concentrations were assessed using the h/p/Cosmos Sirius® measurer, which generates an enzymatic-amperometric lactate detection with a ± 3% precision (Figure 1).

Treatment

The activation protocol with Complex Training consisted in: 4 series of 5 repetitions at 30% of 1MR + 4 repetitions at 60% of 1MR + 3 grenade throws with a 15 second break. Between each of the experimental protocol series there was a 2-minute break. This comprised the lapse between the measurement of the lactate and the start of the next series on bench press. It is important to mention that, between the execution of the five repetitions at 30% of 1MR and the four repetitions at 60% of 1MR, there was a "break" of 5 s, which enabled the researchers to increase the load on the bar in accordance with the individualities of the participants (Figure 2).

During the application of the on Complex Training bench press protocol, the vertical speed of the bar was monitored in the light loads (30% of 1MR) and heavy loads (60% of 1MR) of each series. This analysis allowed for a verification of the appearance of fatigue during the development of the intervention. The grenade throw speeds were also all measured (3 throws per series), which allowed the appearance of PAP to be determined. Finally, upon finishing each series, the [La] concentrations were assessed, with the aim of verifying the appearance of general fatigue and inferring the energy predominance during the application of the Complex Training protocol.

Figure 2. Design of the experimental protocol with Complex Training.



1MR: 1 maximum repetition; s: second; T1: first grenade throw; T2: second grenade throw; T3: third grenade throw; W: Watts; Km/h: kilometres per hour; [La]: lactate concentration; mmol/L: millimoles per litre.

Statistical analysis

The data was analysed in the following way and order: the maxS and aveS of the grenade throw, maxP and aveP on the bench press and the [La] both in the control series (Baseline) as well as in the four experimental series of the Complex Training protocols were subject to the Kolmogorov-Smirnov regulation (K-S). An ANOVA of repeated averages was used to analyse the differences between the control series and the four Complex Training protocol series. The size of the effect (SE) for this analysis was calculated using the Partial Eta Squared test.

For the post hoc analysis of all the assessed variables, a Student t was applied. With the *Student t* the control series was compared against the experimental series 1 (Pair 1), control series against experimental series 2 (Pair 2), control series against experimental series 3 (Pair 3) and control series against experimental series 4 (Pair 4). The SE for this analysis was calculated using the *Cohen d* test. This analysis considers insignificant ($d < 0.2$), minor ($d = 0.2$ up to 0.6), moderate ($d = 0.6$ to 1.2), major ($d = 1.2$ to 2.0) or very major ($d > 2.0$) effects. The significance level for all the statistical analyses was $p < 0.05$. The data analysis was performed using the GRAPHPAD INSTAT Version 3.05® software.

Results

Applying the ANOVA test of repeated measurements, the maximum speeds of the grenade throw revealed no significant changes between the control series and the four experimental series ($p = 0.90$; SE = 0.014), just as the aveS revealed no significant changes ($p = 0.94$; SE 0.061); the evolutions and changes in the series are reported in Table 2 and Figure 3. In the post hoc analysis, upon applying the *Student t* between the control series and the four experimental series, in both the maxS and the aveS of the grenade throw, no significant changes were revealed in the pairs analysed. The results of all the pairs analysed using the *Student t* are displayed in Table 3.

The analysis via the ANOVA test of repeated averages of the maxP of the bench press between the control series and the four experimental series revealed no significant changes ($p = 0.06$; SE = 0.115) (Table 2 and Figure 4). However, in the post hoc analysis, three of the four pairs analysed using the Student t revealed significant decreases in the maxP of the bench press. The results of all the pairs analysed using the Student t are displayed in Table 4. In parallel to this, the aveP revealed a significant

Table 2. Results (average ± SD) of post activation potentiation via Complex Training on the bench press for the control series and the four experimental series.

