Effect of two warm-ups based on PAP on SJFT subsequent performance

L'effet de deux échauffements à base de PAP sur la performance ultérieure au SJFT

Ait Amar Toufik*

IEPS Université Alger 3 - Algeria

toufikaitamar@live.fr

Date of submission: 06/04/2021 Date of acceptance: 18/05/2021

Abstract

Postactivation Potentiation (PAP) is proposed as a method to achieve greater physiological and mechanical strength through the use of pre-loading during warm-up. However, there is a lack of studies on PAP applied to elite athletes, particularly using populations from combat sports such as judo. Even though the proposed mechanisms responsible for the PAP are increasingly complex, about the properties of the conditioned stimulus (intensity, volume, recovery time,...), it appears that the effects of the PAP are the most important among highly skilled subjects. Judo is a weight class combat sport that requires higher levels of developed strength and muscular power, which represents a unique opportunity to examine the effect of PAP in an applied framework within a specialized population. Therefore, the main objective of this study is to examine the effect of two PAP-based warm-up protocols in elite weight-category judokas, one using maximum isometry and the second using the contrast method. **Materials and Methods:** Sixteen elite athletes from the Algerian men's judo team volunteered to participate in this study: Light class (n=8), Middle (n=4), Heavy (n=4). Anthropometric measurements were taken (height, weight) as well as PAP-based warm-up protocols. The first protocol contained 3 series x 5-second 110% 1RM isometry at ½ squats, followed by the SJFT test after 7 min recovery. As for the second protocol, the judoka performed 2 series at 90% 1RM at ½ squats, followed immediately by 6 jumps (CMJB). After 7 min of recovery, the athlete performed the SJFT test. An analysis of variance with repeated measurements of the three protocols showed that all three weight categories improved their power for both experimental warm-up protocols compared to control protocol. **Results:** Both experimental protocols improved the performance of all three weight categories. The light and middleweight categories improved their performance with the contrast protocol by 4.97% and 3.66% respectively, while the heavyweight category had a better performance in the SJFT with the maximum isometry protocol by improving their performance by 3.33%. **Conclusion:** This study showed that the light and middleweight categories improved their performance after the contrast warm-up protocol, while the heavy category had better performance under the influence of the maximum isometry warm-up.

Keywords: **PAP; Weight category; Elite Athlete; Warm-up; Judo**

* ***Corresponding author Ait Amar Toufik*** **Email** : **toufikaitamar@live.fr**

Résumé

La Potentialisation Postactivation (PAP) est proposée comme un moyen pour atteindre une plus grande puissance physiologique et mécanique à travers l'utilisation d'une précharge lors de l'échauffement. Cependant, il y a un manque d'études sur la PAP appliquées aux athlètes d'élite, en particulier en utilisant des populations des sports de combat tel que le judo. Malgré que les mécanismes proposés responsables de la PAP soient de plus en plus complexes, en relation avec les propriétés du stimulus conditionné (intensité, volume, temps de récupération,…), il apparaît que les effets de la PAP sont les plus importants parmi les sujets hautement qualifiés. Le judo, est un sport de combat à catégories de poids qui nécessite des niveaux supérieurs de la force développée et de la puissance musculaire, ce qui représente une occasion unique d'examiner l'effet de la PAP dans un cadre appliqué au sein d'une population spécialisée. Par conséquent, l'objectif principal de cette étude est d'examiner l'effet de deux protocoles d'échauffement à base de PAP chez des judokas d'élite par catégories de poids, l'un utilisant l'isométrie maximale et le second la méthode contraste. **Matériel et Méthodes :** Seize athlètes d'élite de l'équipe de judo masculine Algériens se sont portés volontaires pour participer à cette étude : Légers (n= 8), Moyens (n= 4), Lourds (n= 4). Des mesures anthropométriques ont été effectuées (taille, poids) ainsi que les protocoles d'échauffement à base de PAP. Le premier protocole contenait 3 séries de 5 secondes en isométrie à 110% de 1RM au ½ squat, suivie par le test SJFT après 7 min de récupération. Quant au deuxième protocole, le judoka réalisait 2 séries à 90% de 1RM au ½ squat, suivi immédiatement par 6 sauts (CMJB). Après 7 min de récupération, l'athlète réalisait le test SJFT. Une analyse des variances à mesures répétées des trois protocoles, a fait ressortir que les trois catégories de poids ont amélioré leur puissance pour les deux protocoles d'échauffement expérimentaux par rapport au protocole de contrôle. **Résultats :** Les deux protocoles expérimentaux ont permis l'amélioration du rendement des trois catégories de poids. Les catégories des légers et des moyens ont amélioré leur rendement avec le protocole de la méthode contraste de 4.97% et 3.66% respectivement, alors que les lourds ont eu une meilleure performance au test SFJT avec le protocole d'isométrie maximale en améliorant leur rendement de 3.33%. **Conclusion :** Cette étude a montré que les catégories des légers et des moyens de notre échantillon d'étude, ont amélioré leur rendement après exécution du protocole d'échauffement à base de méthode contraste, alors que la catégorie des lourds a connu un meilleur rendement sous l'influence de l'échauffement à base d'isométrie maximale.

