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Revisando o treinamento complexo: meta-análise das implicações agudas no desempenho da potência de membros inferiores e superiores

Rio de Janeiro
2015

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Dissertação apresentada, como requisito parcial para obtenção do título de Mestre, ao Programa de Pós-Graduação em Ciências do Exercício e do Esporte da Universidade do Estado do Rio de Janeiro. Área de concentração: Aspectos Biopsicossociais do Exercício Físico.

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DEDICATÓRIA

Gostaria de dedicar essa dissertação a memória do meu querido amigo Professor Nelson Carvalho e a meus pais, “principalmente a minha mãe” por acreditarem sempre em mim e me darem forças para chegar até aqui. Por fim gostaria também de dedicá-la a todos os professores que me acompanharam em todas as jornadas de aprendizagem e despertaram em mim a apreciação pela docência.

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RESUMO

SOUZA, André Luiz Gouvêa de. **Revisando o treinamento complexo**: meta-análise das implicações agudas no desempenho da potência de membros inferiores e superiores. 2015. 74 f. Dissertação (Mestrado em Aspectos Biopsicossociais do Exercício Físico) – Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, 2015.

O treinamento complexo pode estar associado a melhoras no desempenho da potência de membros superiores e inferiores. No entanto, a grande diversidade dos desenhos metodológicos fornece dados não conclusivos. Um exemplo disso é a falta de consenso sobre o ótimo intervalo de recuperação após as ações condicionantes. Portanto, esta dissertação de mestrado revisou a extensão e a qualidade dos estudos no efeito agudo de diferentes intervalos de recuperação na altura do salto, assim como o desempenho de potência no exercício de supino arremessado, após a realização de específicas ações condicionantes. Os resultados sugerem que o treinamento complexo não induziu aumentos transitórios na potência produzida pelo exercício de supino arremessado. Quando proporcionados intervalos de recuperação abaixo de três minutos houve queda no desempenho da altura do salto. Contudo, um dos principais achados desta dissertação foi que para intervalos de recuperação entre 8 e 12 minutos a altura do salto era potencializada. O equilíbrio entre os efeitos da fadiga e da PPA é um fator chave para aplicação dessa estratégia. Sendo assim, a ausência de mudanças no desempenho do exercício de supino pode ter ocorrido por uma comum variabilidade dos efeitos da PAP entre os sujeitos dos estudos, assim como um efeito de equivalência entre PPA e fadiga. Nas atividades de salto, o prejuízo encontrado quando eram dados intervalos curtos (0-3 minutos) pode estar associado a uma prevalência dos efeitos da fadiga sobre os da PPA, que podem envolver liberação e diminuição da sensibilidade das fibras musculares ao Ca^{2+}, tal como aumentos do fosfato inorgânico intracelular, diminuindo assim a força de contração das pontes cruzadas. No entanto, para intervalos entre o 8-12 minutos os efeitos da fadiga sucumbiram aos da PPA. Essas mudanças podem estar associadas a alterações conformacionais nas pontes cruzadas, assim como uma otimização da ativação do músculo, o que levaria a melhoras no desempenho neuromuscular do exercício específico. Portanto, o treinamento complexo constitui uma estratégia consistente em melhorar a altura do salto. Porém, os resultados mostram um pequeno benefício para o exercício de supino arremessado.

Palavras-chave: Potencialização pós-ativação. Ação condicionante. Intervalo de recuperação.

ABSTRACT

SOUZA, André Luiz Gouvêa de. **Revising the complex training**: meta-analysis of acute implications in power performance of upper and lower limbs. 2015. 74 f. Dissertação (Mestrado em Aspectos Biopsicossociais do Exercício Físico) – Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, 2015.

The complex training may be associte increased in power performance of upper and lower limbs. However, the inumerous methodological dign does not provide conclusive data. An example of this is the lack of consensus on the optimal range of recovery after the conditioning actions. Therefore, this master´s thesis reviewed the extend and quality of the studies on the acute effects of differents rest intervals on the height of jump, as well as the power performance in bench press throw, after conditioning actions. The results suggest that the complex training does not induce transient increases in power produced by the exercise bench throw. When provided recovery intervals below three minutes there was a decrease in the height jump. However, one of the main findings of this work was that for rest intervals between 8 and 12-minute enhanced the jump height. The balance between the effects of fatigue and PAP is a key factor for implementation of the strategy. Thus, the absence of changes in bench throw performance may be due to a common effect of the variability of PAP between the subjects of the studies, as well as an equivalent effect between PAP and fatigue. When it was given short intervals (0-3 minutes) jumping performance was impaired, it may be associated with a prevalence of the effects of fatigue on the PAP, which may involve release and decreased sensitivity of muscle fibers to Ca 2+, such as increases in intracellular inorganic phosphate, thus decreasing the force of contraction of cross bridges. However, for 8-12 minutes intervals between the effects of fatigue succumbed to PAP. These changes may be associated with conformational changes in cross bridges, as well as muscle activation optimization, leading to improvements in the neuromuscular performance of specific exercise. Thereby, the complex training presents an interesting acute strategy to improve jump height. Furthermore, the results show a small benefit for exercising bench throw.

Keywords: Postactivation potentiation. Conditioning action. Rest interval.

LISTA DE ABREVIATURAS E SIGLAS

CA	Conditioning Activity
CT	Complex Training
MA	Main Activity
PAP	Postactivation Potentiation

SUMÁRIO

INTRODUÇÃO GERAL

Os documentos que compõem esta dissertação foram preparados em língua inglesa de modo a agilizar o processo de submissão dos artigos aos periódicos arbitrados e indexados internacionais. A decisão por priorizar os periódicos internacionais deveu-se ao fato dos mesmos terem um maior alcance científico e permitir que os estudos conduzidos no Laboratório Crossbridges fossem submetidos ao crivo de uma maior comunidade científica.

Ambos os manuscritos que compõem a dissertação revisaram metanaliticamente o impacto residual exercido por ações condicionantes sobre o desempenho do exercício subsequente. A apresentação dessas investigações foi estruturada em capítulos, que por sua vez, foram precedidos por esta apresentação geral.