Variables	Control series Averages ± SD	Series 1 Averages ± SD	Series 2 Averages ± SD	Series 3 Averages ± SD	Series 4 Averages ± SD	ANOVA *p*	Partial ETA squared
Maximum speed (km/h)	62.,6±7.4	62.1±6.1	62.1±7.5	61.8±7.6	61.8±8.7	0.90	0.014
Average speed (km/h)	61.0±7.2	60.4±6.2	60.2±7.0	59.7±7.6	59.0±8.0	0.94	0.061
Maximum power (W)	579.7±53.2	555.9±59.0	558.3±50.8	538.4±80.4	550.1±75.7	0.06	0.115
Average power (W)	367.9±47.8	331.5±46.0	339.1±44.4	317.4±67.2	330.1±53.7	0.002*	0.198
Lactate concentrations (mmol/L)	1.85±0.31	2.09±0.39	2.13±0.38	2.07±0.32	2.16±0.31	0.001*	0.219

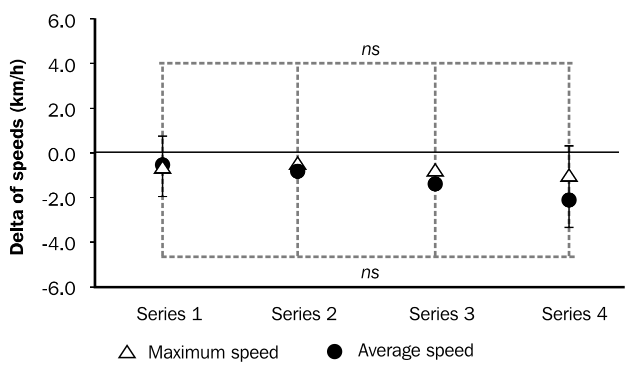
SD: standard deviation; Km/h: kilometres per hour; W: (watts); mmol/L: millimoles per litre. * p <0.01.

Table 3. A *post hoc* analysis of the maximum and average speed of the grenade throw after the post activation potentiation (PAP) via a Complex Training between the control series and the four experimental series.

Contrast conditions (Control series – Series)	Maximum throwing speed				Average throwing speed			
	Control series Medias ± DS	Series Medias ± DS	Students *t* test p	Cohen *d* test	Control series Medias ± DS	Series Medias ± DS	Students *t* test p	Cohen *d* test
Pair 1 (Km/h)	Control series 62.6±7.4	Series 1 62.1±6.1	0.61	0.576	Control series 61.0±7.2	Series 1 60.4±6.2	0.52	0.504
Pair 2 (Km/h)	Control series 62.6±7.4	Series 2 62.1±7.5	0.62	0.523	Control series 61.0±7.2	Series 2 60.2±7.0	0.45	0.505
Pair 3 (Km/h)	Control series 62.6±7.4	Series 3 61.8±7.6	0.53	0.561	Control series 61.0±7.2	Series 3 59.7±7.6	0.32	0.565
Pair 4 (Km/h)	Control series 62.6±7.4	Series 4 61.8±8.7	0.47	0.536	Control series 61.0±7.2	Series 4 59.0±8.0	0.13	0.654

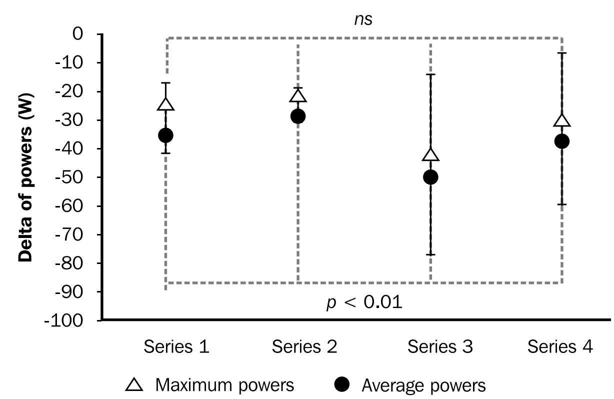
Km/H: kilometres per hour; SD: standard deviation.

Figure 3. Maximum and average delta speed between the control series and four experimental series.



Km/H: kilometres per hour; ns: not significant.

Figure 4. Maximum and average delta power between the control series and four experimental series.