Mots clés : PAP; Catégorie de poids; Athlète d'élite; Echauffement; Judo

Introduction

In sport, achieving high levels of performance depends on many important factors, including biological and physical factors, which are two very important aspects of training and selection process.

In judo, a highly technical discipline where the slightest technical-tactical error or physical failure can ruin months or even years of work; lack of specific theoretical tools or research on topics directly related to training management has not allowed this discipline to take off. Coaches are always looking for training techniques that give them an advantage in competition. New training methods are continually being developed or old methods are modified and renewed. While many of these training approaches have some practical merit, there is often little research evidence to

scientifically support their effectiveness. Therefore, better designed and controlled research studies are warranted.

Warm-up is a phase of body preparation before training and/or competition that requires further clarification and precision through extensive scientific studies (Alves, et al., 2010; Andrews, et al., 2011; Chatzopoulos, et al., 2007).

Despite a significant number of studies on warm-up protocols for a variety of power sports activities (jumping, speed, ...), further research is needed to address the needs of athletes in other power sports such as combat sports (judo, wrestling, ...), for whom optimal performance can be achieved through specific warm-up protocols. Warm-ups that induce PAP can be the key to improve performance in power activities.

PAP is defined as an increased neuromuscular state observed after high intensity exercise (Robbins, 2005). The definition of PAP reflects the observation that an increase in muscle contractile strength comes after maximum or sub-maximum load with maximum voluntary contraction, where PAP increases the rate of strength development (Vandenboom and Houston, 1996; Xenofondos, et al, 2010). To maximize the effect of PAP, appropriate warm-up strategies are necessary.

Although, significant performance improvements have been recorded among participants with a variety of training levels, research suggests that a warm-up effect of PAP is more likely if individuals are highly trained compared to occasional athletes (Chiu, et al., 2003; Gourgoulis, et al., 2003; Young, 1993). The difference in the effect of the warm-up based on PAP between well-trained athletes and occasional athletes may reflect a greater ability of higher level athletes to recruit more motor units, with greater muscle synchronization, and a greater expression of the rate of strength development during PAP movement, than individuals with lower levels of training (Ratamess, 2008; Schmidtbleicher & Buehrle, 1987).

One of the most widely used tests in judo research is the Special Judo Fitness Test (SJFT). It is used by several national team coaches to assess the specific physical abilities of their judokas. Also, this test meets the physiological demands imposed by judo fighting (Franchini, 2011).

A recent in-depth meta-analysis of the identified factors that modulate PAP responses, based on 32 studies, attempted to identify the overall magnitude of the effects of these constraints that influence this phenomenon (Wilson et al., 2013). Among these variables, the level of training is one of the most important in the expression of PAP.

Materials and Methods

Sample

The sample of this study is composed of 16 elite athletes of the Algerian men's judo team, selected to prepare the 36th edition of the African judo championship. In the end, the team won three gold and one silver medal, with four athletes qualifying for the Rio 2016 Olympic Games. The athletes are of a homogenous level, their rank varies between 1st Dan (black belt) and 3rd Dan (black belt), training 6 times a week for 2 hours a day. Their age varies between 20 and 31 years old, while their seniority in practicing judo is between 10 and 26 years. The subjects were divided into weight

categories according to the division used by (D. Boguszewski, 2009, T. Okada et al., 2007). The light weight category includes (-60 kg, -66 kg, -73 kg), medium weight (-81 kg, -90 kg) and heavy weight (-100 kg and +100 kg).

Table 1: Biometric characteristics of subjects

	Age (years)	Weight (kgs)	Height (cm)	Years of practice
Light weight	24.87 ± 3.35	69.13 ± 6.45	166.76 ± 2.7	18 ± 4.27
Medium weight	25.5 ± 4.04	87.4 ± 4	176.65 ± 2.01	17 ± 5.47
Heavy weight	29.75 ± 1.5	139.17 ± 27.64	186.67 ± 5.56	21.25 ± 4.85
Mean ± SD	26.25 ± 3.66	91.21 ± 32.44	174.21 ± 9.11	18.56 ± 4.68

Protocols and Tests

Each evaluation session is preceded by a familiarization session, emphasizing the conduct of the experiment at the same time of day (between 10 and 11 am), before the subjects' daily training.

For all the tests, subjects were advised not to get involved in strenuous tasks 72 hours before each session, apart from training with the national team. None of the test subjects suffered an injury that kept them away from the tatami for the six months prior to the testing sessions.