A primeira revisão foi a intitulada "*The Effects of Rest Intervals on Jumping Performance: A Meta-Analysis on Postactivation Potentiation Studies*", que constituiu o segundo capítulo. A versão completa desse manuscrito envolveu a revisão metanalítica dos efeitos agudos de diferentes níveis de intervalos entre ação condicionante e principal, sobre o desempenho do salto. Uma versão desta investigação (apresentada no apêndice 4) está em processo de revisão por pares no periódico *Journal of Sports Science*.

No segundo capítulo foi apresentado o manuscrito titulado "*Is there any evidence of a postactivation potentiation effect on upper body power performance? A Meta-analytic study*", também está em processo de revisão por pares no periódico *Journal of Strength and Conditioning Research* . Este foi destinado a investigar o efeito da potencialização pós-ativação na potência gerada pelo exercício de supino arremessado. Por fim, o terceiro capítulo foi destinado a apresentação de uma conclusão geral com base nos principais achados dos dois estudos.

1 ESTUDO DE METANÁLISE 1 – THE EFFECTS OF REST INTERVALS ON JUMPING PERFORMANCE: A META-ANALYSIS ON POSTACTIVATION POTENTIATION STUDIES

ABSTRACT

The purpose of this review and meta-analysis was to examine the extent and quality of current research on the acute effect of rest interval on strength/ power performance, determined by jump height performance. This manuscript was conducted according to the criteria and recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA. Criteria eligibility included cross-over, randomized, not randomized and counterbalanced studies, and all were aimed at observing the voluntary muscle action-induced postactivation potentiation. Fourteen studies were selected by two independent raters and then were included in the final analysis. The rest intervals analysis involved ranges from 0-3, 4-7, 8-12 and equal or greater than 16 minutes. The results demonstrated medium effect sizes for rest intervals 0-3min and 8-12 (-0.25 CI: -0.51 to 0.01 for 0-3min and 0.24 CI: -0.02 to 0.49 for 8-12min, respectively) and a small effect for other rest intervals (0.15 CI: -0.08 to 0.38 for 4-7min, and 0.07 CI: -0.21 to 0.24 for 16min or more). There was no evidence of heterogeneity for any sub-groups tested (I^2 = 0%; P<0.001), as well as no indication of significant publication bias (Egger's test; P=0.179). Based on these results, the rest intervals between 0-3 minutes have a detrimental effect on jump performance as opposed to ranges between 8-12 minutes which have a beneficial effect on jump performance. Findings therefore suggest that the training complex is a viable strategy to improve the strength/power performance of the jump.

Keywords: benefic. complex training. muscle power. resistance exercise.

INTRODUTION

In the early seventies, Verkhoshansky (1983) proposed that when maximal strength exercises (now known as conditioning activity – CA) preceded plyometric drills that had similar motor activity, this main activity (MA) would be significantly improved. Currently, this strategy better known as complex training (CT) (Jensen & Ebben, 2003) has been applied to activities other than plyometrics and used by coaches and athletes to improve strength and power performance. However, other authors (Hough, Ross, & Howatson, 2009; A.V. Khamoui et al., 2009; Kilduff et al., 2007) demonstrated a reduction in performance, which might have been associated to fatigue due to the pre-stimulus. The underlying mechanisms responsible for a CA-induced improvement in performance have been termed as post-activation potentiation (PAP) (Hamada, Sale, & Macdougall, 2000).

Several studies (Batista, Coutinho, Barroso, & Tricoli, 2003; Comyns, Harrison, Hennessy, & Jensen, 2006; Jensen & Ebben, 2003) have been conducted to determine the time when the mechanisms of fatigue succumbed to those associated to the PAP. Nevertheless, due to the differences between the studies' experimental conditions, there is no available consensus that indicates the best interval between a conditioning activity and the main motor task.

Although CT has been widely used in the athletic field, there have been several issues regarding to variables that possibly affect PAP occurrence such as the rest interval between CA and MA, which need to be resolved. Thus, there is a need to better understand the recommended dose for the several training variables involved in the CT method in order to make ~~a~~ more efficient use of such a strategy. The aim of this review and meta-analysis was to examine the acute effects of the different interval ranges between the stimulus and the main activity in order to find out what is the most effective stimulus to provoke significant positive results in jumping performance.

1 **METHODS**

This meta-analysis was conducted according to the criteria and recommendations by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA (Liberati et al., 2009).

1.1 **Criteria eligibility**

Types of studies and interventions: Cross-over, randomized, not randomized and counterbalanced studies that were published either in English or Portuguese were selected for inclusion. All studies needed to aim the acute effects of isotonic voluntary muscle action-induced PAP on jumping performance.

Characteristics of the participants: Subjects included in the studies were young male adults, aged between 18 to 33 years, involved in strength/power sport modalities and/or strength conditioning programs for more than six months.

Characteristics of the variables measured: The current review included studies that had jump height (JH) as their main outcome dependent variable. Jumping performance obtained in different models such as drop, squat and counter movement jumps were all considered for the analysis. These are all considered good indirect indicators of power performance.

1.2 **Selection strategy**

The studies were retrieved from various databases including Medline, Scielo, Lilacs, Cochrane Library of Systematic Reviews and EMBASE. Literature search involved only complete papers published from 1961 to January 2012. The following keywords were used either independently or combined but not necessary listed in the respective mesh databases:

“postactivation potentiation”, “strength”, “power”, “complex training”, and “PAP”. Additional studies were included from the reference lists of papers retrieved in the search strategy.

1.3 **Study selection**

Initially, the studies were selected based on either their title or abstract content. They were then read in full. Two reviewers were responsible for identifying the studies in an independent and non-blind fashion. A third experienced investigator, if needed, would be responsible to settle any disagreement between the two reviewers.

1.4 **Data extraction**

Data were analyzed based on subject’s characteristics (age, years/months of experience and training status), rest interval between CA and MA, study’s sample size and the outcome measure jump height (jump height mean, and standard deviation).

Rest interval analysis included four arbitrary different subgroups in which the effects of the ranges from 0 to 3, 4 to 7, 8 to 12 and 16 or more minutes were independently examined.