W: Watts; ns: not significant.

Table 4. ***Post hoc*** **analysis of the maximum and average powers on bench press between the control series and the four experimental series during the application of a post activation potentiation protocol.**

Contrast conditions (Control series–Series)	Maximum power on bench press				Average power on bench press			
	Control series	Series Averages ± SD	Students *t* test Averages ± SD	Cohen *d* test *p*	Control series	Series Averages ± SD	Students *t* test Averages ± SD	Cohen *d* test *p*
Pair 1 (W)	Control series 579,7 ± 53,2	Series 1 555,9 ± 59,0	0,08	0,424	Control series 367,9 ± 47,8	Series 1 331,5 ± 46,0	0,001**	0,776
Pair 2 (W)	Control series 579,7 ± 53,2	Series 2 558,3 ± 50,8	0,02*	0,411	Control series 367,9 ± 47,8	Series 2 339,1 ± 44,4	0,001**	0,624
Pair 3 (W)	Control series 579,7 ± 53,2	Series 3 538,4 ± 80,4	0,02*	0,619	Control series 367,9 ± 47,8	Series 3 317,4 ± 67,2	0,01*	0,878
Pair 4 (W)	Control series 579,7 ± 53,2	Series 4 550,1 ± 75,7	0,04*	0,459	Control series 367,9 ± 47,8	Series 4 330,1 ± 53,7	0,004**	0,745

W: Watts; SD: standard deviation; * p <0.05; ** p <0.01.

decrease between the control series and the four experimental series (p = 0.002; SE = 0.198) (Table 2 and Figure 4). In the post hoc analysis for this variable, upon applying the *Student t* between the control series and the four experimental series on the bench press, all the pairs analysed revealed significant decreases. The results of all the pairs analysed using the Student t are displayed in Table 4.

Applying the ANOVA test of repeated averages for the [La] between the control series and the four experimental series revealed significant increases in this variable (p = 0.001; SE = 0.219) (Table 2 and Figure 5). In the post hoc analysis for this variable, all the pairs analysed displayed significant increases (Table 5).

Discussion

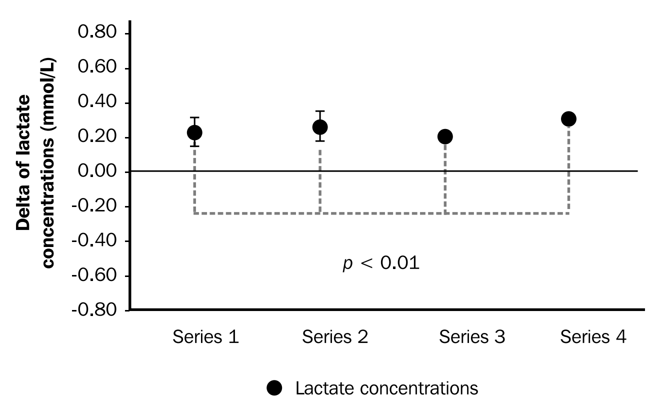
With regards to the main aim of this study, the results did not reveal acute effects of the Complex Training protocol on the bench press on the maximum and average grenade throwing speeds by military pentathletes. These results did not allow for a definite PAP of the muscles involved in the grenade throw. Despite the variables mentioned not presenting significant modifications between the control series and the four experimental series, there are numerous authors that have found significant differences in throwing speed[20-24], but the majority of the researchers applied constant resistance protocols[23,24]. It is also important to analyse the fact that various studies consulted did not observe

Table 5. *Post hoc* analysis of the lactate concentrations between the control series and the four experimental series during the application of a post activation potentiation protocol.

	Lactate concentrations			
Contrast conditions (Control series - Series) Averages ± SD	Control series Averages ± SD	Series *p*	Student *t* test	Cohen *d* test
Pair 1 (mmol/L)	Control series 1.85 ± 0.31	Series 1 2.09 ± 0.39	0.03*	-0.680
Pair 2 (mmol/L)	Control series 1.85 ± 0.31	Series 2 2.13 ± 0.38	0.01*	-0.793
Pair 3 (mmol/L)	Control series 1.85 ± 0.31	Series 3 2.07 ± 0.32	0.02*	-0.693
Pair 4 (mmol/L)	Control series 1.85 ± 0.31	Series 4 2.16 ± 0.31	0.005**	-1.006

mmol/L: millimoles per litre; SD: standard deviation; * p <0.05; ** p <0.01.