Before the beginning of each test, all the subjects were informed about the progress and the measurements carried out during the experimental sessions, without omitting to specify the difficulties of the tasks to be carried out.

Before starting the sessions, the subjects carried out a 5-minute run, a 3-minute joint warm-up followed by 2 series of squats at 65% and 75% of 1RM. At the end of the warm-up, 2 minutes of rest were prescribed before the sessions began.

Special Judo Fitness Test (SJFT)

It is a specific test used in judo to determine an athlete's state of readiness. It is composed of three phases which can be summarized as follows (Sterkowicz, 1995):

The attacker (Tori) is in the middle of two defenders (Uke) of the same weight and height, 3 meters apart from each of them. At the signal, Tori moves towards Uke to make him fall on his back with an arm technique "Ippon Seoi Nage", and moves towards the other Uke to execute the same technique as quickly as possible for 15 seconds. At the end of this phase, Tori rests for 10 seconds, then he starts a second series of falls as fast as possible for 30 seconds. He recovers 10 seconds, to continue with the third phase of 30 seconds. The evaluator reads the heart rate at the end of the test, and after 1 minute of recovery with a polar type heart rate meter (RS 800 CX) for better accuracy.

Isometry and SJFT

Individuals are divided into groups of 3 of the same weight and height, and each of them performs 3 series of 5 seconds of maximum isometric holding (110% of 1RM) at

½ squats, with a rest time of 15 seconds between series. At the end of the series, a recovery time of 7 minutes is granted. Following this work, the subjects perform the SJFT.

Contrast method and SJFT

For this session, the stimuli were alternated using the contrast method. In each series, the subject performs 2 repetitions of ½ squats at 90% of its maximum concentric load, followed immediately by 6 Counter Movement Jumps. The series are followed by 2 minutes of recovery. At the last series, the subject recovers for 7 minutes, and then proceeds to the SJFT test.

Statistical analysis

The statistical analysis was carried out using Statistical Package for Social Science version 19.0 (SPSS, Inc., Chicago, IL, USA) for Windows. All data were presented in mean values ± standard deviations. The significance threshold was set at $p \leq 0.05$.

The normal distribution of the data was verified by the Kolmogorov-Smirnov test, and a Levene test was performed to verify the equality of variances. The ANOVA (Analysis of Variance) repeated measures test was applied to compare the evaluated variables. Our values were subjected to Mauchly's sphericity test to verify the analysis of repeated measures of variance. When differences were detected, the Bonferroni test was used as a post-hoc test to identify specific differences between the three warm-up protocols according to weight categories. In order to compare two independent series of values, we used the Student's T-test.

Results

The table of estimated marginal means indicates that performance after performing both warm-ups based on maximum isometry and contrast method had a significant effect on the improvement in SJFT performance for all weight categories.

Table 2: Estimated Marginal Means (Total Falls)

Categories	SJFT	Means	Standard error	Confidence interval at 95%	
				Lower Limit	Upper Limit
Light Weight	Control	27,625	,648	26,226	29,024
	Isometry	**28,375**	,549	27,188	29,562
	Contrast method	***29,000***	,561	27,788	30,212
Middle Weight	Control	27,250	,916	25,271	29,229
	Isometry	**27,750**	,777	26,072	29,428
	Contrast method	***28,250***	,794	26,536	29,964
Heavy Weight	Control	22,500	,916	20,521	24,479
	Isometry	**23,250**	,777	21,572	24,928

Categories	SJFT	Means	Standard error	Confidence interval at 95%	
				Lower Limit	Upper Limit
Light Weight	Control	27,625	,648	26,226	29,024
	Isometry	**28,375**	,549	27,188	29,562
	Contrast method	***29,000***	,561	27,788	30,212
Middle Weight	Control	27,250	,916	25,271	29,229
	Isometry	**27,750**	,777	26,072	29,428
	Contrast method	***28,250***	,794	26,536	29,964
Heavy Weight	Control	22,500	,916	20,521	24,479
	Isometry	**23,250**	,777	21,572	24,928
	Contrast method	***23,000***	,794	21,286	24,714

Two-by-two comparisons of the averages (with total error control according to the Bonferroni method) give:

Table 3: Comparisons by pairs (Total of fall)

(I) SJFT	(J) SJFT	Difference of means (I-J)	Standard Errors	Sig.[a]	Confidence interval of the difference at 95%	
					Lower Limits	Upper Limits
Control	**Isometry**	**-,708***	,124	**,000**	-1,049	-,368
	Contrast method	**-1,125***	,260	**,002**	-1,838	-,412
Isometry	**Control**	**,708***	,124	**,000**	,368	1,049
	Contrast method	-,417	,203	,184	-,975	,142
Contrast method	**Control**	**1,125***	,260	**,002**	,412	1,838
	Isometry	,417	,203	,184	-,142	,975

The two-by-two mean comparison test shows that the means of both warm-up protocols (maximum isometry and contrast method) are significantly different from those of control test at $p \leq 0.05$. Nevertheless, the difference in means between the

control test and the maximum isometry is (0.708), while the difference between the control test and the contrast method is (1.125), suggesting that the results obtained in the SJFT test when applying the warm-up with contrast method is slightly better despite the fact that there is no statistically significant difference between both warm-up protocols (maximum isometry and contrast) at $p \leq 0.05$.