When detailed results outcome measures were not available, authors were contacted to provide missing information. If authors did not provide raw data, a dimensional tool for graphic analysis (CorelDRAW®, Graphics Suite, version 12.0 for Windows) was used to derive mean and standard deviation from available graphs. When data could not be obtained from the graphs, the study was not included in the analysis.

1.5 **Bias risk assessment and degree of between rater agreements**

Two reviewers also worked independently on the bias risk assessment of the studies included in this review. The Jadad scale (Jadad et al., 1996) was used to classify their methodological quality level. Agreement between raters was tested using the Kappa statistics (Sim & Wright, 2005). Assessment of bias publication was performed through a visual analysis of a funnel plot graph (STATA 10.0, StataCorp LP, College Station, USA) that involved overall effect size mean of all cohorts in each individual study. This graph was designed to express overall mean on the X-axis while the sample size (standard error) was presented on the Y-axis. Egger's test was then used to determine if the mean effect size decreased with an increased sample (Egger, Smith, Schneider, & Minder, 1997).

1.6 **Consistency of the selected studies**

The analysis of the heterogeneity among the studies involved the application of the Cochran Q test (Cochran, 1954) that was followed by the I^2 statistics (Higgins, Thompson, Deeks, & Altman, 2003):

$$I^2 = \frac{(Q - df)}{Q} \times 100\%$$

Where Q is the Cochran Q test and df the degrees of freedom;

1.7 **Effect size**

The pooled standard deviation and effect size were calculated by extracting the mean, standard deviation and sample size pre and post-treatment. Pooled analyses of the estimated ranges were developed with a fixed effects model. Statistical analyses were performed using commercially available software (STATA 10.0, StataCorp LP, College Station, USA).

2 RESULTS

The search strategy, inclusion criteria and eligibility of studies included in this review are presented in Figure 1.

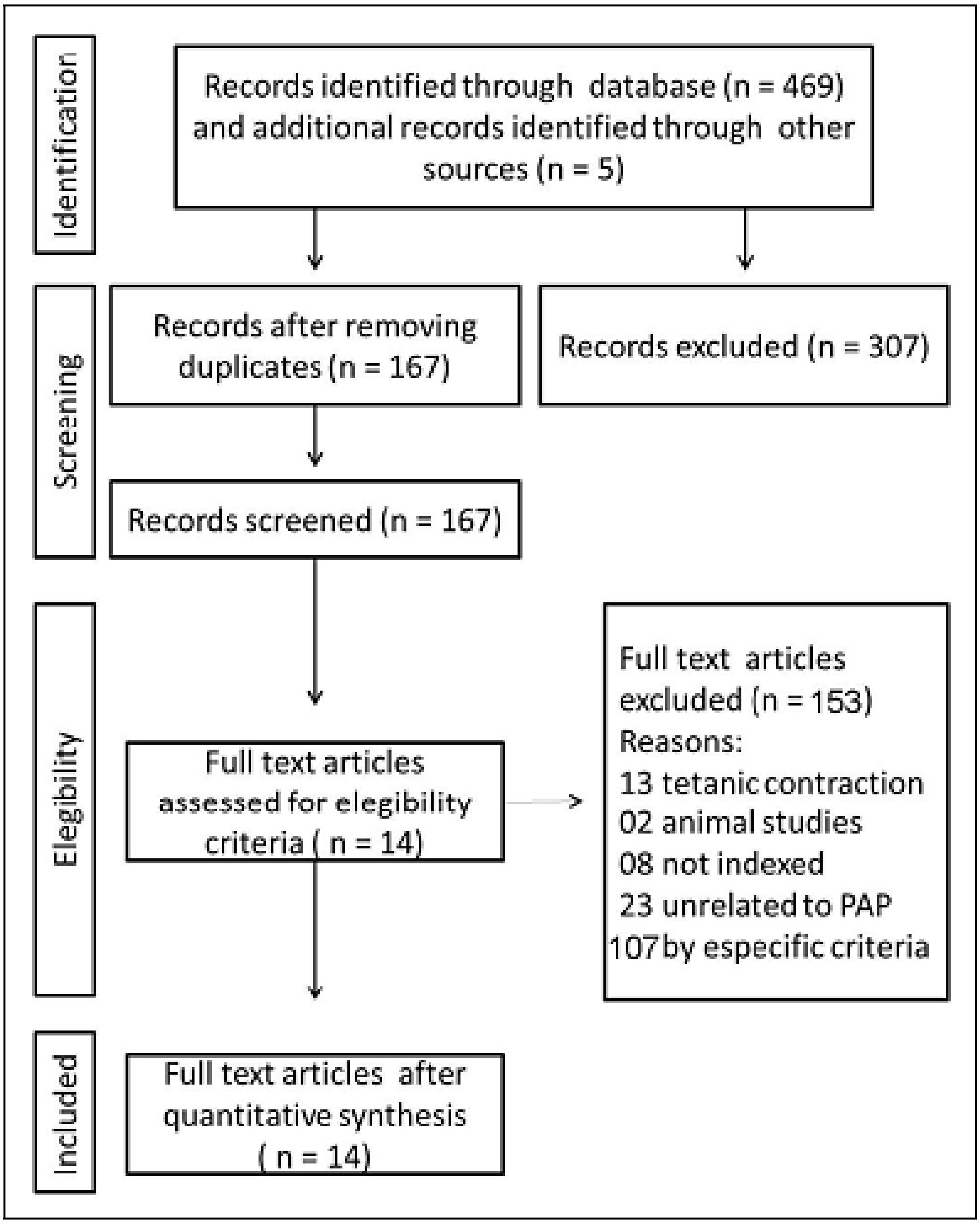

Figure 1 – Flow diagram of studies that underwent the review process.

2.1 **Characteristics of the studies selected**

Based on the above-mentioned selection strategy, 469 studies were retrieved. Fourteen (with 36 cohorts) out of the 469 were selected based on inclusion and eligibility criteria (Table 1). Eight of the 14 studies scored three points on the Jadad Scale. The remaining six achieved only one point each on this 5-point quality assessment instrument. Kappa statistics showed a perfect inter rater agreement ($r = 1.000$; $P < 0.001$).

2.2 **Subjects characteristics**

Data from a pool of 193 subjects were used in this analysis. All male subjects reported engagement in resistance training programs (with at least 6 months experience) and/or strength/power modalities such as rugby, volleyball, soccer.