Figure 5. Maximum and average lactate concentrations between the control series and four experimental series.



mmol/L: millimoles per litre.

significant increases in the throwing speed[7,22,25]. Likewise, just as in this study, Gómez-Navarrete *et al.* (2011)[7] did not observe PAP after applying a training programme based on combined methods (4 series of 3MR on bench press with a 4-minute break + 4 series of 5 medicine ball throws [5 Kg] + 3 handball throws), they discovered a significant decrease in the maxP and in the curve of strength after the activation ($p < 0.05$). However, some research studies have reported significant changes after applying protocols based on Complex Training; it is worth noting that these studies have focused on motor actions that are not throwing, therefore the body segment worked also differs from this study. Likewise, Okuno *et al.* (2013)[26] looked for PAP for the lower extremity and found a significant increase in the movement speed ($p = 0.01$) (30 m with a direction change in 15 m) following an activation with incremental loads (1 x 5 at 50% of 1MR + 1 x 3 at 70% of 1MR + 5 x 1 at 90% of 1MR). On the other hand, Walker *et al.* (2010)[15] observed the chronic effects of Complex Training on PAP and the fatigue indicators, finding a significant increase in the power levels measured using the Squat Jump test ($p < 0.05$), and also a significant increase in post-activation muscle fatigue ($p < 0.05$). As a result of the aforementioned, it is necessary to continue to explore this issue with Complex Training, as this work methodology seems to be a good activation tool to achieve PAP in explosive muscle strength.

With regards to the study's secondary target, the maxP did not undergo any significant changes ($p = 0.06$; SE = 0.115), however, the aveP on bench press revealed a significant decrease between the control series and the four experimental series ($p = 0.002$; SE = 0.198). In this respect Marques *et al.* (2007)[27] related the bar speed, the maxP and the aveP on the bench press with the throwing speed, though unfortunately in this experiment PAP was not considered as a study variable. Along with measuring the powers, in the development of this study the measurement of the post-stress blood lactate concentrations was included. At the start of this research study, it was speculated that the presence of general fatigue could provoke the dissipation of the neural signals in the motor plate, reducing the possibilities of triggering PAP. This is how the statistical results revealed significant changes in the [La] ($p < 0.001$; SE = 0.219). Despite the measurement of the post-stress [La] in this kind of stimulus not enabling the specific determination of general fatigue in the study participants, it concedes an antecedent that, along with the powers in bench press, allows for the identification of a trend regarding the intra-cellular and neural events during the application of the treatment, therefore as well as the indirect indicators of muscle and general fatigue exposed, other indicators should also be included, such as the Insulin Growth Factor-I or IGF Union Protein-328. With regards to the same variable, West *et al.* (2014)[29] revealed an increase in the [La] after finishing the exercise ($p < 0.0001$). Likewise, Cadore *et al.* (2013)[30] noted a significant increase in the [La] after the work load. It would appear that both in this study and in those consulted, there has been a significant increase in the post-stress lactate concentrations. The aforementioned may indicate two situations; the first, that the work loads used modify a glycolytic metabolism indicator during the development of the experimental protocols, which entails general fatigue in the study participants; and the second, that a possible alternative to control this variable better would be to increase the breaks between the series, and therefore enable the activation loads to trigger a PAP in the stimulated muscle.

Our work hypothesis is based on the fact that the intensities of 60% of 1MR will enable the recruiting of fast-twitch fibers (llx) due to the movement speed on the bench press. Furthermore, this work percentage would avoid the appearance of local and general fatigue. Therefore, based on the aforementioned, we speculate that upon finishing the activation using the Complex Training protocol we would achieve an increase in the throwing speeds. Unfortunately, we did not achieve this increase, and furthermore, the aveP on bench press decreased and increased significantly between the control series and the four experimental series.