Table 4: Multiple Comparisons (Total of fall)

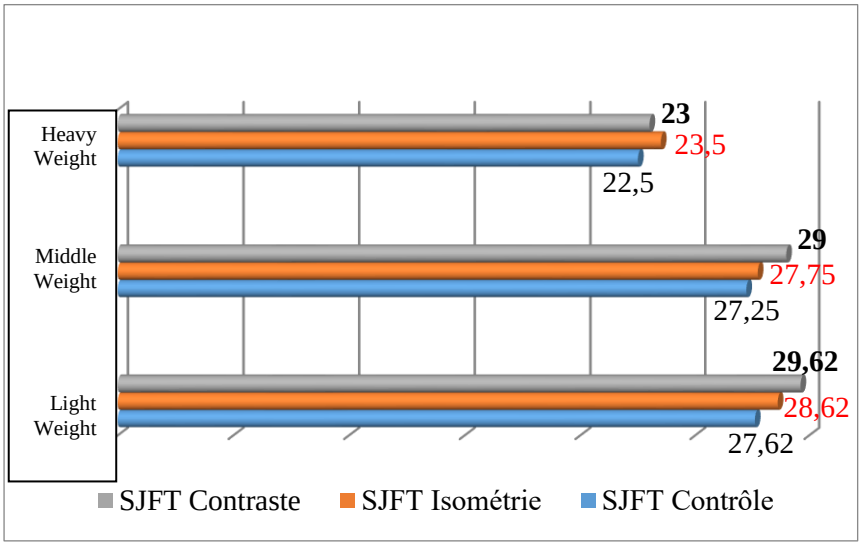
Two-by-two

(I) Categories	(J) Categories	Différence des moyennes (I-J)	Erreur standard	Sig.	Intervalle de confiance à 95%	
					Borne inférieure	Limite supérieure
Light Weight	Middle	,62	1,066	1,000	-2,30	3,55
	Heavy	5,29*	1,066	**,001**	2,37	8,22
Middle Weight	Light	-,62	1,066	1,000	-3,55	2,30
	Heavy	4,67*	1,231	**,007**	1,29	8,05
Heavy Weight	**Light**	-5,29*	1,066	**,001**	-8,22	-2,37
	Middle	-4,67*	1,231	**,007**	-8,05	-1,29

comparison tests of the means show that the values of both warm-up protocols (maximum isometry and contrast) of the light category with heavy category are significantly different from those of the control test at $p \leq 0.05$ in favor of light category. Similarly, the values of both warm-up protocols of Middle category with the Heavy category are significantly different from those of the control test in favor of middle-weight subjects. The difference between the Light and Heavy categories ($p = 0.001$) is much greater than the difference between the Middle and Heavy categories ($p = 0.007$). While the values of both warm-up protocols of the Light and Middle categories are not statistically different at $p \leq 0.05$.

Our data are represented by a diagram showing means of the three weight categories.

Graph n°1: Total falls per weight category



Recent studies have suggested that individuals need a certain level of strength or training to be able to capitalize on the benefits of Post Activation Potentiation (Chiu et al., 2003; Duthie et al., 2002; Young et al., 1998).

According to Comyns et al, (2006), there is probably an optimal moment which allows the muscle to recover from the fatigue induced by the effect of the heavy load, but which is still potentiated. However, this optimal recovery time is highly individualized. If the performance or training activity does not take place after sufficient recovery time for the individual, it could lead to a decrease in performance. It is therefore important to identify this optimal recovery time for each athlete, trying to capitalize on the potential effect of PAP on performance.

On the basis of the results obtained in the control test, we observed an improvement in performance in the SJFT test of 4.97%, 3.66% and 2.22% respectively for the light, middle and heavy weight categories when using the warm-up protocol with the contrast method. The use of the warm-up protocol based on the maximum isometric method, resulted in an improvement of the results in the same test (Special Judo Fitness Test) of 2.69%, 1.83% and 3.33% respectively for the same weight categories in the same order. These results tell us that both types of contractions used in this study, maximum isometry and the contrast method (large concentric load followed by a plyometric exercise with the same biomechanical structure) improved performance on the SJFT test for all weight categories of our sample.

Research on performance improvement after a warm-up containing a potentiation component suggests that any type of muscle contraction can have an effect on PAP; only the extent to which potentiation occurs is likely to be variable depending on the type of contraction used (Sale, 2002; Tillin and Bishop, 2009).