2.3 **Characteristics of the treatment**

The conditioning activities reported in the studies consisted of dynamic leg press, knee extension, dead lifts and squat exercises. Exercise intensity was over 80% of 1 repetition maximum. Rest intervals ranged from 0 to 360 min. The number of sets and repetitions ranged from 1 to 6 and 1 to 7, respectively. When jumps were applied as conditioning activities, 1 to 8 trials were performed being done with their body mass of individuals or additional weights (see table 1).

Table 1. Studies retrieved from the literature search strategy

Study	**Subjects**	**CA**	**Volume Intensity**	**Interval CA between MA**	**MA**	**Results Jump Height**
Kilduff et al. 2007	23 ATL rugby	Squat	1 x 3 RM	15s, 4, 8, 12, 16 and 20 min	CMJ	ND
Kilduff et al. 2008	20 ATL rugby	Squat	3 x 3 RM (87% 1RM)	15s, 4, 8, 12, 16 and 20 min	8 CMJ	↓ (15 s) ↑ (8 min)
Jones & Lees 2003	8 TRA	Squat	1 x 5 rep (85% 1 RM)	3, 10 and 20 min	3 CMJ 3 DJ	ND
Esformes et al. 2010	13 ATL power	Squat	1 x 3 RM	5 min	3 CMJ	ND
Villarreal et al. 2007	12 ATL volleyball	Squat	4 x 7 rep (± 82,5% RM) 6 x 7 rep (± 88% RM)	5 min and 6 h	CMJ DJ	↑ (5min, 6h)
Mitchell et al. 2011	11 ATL rugby	Squat	1 x 5 RM	4 min	5 CMJ	↑

Crewther et al. 2011	9 ATL	Squat	1 x 3 RM	15s, 4, 8, 12, and 16 min	CMJ	↑ (4, 8, 12 min) ↓ (15s, 16 min)

ATL – athletes; CA – conditioning activity; CMJ – countermovement jump; DJ – drop jump; MA – main activity; ND – no significant difference; rep – repetitions; RM – repetition maximum; s – second; ↑ – significant increment in jump height; ↓ – significant decrement in jump height; TRA – trained

2.4 **Main Effect**

When all studies (Baker, 2003; Deutsch & Lloyd, 2008; Esformes, Cameron, & Bampouras, 2010; Gourgoulis, Aggeloussis, Kasimatis, Mavromatis, & Garas, 2003; Jensen & Ebben, 2003; Jones & Lees, 2003; A. V. Khamoui et al., 2009; Kilduff, et al., 2007; Kilduff et al., 2008; Mitchell & Sale, 2011; Saez Saez de Villarreal, Gonz, lez-Badillo, & Izquierdo, 2007; K. R. Weber, L. E. Brown, J. W. Coburn, & S. M. Zinder, 2008; Warren B. Young, Andrew Jenner, & Kerrin Griffiths, 1998) were pooled (36 cohorts from 14 studies), Cochran's Q test and I^2 statistics analyses showed significant results ($X^2 = 0.978$; $I^2 = 0\%$) indicating an absence of data heterogeneity. In order to provide a better understanding of the influence of rest intervals on the PAP occurrence, subgroup analyses involving different interval ranges were subsequently performed.

2.5 **Rest interval**

When a subgroup analysis was performed for different ranges of rest intervals between conditioning activity and main activity, the pooled estimate of the effect size for the rest interval range 0 to 3 min was - 0.25 (95%CI; -0.51 to 0.01) (Fig. 2). There was no evidence of data heterogeneity ($I^2 = 0\%$; $X^2 = 0.977$; $P < 0.001$) when 9 treatments cohorts of 6 studies were considered.