Conclusion

Upon finishing the research, the following conclusions can be drawn: upon applying the Complex Training protocol, PAP was not generated on the grenade throwing speed among Military Pentathletes. Furthermore, the use of the Complex Training protocol provoked general and local fatigue in the study participants. As a result of the aforementioned, it is necessary to continue exploring the Complex Training protocols so as to achieve PAP in the throwing speeds of Military Pentathletes. Perhaps a good way to do this would be to increase the activation on the bench press up to 70% of 1MR or to increase 1 or 2 work series.

Practical applications

From a practical perspective, the grenade throwing speed levels in this Complex Training protocol study did not increase, and fatigue was produced in the study participants. However, this kind of activation protocol could be tested with some modifications, within which one suggestion could be to increase the work intensity, increase the break or reduce the number of repetitions per series. It would also be important to include the measurement of the distance of the grenade throw, as this is the variable used as the performance indicator in the Military Pentathlon. However, this parameter is subject to a technical component, which may lower the reliability of the study. On the other hand, these kinds of low-intensity protocols (below 70% of 1MR), which are based on high speeds of movement, should be applied in the specific periods of a training curve, where the application of maximum strength achieved in a basic period in a specific sporting gestural action is fundamental. Finally, according to the findings of this study, PAP was not achieved in an acute phase, but it is not definite as to whether or not these kinds of loads may generate long-term adaptations. For this reason, more research should be carried out.

References

1. Sale D. Postactivation potentiation: Role in human performance. *Exerc Sport Sci Rev.* 2002;30(3):138-43.
2. Tillin MN, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med.* 2009;39(2):147-66.
3. Sale D. Postactivation potentiation: Role in performance. *Br J Sports Med.* 2004;38(4):386-7.
4. Naclerio F, Faigenbaum AD, Larumbe-Zabala E, Ratamess NA, Kang J, Friedman P, *et al*. Effectiveness of different postactivation potentiation protocols with and without whole body vibration on jumping performance in college athletes. *J Strength Cond Res.* 2014;28(1):232-9.
5. Talpey SW, Young WB, Saunders N. The acute effects of conventional, complex, and contrast protocols on lower-body power. *J Strength Cond Res.* 2014;28(2):361-6.
6. Batista MA, Roschel H, Barroso R, Ugrinowitsch C, Tricoli V. Influence of strength training background on postactivation potentiation response. *J Strength Cond Res.* 2011;25(9):2496-502.
7. Gómez-Navarrete JS, Solana RS, Horrillo JMG, Murillo DB. Influencia aguda de la aplicación de un tratamiento de fuerza basado en el método de contrastes combinado, sobre la precisión y la velocidad del lanzamiento en balonmano. E-balonmano.com: *Rev Int Cienc Deporte.* 2011;7(1):5-16.
8. Lim JJ, Kong PW. Effects of isometric and dynamic postactivation potentiation protocols on maximal sprint performance. *J Strength Cond Res.* 2013;27(10):2730-6.
9. Wilson JM, Duncan NM, Marin PJ, Brown LE, Loenneke JP, Wilson SM, *et al.* Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res.* 2013;27(3):854-9.
10. Bellar DM, Muller MD, Barkley JE, Kim CH, Ida K, Ryan EJ, *et al.* The effects of combined elastic- and free-weight tension vs. free-weight tension on one-repetition maximum strength in the bench press. *J Strength Cond Res.* 2011;25(2):459-63.
11. Garcia-Lopez D, Herrero AJ, Gonzalez-Calvo G, Rhea MR, Marin PJ. Influence of "in series" elastic resistance on muscular performance during a biceps-curl set on the cable machine. *J Strength Cond Res.* 2010;24(9):2449-55.
12. Shoepe T, Ramirez D, Rovetti R, Kohler D, Almstedt H. The effects of 24 weeks of resistance training with simultaneous elastic and free weight loading on muscular performance of novice lifters. *J Hum Kinet.* 2011;29:93-106.
13. Cormie P, McGuigan MR, Newton RU. Adaptations in athletic performance after ballistic power versus strength training. *Med Sci Sports Exerc.* 2010;42(8):1582-98.
14. Iglesias E, Boullosa DA, Dopico X, Carballeira E. Analysis of factors that influence the maximum number of repetitions in two upper-body resistance exercises: Curl biceps and bench press. *J Strength Cond Res.* 2010;24(6):1566-72.
15. Walker S, Ahtiainen J, Häkkinen K. Acute neuromuscular and hormonal responses during contrast loading: Effect of 11 weeks of contrast training. *Scand J Med Sci Sports*. 2010;20(2):226-34.
16. Durnin J, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr.* 1974;32(01):77-97.
17. Sanchez-Medina L, Perez C, Gonzalez-Badillo J. Importance of the propulsive phase in strength assessment. *Int J Sports Med.* 2010;31(2):123-29.
18. Bautista IJ, Chirosa IJ, Chirosa LJ, Martín I, González A, Robertson RJ. Development and validity of a scale of perception of velocity in resistance exercise. *J Sport Sci Med.* 2014;13:542-9.
19. International Military Sports Council. Military pentathlon regulations. (Consultado 15/02/2016). Disponible en: http://www.militarypentathlon.org/public/milpent/index.php?option=com_phocadownload&view=sections&Itemid=54. Updated 2015.
20. Ramos R, Requena B, Suarez-Arrones L, Newton RU, Saez de Villarreal E. Effects of 18-week in-season heavy-resistance and power training on throwing velocity, strength, jumping, and maximal sprint swim performance of elite male water polo players. *J Strength Cond Res.* 2014;28(4):1007-14.
21. van den Tillaar R, Marques MC. Effect of different training workload on overhead throwing performance with different weighted balls. *J Strength Cond Res.* 2013;27(5):1196-201.
22. Marques M, Saavedra F, Abrantes C, Aidar F. Associations between rate of force development metrics and throwing velocity in elite team handball players: A short research report. *J Hum Kinet.* 2011;29(Special Issue):53-7.
23. Hermassi S, Chelly MS, Fathloun M, Shephard RJ. The effect of heavy- vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *J Strength Cond Res.* 2010;24(9):2408-18.