Berning et al, (2010) demonstrated that performance at maximum isometric squat against a horizontal bar for 3 seconds, recorded an increase in performance at the Counter Movement Jump (CMJ) of 2.4 cm (5.1% power) 4 minutes after pre-load, and 2.6 cm (5.5% power) 5 minutes after pre-load. These modifications following a pre-load are the result of isometric contractions which are related to the increase in light chain phosphorylation (LCP), among other things responsible for the manifestation of PAP (Moore and Stull, 1984). Consequently, the strength and rate of force development would be increased in response to this type of contraction (Feros et al., 2012; Güllich and Schmidtbleicher, 1996), resulting in a beneficial impact during the dynamic activity that follows a pre-load (Tillin and Bishop, 2009; Rixon et al., 2007; French et al., 2003).

Rixon et al. (2007) also studied the influence of different types of contractions on the amplitude of PAP, and noted that isometric contraction allowed a better manifestation of PAP than dynamic contraction (concentric alone, eccentric alone, concentric-eccentric). According to the work of the research team of Esformes et al. (2010) on the effects of different types of contractions on PAP, isometric contraction seemed to be the type of pre-load that had positive effects on PAP after a long recovery period (8 min).

The contrast method (heavy concentric load followed by a plyometric exercise of similar biomechanical structure) has also been shown to be effective in increasing the

athlete's mechanical strength (Bevan et al., 2009). Moreover, studies show that the improvement of performance on an explosive task is more important in athletes who have performed high load exercises (e.g. 5 sets at 90% 1RM) (Batista et al., 2011; Esformes et al., 2010; DeRenne, 2010). Miarka et al,(2011) conducted a study of eight Brazilian regional-level judokas (5-7 years of practice) who were subjected to various pre-load (concentric sub-maximal load, drop jumps of different heights and contrast method). Subsequently, they compared the results with the control test during the SJFT after a recovery time of 3 minutes. The improvement in performance was recorded when using the plyometric exercises during the first phase of the test, and the improvement in the performance index in the SJFT test after using the contrast method. Conversely, some studies addressing the same issue have shown no improvement in performance following pre-contraction, both in the application of isometric contractions (e.g., Folland et al., 2007; and Robbins and Docherty, 2005) and dynamic contractions (e.g., Esformes et al., 2010, and Jones and Lees, 2003).

Since light chain phosphorylation (LCP) is different in humans and animals, the difference in fiber types in individuals, intra- and intermuscular coordination (Scott and Docherty, 2004) and the wide range of methodologies used in the literature would explain the presence of equivocal results (Hodgson et al., 2005; Kilduff et al., 2008). Indeed, the type of contraction, the intensity and volume of pre-loads, recovery time between sets of pre-load, level of training, absolute maximum force and different neuromuscular response in subjects may represent sources of bias in studies related to the phenomenon of PAP (Robbins and Docherty, 2005).

These contradictory results to those found in numerous scientific articles demonstrating the beneficial effects of PAP, are related to several individual factors. The manifestation of PAP depends on a number of variables, including the volume and intensity of pre-loading, recovery time, the type of activity following pre-loading, and the characteristics of the subject (Tillin and Bishop, 2009). Studies by Batista et al, (2007), Miyamoto et al, (2010), Weber et al, (2008), Esformes et al, (2010) and Rassier and Macintosh, (2000) have pointed out that the application of short pre-loading exercises (less than 10 seconds) would induce PAP more significantly. On the other hand, pre-solicitation longer than 10 seconds would decrease the benefits of PAP (Gossen and Sale, 2000; Hodgson et al., 2005). Regarding the volume applied during pre-solicitation, according to Wilson et al. (2013), the use of several series shows a significantly greater gain compared to the use of a single series.

There is a consensus in the literature (Batista et al., 2011; Miyamoto et al., 2010; Esformes et al., 2010; Khamoui et al., 2009; Weber et al., 2008; Rassier and Macintosh, 2000) that high intensity pre-solicitation would more significantly induce PAP, improving neuromuscular performance in the short term (Gilbert and Lees, 2005). Athletes respond better to a high-intensity pre-solicitation exercise (1 to 5 sets of 85% to 90% 1RM) before performing explosive exercise (Tillin and Bishop, 2009).