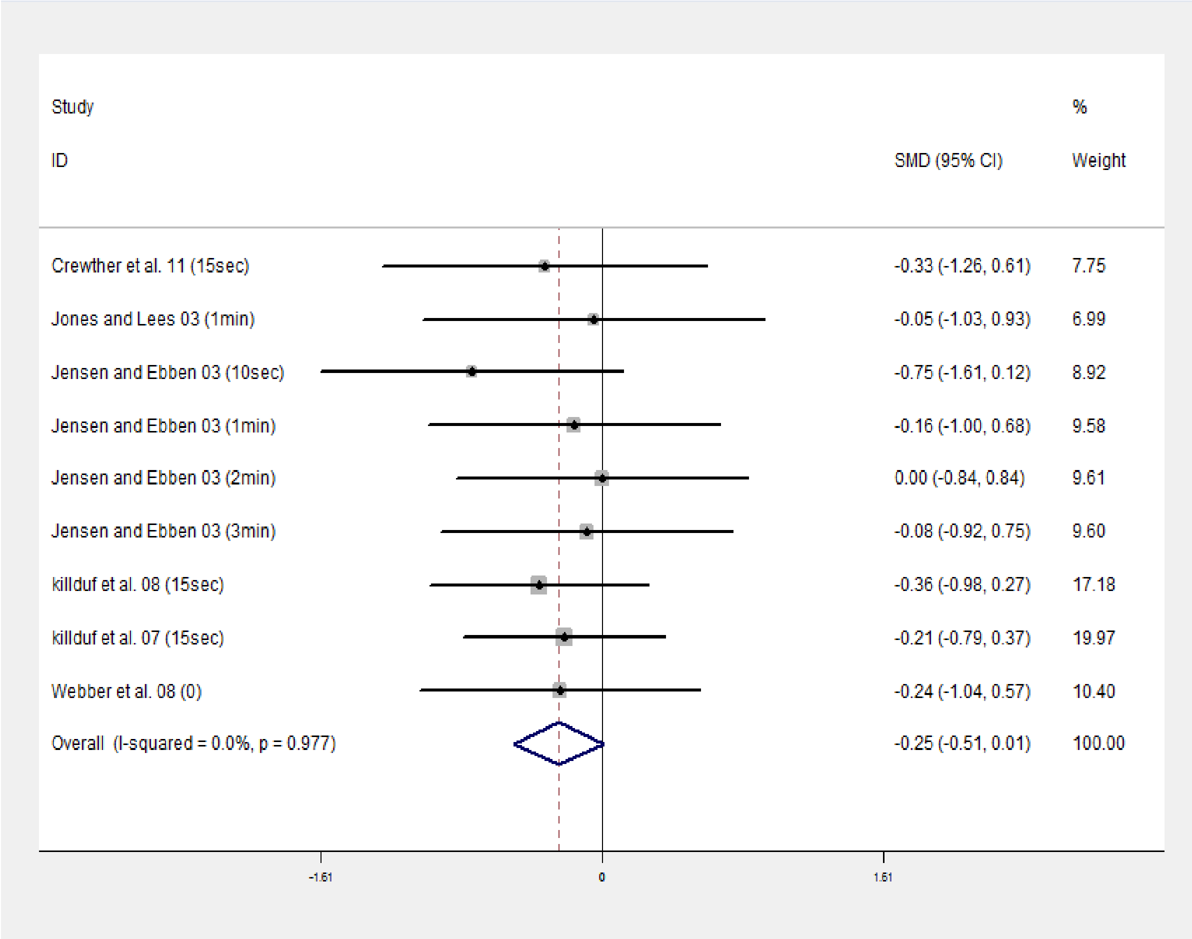

Figure 2 – Forest plot of rest intervals between 0 to 3 minutes.

For the rest interval range from 4 to 7 min, the pooled estimate of the effect size was 0.15 (95% CI; -0.08 to 0.38) (Fig. 3). Data did not present heterogeneity ($I^2 = 0\%$; $X^2 = 0.997$; $P < 0.001$) for 10 cohorts of 10 studies included in this analysis.

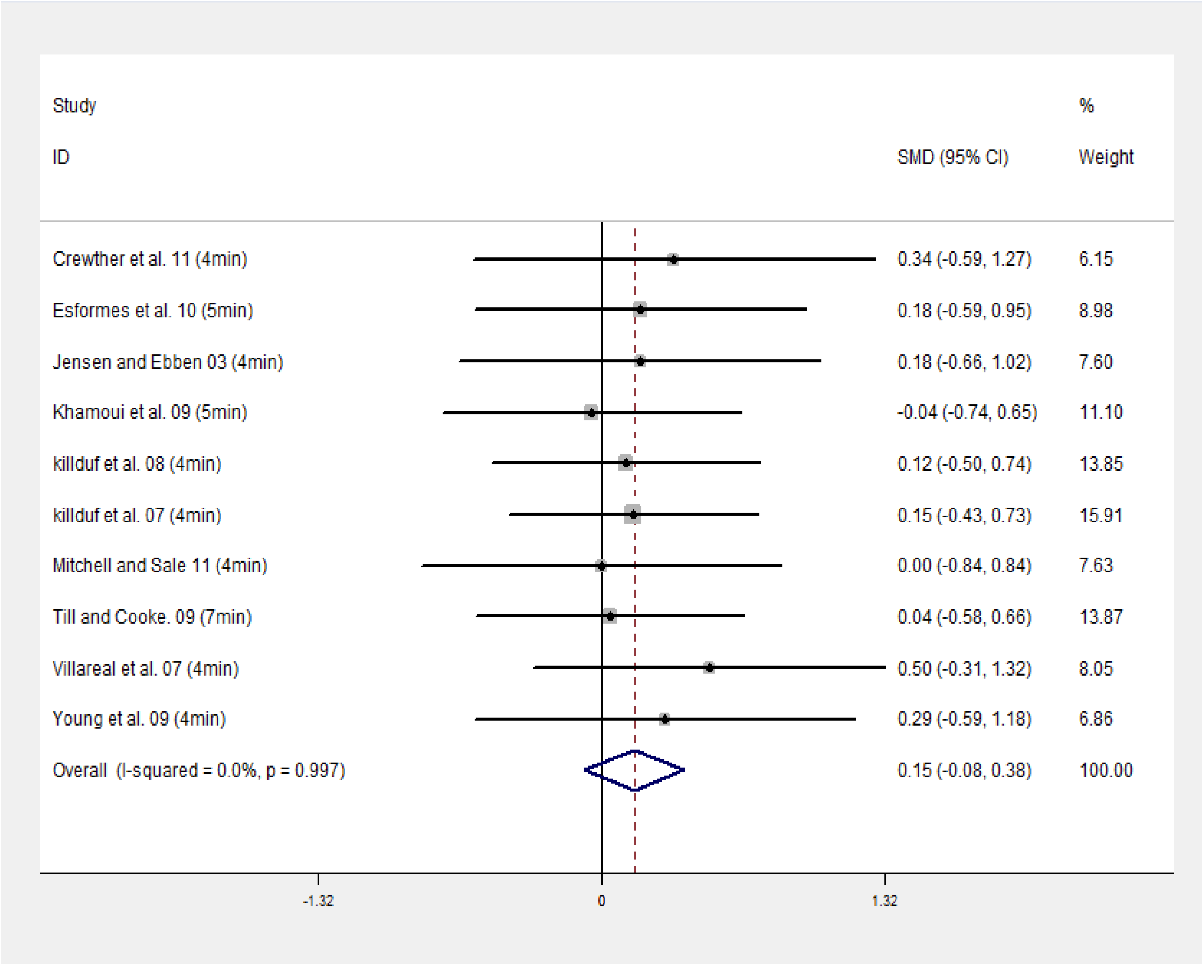

Figure 3 – Forest plot of rest intervals between 4 to 7 minutes.

The pooled estimate of the effect size for the rest interval range from 8 to 12 min was 0.24 (95% CI; -0.02 to 0.49) (Fig. 4). There was also no evidence of data heterogeneity (I^2 = 0%; X^2 = 0.977; P < 0.001) for 8 cohorts of 5 studies analyzed. Finally, for the range that included rest intervals longer than 16 min, the pooled estimate of the effect size was 0.01 (95% CI; -0.21 to 0.24) (Fig. 5). Similar to the other rest interval ranges, there was no evidence of data heterogeneity (I^2 = 0%; X^2 = 0.935; P < 0.001) for 9 cohorts of 5 studies.