24. van den Tillaar, Roland J, Marques MC. Effect of two different training programs with the same workload on soccer overhead throwing velocity. *Int J Sport Physiol.* 2009;4:474-84.
25. Hermassi S, Chelly MS, Tabka Z, Shephard RJ, Chamari K. Effects of 8-week in-season upper and lower limb heavy resistance training on the peak power, throwing velocity, and sprint performance of elite male handball players. *J Strength Cond Res.* 2011;25(9):2424-33.
26. Okuno N, Tricoli V, Silva S, Bertuzzi R, Moreira A, Kiss M. Postactivation potentiation on repeated-sprint ability in elite handball players. *J Strength Cond Res.* 2013;27(3):662-8.
27. Marques M, van den Tillaar R, Vescovi J, González-Badillo J. Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. *Int J Sport Physiol.* 2007;2(4):414-22.
28. Meckel Y, Nemet D, Bar-Sela S, Radom-Aizik S, Cooper D, Sagiv M, Eliakim A. Hormonal and inflammatory responses to different types of sprint interval training. *J Strength Cond Res.* 2011;25(8):2161-9.
29. West D, Cunningham D, Finn C, Scott P, Crewther B, Cook C, Kilduff L. The metabolic, hormonal, biochemical, and neuromuscular function responses to a backward sled drag training session. *J Strength Cond Res.* 2014;28(1):265-72.
30. Cadore E, Pinheiro E, Izquierdo M, Correa C, Radaelli R, Martins J, Lhullier F, Laitano O, Cardoso M, Pinto R. Neuromuscular, hormonal, and metabolic responses to different plyometric training volumes in rugby players. *J Strength Cond Res.* 2013;27(11):3001-10.