The time window needed to induce PAP is specific to each individual and is subject to the conditions of the pre-solicitation exercise (Docherty and Hodgson, 2007). However, some studies have established standards based on the requirements of the subsequent type of activity (Kilduff et al., 2008). Taking into account individual

differences, a period of 8 to 12 minutes between the high-intensity pre-charge and the explosive task to be performed would be the optimal window of opportunity to improve performance (Bevan et al., 2009; Kilduff et al., 2008). It is important to note that the recovery time required to benefit from the effects of PAP is dependent on the training level of the individuals. Based on the study by Wilson et al. (2013), it would appear that the important period for improved performance in elite athletes is shorter, ranging from 3 to 7 minutes, while in confirmed subjects, it is between 7 and 10 minutes. However, for untrained subjects, this period would be longer and of greater amplitude (more than 10 minutes). The recovery time that was used on our sample of elite athletes with 18.56 ± 4.68 years experience in judo practice for all weight categories was 7 minutes.

According to studies by Sale, (2002), Abbate et al, (2000), Hamada et al, (2000) and Moore and Stull, (1984), there appears to be a correlation between the percentage of type II fibers and the potential for PAP. Indeed, there is a positive correlation between the percentage of fast type II fibers, motor neuron activity and light chain phosphorylation RLC (greater RLC phosphorylation in response to pre-solicitation activity), leading to better PAP (Tillin and Bishop, 2009; Hodgson et al., 2005; Sweeney et al., 1993). The magnitude of PAP is reported to be dependent on the intensity and duration of exercise, the type of muscle fiber (Hamada et al., 2000; Hodgson et al., 2005) and specific to the training experience (Duthie et al., 2002; Rixon et al., 2007). It is recognized that in high performance athletes in explosive and short duration disciplines, the proportion of fast fibers (IIa, IIb) is higher (Tesch and Karlsson, 1982). This may be one of the reasons why athletes in these disciplines are more likely to induce PAP (Güllich and Schmidtbleicher, 1996) than untrained individuals (Khamoui, 2009; McBride et al., 2005; Gilbert and Lees, 2005; Chiu et al., 2003; Izquierdo et al., 2002).

In addition to the above elements (type of contraction, intensity and volume of preload, recovery time from preload to performance, level of training, absolute maximum strength, and the different neuromuscular response in subjects), elite athletes develop greater resistance to fatigue through training adaptations (Tillin and Bishop, 2009; Rixon et al., 2007). Moreover, subjects with greater maximal strength would improve their performance more than subjects with lower capacity (4.01% in trained subjects versus 0.42% in untrained subjects) according to Gourgoulis et al. (2003) and Young et al. (1998).

Conclusion

Warm-ups that involve post-activation potentiation should receive more attention as a strategy for improving power, particularly with regard to performance in judo bouts. The results of both warm-up protocols for the elite athletes in our sample showed improvements in performance in the SJFT test. As judo is a weight class sport, the correlation between weight and strength is important (Takahashi et al., 2005). Despite the excess weight of our heavy athletes, when applying the warm-up protocol based on maximum isometry, their performance in the SJFT test improved

significantly. The performance of light and middle weight category athletes in the same test was significantly improved when using the warm-up protocol that included the contrast method. Future Studies that aim to use specific judo exercises with the same regimen of muscle contractions are recommended, in order to explore the effects of these loads on potentiation.

Bibliography

1. Abbate F, Sargeant AJ, Verdijk PW, et al. (2000), Effects of high-frequency initial pulses and posttetanic potentiation on power output of skeletal muscle. J Appl Physiol Jan; 88 (1): 35-40.
2. Alves, J., Rebelo, A., Abrantes, C., & Sampaio, J. (2010). Short-term effects of complex and contrast training in soccer players vertical jump, sprint, and agility abilities. *Journal of Strength & Conditioning Research, 24*(4), 936-941.
3. Andrews, T. R., Mackey, T., Inkrott, T. A., Murray, S. R., Clark, I. E., & Pettit, R. W. (2011). Effect of hang cleans or squats paired with countermovement vertical jumps on vertical displacement. *Journal of Strength & Conditioning Research, 25*(9), 2448-2452.
4. Batista, M. A., Ugrinowitsch, C., Roschel, H., Lotufo, R., Ricard, M. D., Tricoli, V. A. (2007), Intermittent exercise as a conditioning activity to induce postactivation potentiation. Journal of Strength and Conditioning Research, 21(3), 837-840.
5. Berning, J.M.; Adams, K.J.; DeBeliso, M.; Sevene-Adams, P.G.; Harris, C.; Stamford, B.A (2010). Effect of functional isometric squats on vertical jump in trained and untrained men. J. Strength Cond. Res. 2010, 24, 2285–2289.
6. Bevan, H. R., Cunningham, D. J., Tooley, E. P., Owen, N. J., Cook, C. J., & Kilduff, L. P. (2010). Influence of postactivation potentiation on sprinting performance in professional rugby players. Journal of Strength and Conditioning Research, 24(3), 701-705.
7. Boguszewski, D., (2009), Defensive Actions of Contestants during Polish Judo Championships in the Years 2005-2008, Baltic Journal of Health and Physical Activity, 1(2):111-7.
8. Chatzopoulos, D., Michailidis, C., Giannakos, A., Alexiou, K, Patikas, D., Antonopoulos, C., & Kotzmanidis, C. (2007). Postactivation potentiation effects after heavy resistance exercise on running speed. *Journal of Strength and Conditioning Research, 21*(4), 1278-1281.
9. Chiu, L.Z, Fry, A.C, Weiss, L.W et al.,(2003), Postactivation potentiation response in athletic and recreationally trained individuals. J.Strength Cond Res Nov; 17 (4): 671-7.
10. Comyns,T, Harrison,A.J, Hennessy, L.K, and Jensen, R (2006), The Optimal Complex Training Rest Interval For Athletes From Anaerobic Sports Journal of Strength and Conditioning Research, 20(3), 471–476
11. DeRenne, C. (2010). Effects of postactivation potentiation warm-up in male and female sport performances: A brief review. Strength & Conditioning Journal, 32(6), 58- 64.