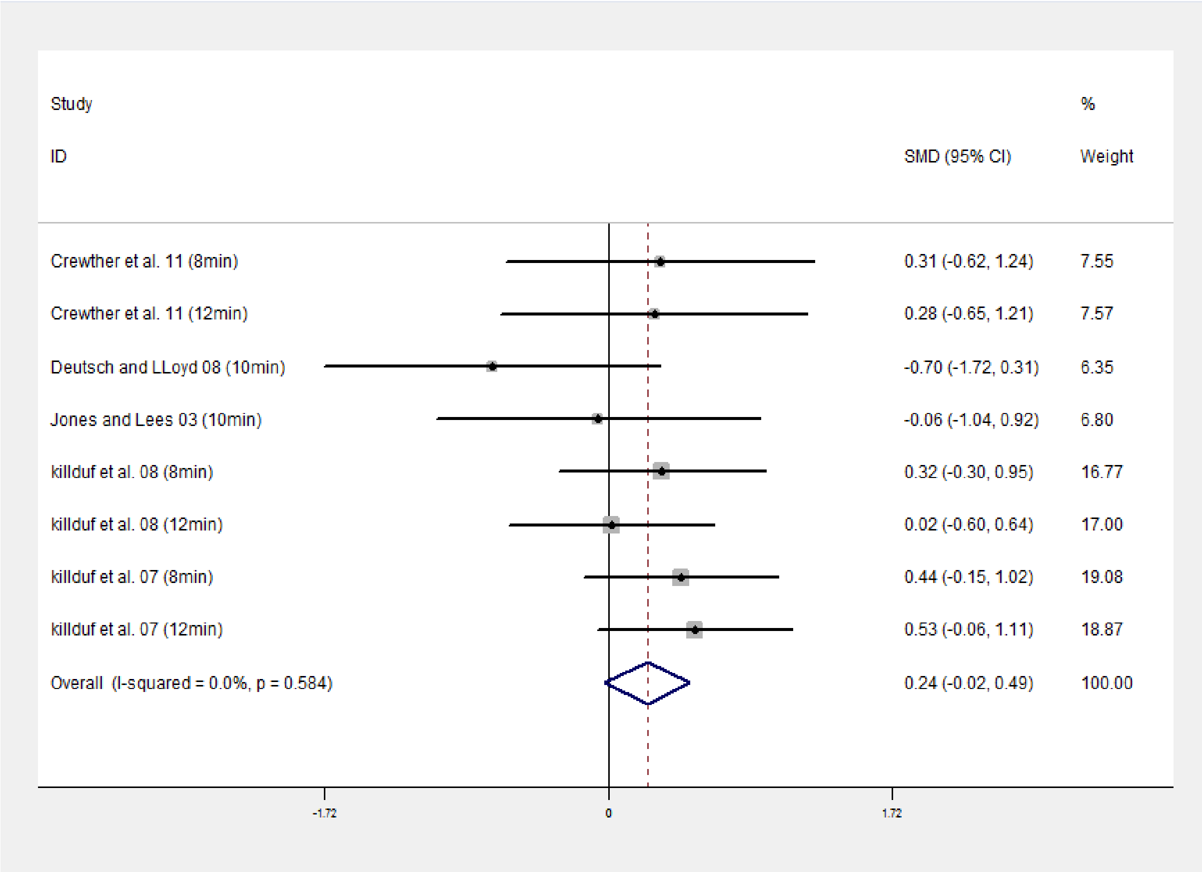

Figure 4 – Forest plot of rest intervals between 8 to 12 minutes.

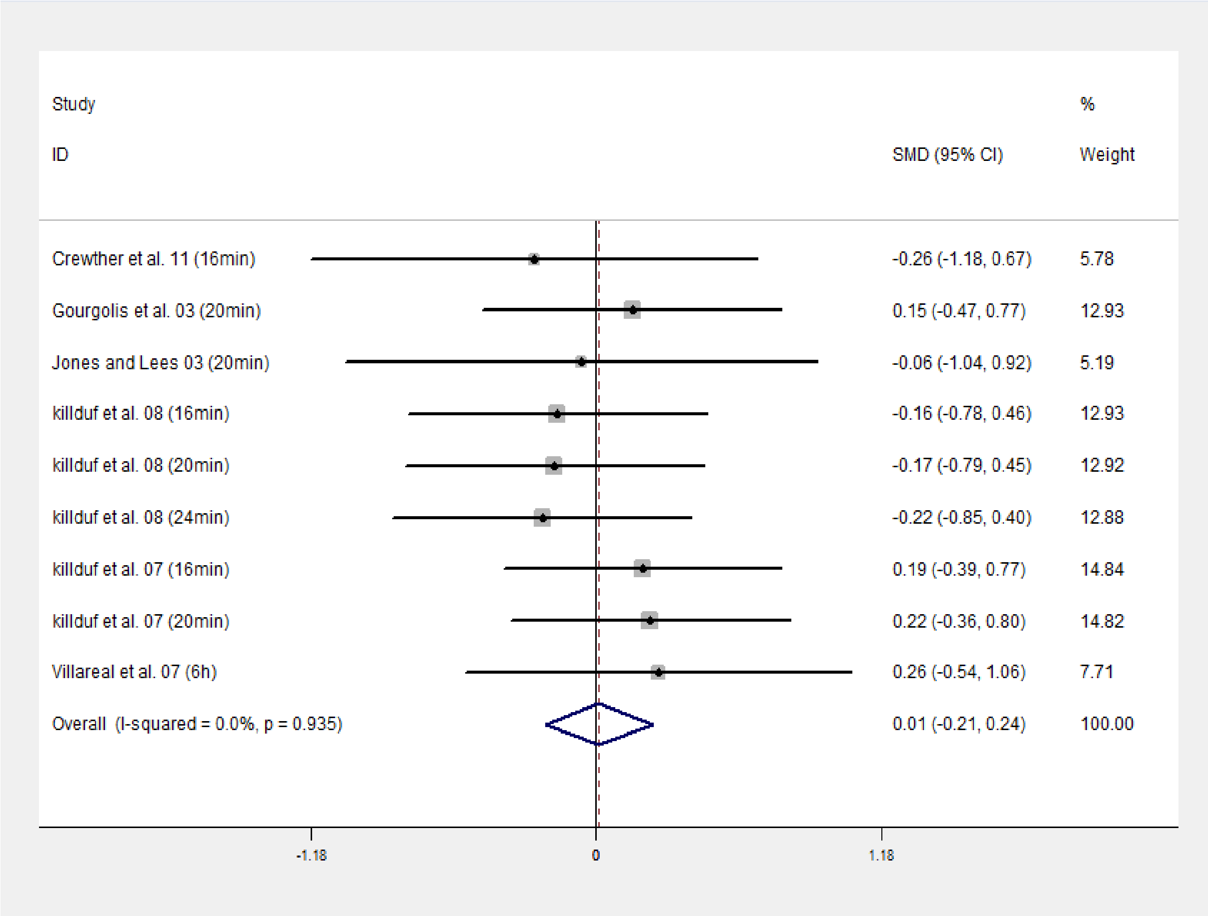

Figure 5 – Forest plot of rest intervals from 16 minutes or more.

2.6 **Risk of bias within studies**

A visual analysis based on the funnel plot (Figure 6) did not show a considerable data asymmetry. In addition, an absence of statistical significance in the Egger test (P = 0.179) evidenced a non-significant publication bias.

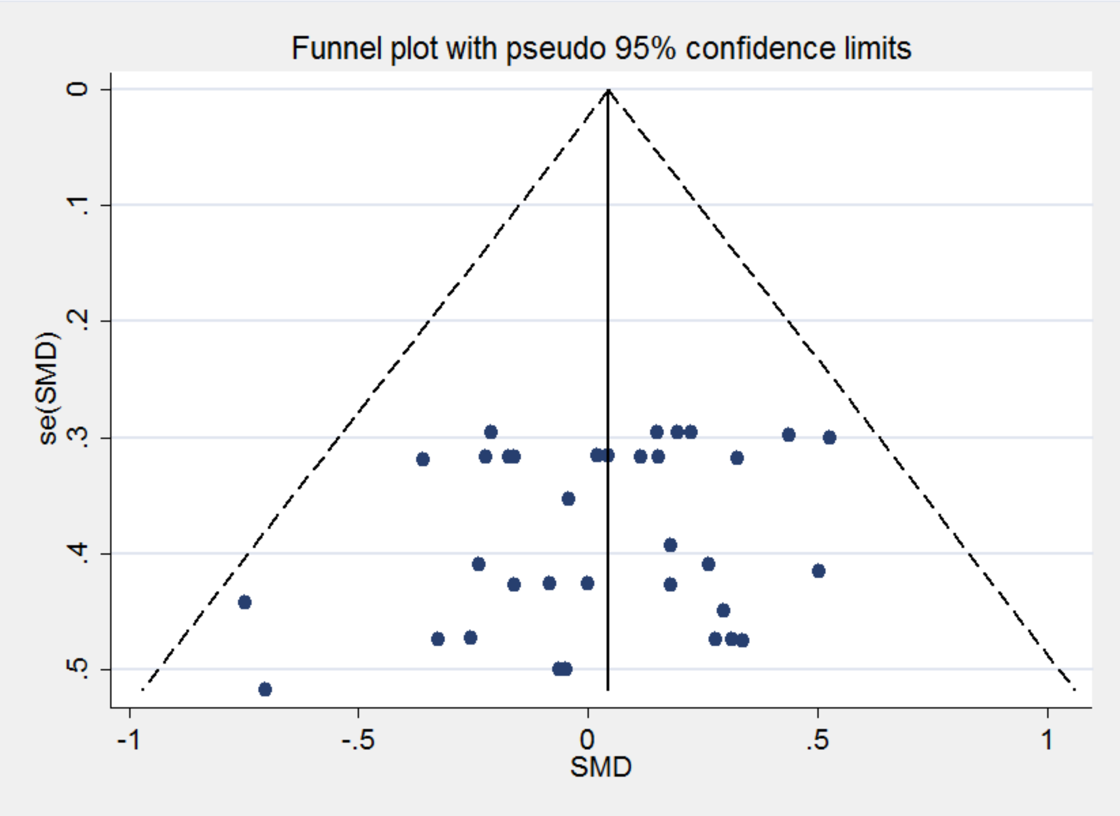

Figure 6 – Funnel plot of standardized mean difference (SMD) against standard error (SE).

DISCUSSION

The present study analyzed the magnitude of PAP-induced increment on jump performance as well as the influence of manipulating one specific variable that may have an impact on the treatment effects. The current results support the hypothesis that complex training constitutes an effective method of inducing increases in vertical jumping performance of young males engaged in either strength/power sport modalities or resistance training. Furthermore, the manipulation of the rest interval that precedes the main activity performance seemed to affect PAP magnitude and jump height.

Evidence has attributed changes on PAP magnitude to the manipulation of complex training variables other than the rest interval that precedes the main activity (Kilduff, et al., 2007; Kilduff, et al., 2008). These variables were not included in the meta-analysis due to limited data available in the literature. When data were available, the depth of analysis did not fit the established inclusion criteria. Therefore, the rest interval between conditioning activity and main activity constituted the main focus of the review analysis.

Based on the inclusion and eligibility criteria, eleven studies (with 29 treatments cohorts) were selected and then subjected to the assessment of their bias publication risk and methodological quality level. A subsequent analysis that involved a visual interpretation of the funnel plot graph did not detect data asymmetry, indicating no presence of possible outliers. A second and quantitative analysis of the funnel plot characteristics using the Egger test, confirmed absence of significant publication bias.

The rate of agreement between assessments performed by two independent reviewers was classified as very high since the Kappa correlation coefficient was 1.0 (P = 0.000). According to Landis and Koch's proposal (Jadad et al., 1996), the current inter-reviewer reliability for quality rating analysis was classified as "perfect". In addition to previous research that reported its validation (Higgins, Thompson, Deeks, & Altman, 2003), these findings also suggested that the Jadad scale seems to be an appropriate tool to assess methodological quality rating.