12. Docherty D, Hodgson M. (2007), The application of postactivation potentiation to elite sport. Int J Sports Physiol Perf; 2 (4): 439-44
13. Duthie, G.M, Young, W.B, and Aitken, D.A. (2002), The acute effects of heavy load on jump squats performance: an evaluation of the complex and contrast methods of power development. *Journal of strength and conditioning research 16*: 530-538.
14. Esformes, J.I., Cameron, N. and Bampouras, T.M. (2010), Postactivation potentiation following different modes of exercise. Journal of Strength and Conditioning Research, 24(7): 1911–1916.
15. Feros, S. A., Young, W. B., Rice, A. J., Talpey, S. W. (2012), The effect of including a series of isometric conditioning contractions to the rowing warm-up on 1,000- m rowing ergometer time trial performance. Journal of Strength and Conditioning Research, 26(12), 3326-3334.
16. Folland JP, Williams AG. (2007), The adaptations to strength training: morphological and neurological contributions to increased strength. Sports Med. 37 (2): 145-68
17. Franchini,E, Sterkowicz,S, Szmatlan-Gabrys,U, Gabrys,T, Garnys,M *(*2011), Energy System Contributions to the Special Judo Fitness Test. International Journal of Sports Physiology and Performance, 6, 334-343
18. French, D. N., Kraemer, W. J., & Cooke, C. B. (2003), Changes in dynamic exercise performance following a sequence of preconditioning isometric muscle actions. Journal of Strength and Conditioning Research, 17(4), 678-685.
19. Gilbert, G and Lees, A. (2005), Changes in the force development characteristics of muscle following repeated maximum force and power exercise. Ergonomics 48: 1576–1584.
20. Gossen, E. R., Sale, D. G. (2000), Effect of postactivation potentiation on dynamic knee extension performance. European Journal of Applied Physiology, 83(6), 524-530.
21. Gourgoulis, V., Aggeloussis, N., Kasimatis, P., Mavromatis, G., Garas, A. (2003), Effect of a submaximal half-squats warm-up program on vertical jumping ability. J Strength Cond Res May; 17 (2): 342-4.
22. Gullich, A, Schmidtbleicher,D. (1996), MVC- induced short-term potentiation of explosive force . N*ew studies in athletics 11* : 67-81.
23. Hamada, T, Sale, D.G, MacDougall, J.D, Tarnopolosky, M.A.(2000), Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. *Journal of applied physiology 88*: 2131-2137.
24. Hodgson, M., Docherty, D., and Robbins, D. (2005), Post-activation potentiation: Underlying physiology and implications for motor performance. Sports Medicine, 35(7), 585-595. doi: 0112-1642/05/0007-0585.
25. Izquierdo, M., Hakkinen, K., Gonzalez-Badillo, J. J., Ibáñez, J., & Gorostiaga, E. (2002). Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. European Journal of Applied Physiology, 87, 264–271. doi: 10.1007/s00421-002-0628-y

26. Jones P, Lees A. (2003), A biomechanical analysis of the acute effects of complex training using lower limb exercises. J Strength Cond Res 17: 694–700.
27. Khamoui, AV, Brown, LE, Coburn, JW, Judelson, DA, Uribe, BP, Nguyen, D, Tran, T, Eurich, AD, and Noffal, GJ. (2009), Effect of potentiating exercise volume on vertical jump parameters in recreationally trained men. *J Strength Cond Res* 23(5): 1465 – 1469.
28. Kilduff, L. P., Owen, N., Bevan, H., Bennett, M., Kingsley, M. I. C., Cunningham, D. (2008), Influence of recovery time on post-activation potentiation in professional rugby players. Journal of Sports Sciences, 26(8), 795-802.
29. Mc Bride, JM, Nimphius, S, Erickson, TM. (2005), The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. *J Strength Cond Res* 19(4): 893 – 897.
30. Miarka, B, Del Vecchio, F.B and Franchini, E.(2011) Acute Effects And Postactivation Potentiation In The Special Judo Fitness Test. Journal of Strength and Conditioning Research 25 (2) / 427–431
31. Miyamoto, N., Mitsukawa, N., Sugisaki, N., Fukunaga, T., Kawakami, Y. (2010), Joint angle dependence of inter muscle difference in postactivation potentiation. Muscle and Nerve, 41, 519-523.
32. Moore, R. L., Stull, J. T. (1984), Myosin light chain phosphorylation in fast and slow skeletal muscles in situ. American Journal of Physiology, 247(5 Pt 1), C462-471.
33. Okada, T., Nakazato, K., Iwai, K. et al., (2007), Body Mass, Nonspecific Low Back Pain, and Anatomical Changes in the Lumbar Spine in Judo Athletes, The Journal of Orthopaedic and Sports Physical Therapy, 37(11):688-93.
34. Rassier, DE and Macintosh,BR. (2000), Coexistence of potentiation and fatigue in skeletal muscle. B*razilian journal of medecine and biolgical research 3* : 499-508.
35. Ratamess, N. (2008). Adaptations to anaerobic training programs. In T.Baechle and R. Earle, (Eds.), *Essentials of strength and conditioning (3rd ed.;* pp. 94-119). Champaign, IL: Human Kinetics.
36. Rixon KP, Lamont HS, Bemben MG (2007), Influence of type of muscle contraction, gender, and lifting experience on postactivation potentiation performance. J Strength Cond Res; 21 (2): 500-5.
37. Robbins, DW, Docherty, D. (2005), Effetcs of loading on enhancement of power performance over three consecutive trials. *Journal of strength and conditioning research 19*: 898-902.
38. Robbins DW. (2005), Postactivation potentiation and its practical applicability: a brief review. J. Strength Cond Res May; 19 (2): 453-8.
39. Sale, D. G. (2002). Postactivation potentiation: Role in human performance. Exercise and Sports Science Reviews, 30(3), 138-143.
40. Schmidtbleicher, D., Buehrle M. (1987). Neuronal adaptation and increase of cross-sectional area studying different strength training methods. *Biomechanics XB.* B. Jonsson, ed. Champaign, IL: Human Kinetics, pp. 615–620.
41. Scott, SL, and Docherty, D. (2004), Acute effects of heavy preloading on vertical and horizontal jump performance. *J Strength Cond Res* 18(2): 201 – 205.

42. SPSS Inc. (2009). SPSS Base 19.0 for Windows User's Guide. SPSS, Inc., Chicago, IL.
43. Sweeney, H.L, Bowman, F.B, Stull, J.T. (1993), Myosin light chain phosphorylation in vertebrate striate muscle: Regulation and function. A*merican journal of physiolgy 264* : 1085-1095.
44. Takahashi, M., Takahashi, R., Takahashi,J.et al., (2005), Mastering Judo, Human Kinetics, Champaign, USA.
45. Tesch P, Karlsson J, Sjodin B (1982) Muscle fiber type distribution in trained and untrained muscles of athletes. In: Komi PV (ed) Int seminar on sports biology. Human Kinetics Publishers, Champaign, IL, pp 79-83
46. Tillin, N.A and Bishop, D (2009) Factors Modulating Post-Activation Potentiation and its Effect on Performance of Subsequent Explosive Activities, Sports Med; 39 (2): 147-166.
47. Vandenboom R, Houston ME, (1996) Phosphorylation of myosin and twitch potentiation in fatigued skeletal muscle. Can J Physiol Pharmacol 74(12):1315–1321.
48. Weber, K. R., Brown, L. E., Coburn, J. W., & Zinder, S. M. (2008). Acute effects of heavy-load squats on consecutive squat jump performance. Journal of Strength and Conditioning Research, 23(3), 723-730.
49. Wilson, J.M, Duncan, N.M, Marin, P.J, Brown, L.E, Loenneke,J.P, Wilson, S.M.C, Lowery, I.J.R.P And Ugrinowitsch, C.(2013), Meta-Analysis Of Postactivation Potentiation And Power: Effects Of Conditioning Activity, Volume, Gender, Rest Periods, And Training Status Journal of Strength Conditionning Research 27(3): 854–859.
50. Young, W., Jenner, A., Griffiths, K. (1998). Acute enhancement of power performance from heavy load squats. Journal of Strength and Conditioning Research, 12, 82-84.
51. Young, W.B. (1993) Training for speed/strength: Heavy versus light loads. *National Strength & Conditioning Journal*, *15*(5), 34–43.
52. Xenofondos, A., Laparidis, K., Kyranoudis, A., Galazoulas, Ch., Bassa, E., & Kotzamanidis C. (2010). Post-activation potentiation: Factors affecting it and the effect on performance. Journal of Physical Education and Sport, 28(3), 32-38.