Considering that the studies reviewed did not use double-blind models due to the characteristics of the subject under investigation, the scores obtained by some of these studies did not reach more than 3 out of five points, which is within the criteria used by the Jadad scale. In addition to this fact, the average quality level was even more reduced due to the non-randomized features of the five out of eleven selected studies. Therefore, although average quality level was classified as LOW, such an analysis should also consider the applicability of the Jadad Scale to the characteristics of these studies. Moreover despite the great debates about the randomization of the included studies, evidence supports that there is no difference in the size of the effects between randomized and nonrandomized studies (Benson & Hartz, 2000; Concato, Shah, & Horwitz, 2000)

Conflicting findings are found when it comes to the intensity of the conditioning activity. Villareal et al. (2007) and Comyns et al. (2007) found better results with jump intensities above 80% 1RM. These findings may be associated to higher levels of muscle-tendon stiffness, which would reduce the transfer time of the strength of the bone muscle-tendon unit (Till & Cooke, 2009). This way, it would explain improvements in some variables in the jump, but not absolute additions in jump height, as evidenced by Comyns et al. (2007), that found an increase in stiffness and ground reaction force but not in the jump height. In addition, other findings revealed no differences for intensities lower than 40% as compared to higher than 80% of 1RM (Parry et al., 2008; Weber, Brown, Coburn, & Zinder, 2008). Thus, intensities between 80 and 100% of 1RM were chosen based theoretical physiological concepts from different authors based on other evidences rather than just performance (Hamada, Sale, MacDougall, & Tarnopolsky, 2000; Tillin & Bishop, 2009)

The number of sets and repetitions may play an important role in generating PAP. Obviously the higher the volume the greater the stimulus imposed fatiguing the muscle. As discussed by some authors, fatigue possibly coexists with PAP (Comyns, et al., 2006; Kilduff, et al., 2007), so a balance between the volume, intensity and resting interval time is needed to generate the beneficial effects of PAP (Sale, 2002). However, a consensus on what is the optimal volume has not been established yet.

Studies selected for the current review used similar volume to those that observed a potentialization effect inducing a positive jump performance result (Gourgoulis, et al., 2003; Saez Saez de Villarreal, et al., 2007).

Evidence suggests that the experience in strength and power activities may influence the generation of PAP (Chiu et al., 2003; Rixon, Lamont, & Bemben, 2007). Indeed, it has been shown that PAP was most effective when type II fibers constituted a greater percentage of the muscle under investigation (Hamada, Sale, & Macdougall, 2000). PAP effectiveness would occur due to an increased sensitivity of the fast twitch white muscle fibers to the contraction-induced myosin light chain phosphorylation (MLCP) (Moore & Stull, 1984). This justifies our decision to include only the studies that included trained subject or athletes.

In addition, current findings confirm that training status influences the PAP occurrence and effectiveness at least when jump performance constitutes the main activity studied. A mean pooled overall estimate of the effect size that involved 165 subjects, indicated a small or non-existing change on performance when data analysis was performed for rest interval between CA and MA (0.05: CI; -0.07 to 0.18).

Subgroups analysis though, generated different effects. The pooled estimate of the effect size for rest interval range from 8 to 12 min (0.24: CI; -0.02 to 0.49) indicated a medium improvement, while ranges from 4 to 7 min (0.15: CI; -0.08 to 0.38) and from 16 min or more (0.01: CI; -0.21 to 0.24) indicated a small improvement on jump performance. This classification is based on Cohen (1992). When subgroup analysis only involved the range from 0 to 3 min, the pooled effect size (-0.25; CI: -0.51 to 0.01) did tend to emphasize a decrease in jump performance, indicating a harmful effect.

Although a possible effect inter-individual discussed in the literature, increase the variability of results (Jo, Judelson, Brown, Coburn, & Dabbs, 2010; K. A. Till & C. Cooke, 2009), at different cutoff points of rest interval produces magnitude distinct of results. According to other studies (Comyns, et al., 2007; Jensen & Ebben, 2003; Kilduff, et al., 2008) intervals less than 3 minutes long can produce significant reductions in performance. This may be associated to a poor phosphocreatine resynthesis (Young, Jenner, & Griffiths, 1998), which would impact the phosphagenic system to properly regenerate energetic substrate for the main action. In the 4 to 7 interval range and above 16 minutes or more, data are consistent with other findings (Cabrera, Morales, Greer, & Pettitt, 2009; Comyns, et al., 2006) where no performance difference was obtained after conditioning action. This probably occurred simply because the effects of fatigue equaled those of PAP, for ranges 4 to 7 minutes, while 16 minutes and above effects dissipated.

Current research indicates a medium effect size for the performance of jump height (0.24 CI: 0.02 to 0.49) when the recovery intervals between 8 and 12 minutes. These findings corroborate those of other authors (Cabrera, et al., 2009; Comyns, et al., 2006; Kilduff, et al., 2008) that clearly showed the possible window of time where the values of PAP outweigh fatigue, thus contributing for improving performance.

This ergogenic effect may be possible by aforementioned MLCP, where part of the released calcium by the sarcoplasmic reticulum in the stage of conditioning activities will bind calmodulin and stimulate a higher sensitivity crossbridges to calcium, thus improving the ability of the sarcomere to produce force in a smaller unit of time (Sweeney & Stull, 1990). Other aspects associated with neural mechanisms have also been postulated as to increase recruitment and synchronization of motor units and to decrease pre-synaptic inhibition (Cabrera, et al., 2009). Nevertheless, these mechanisms still need to be investigated in environments similar to daily sports in order to make causal inferences more secure and improve external validity of the experiments.

CONCLUSION

In conclusion, the results of this study indicated that an interval range of 8 to 12 minutes seems to be the best rest interval between conditioning activity and jumping performance, as compared to the other interval ranges compared here. In addition, more studies are needed to investigate other variables not specifically addressed here, as well as number of sets, intensity and type of conditioning activity. A combination of activity intensity, rest interval, characteristic of the main activity and level of training also play an important role in determining the acute effect on performance.

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2 ESTUDO DE METANÁLISE 2 - IS THERE ANY EVIDENCE OF A POSTACTIVATION POTENTIATION EFFECT ON BENCH-PRESS POWER PERFORMANCE? A META-ANALYTIC STUDY

ABSTRACT

The purpose of this meta-analytic review was to examine the extent and quality of the current research on the post-activation potentiation-induced acute effect on bench press throw power output performance. This manuscript adopted the criteria and recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA. Criteria eligibility included crossover, randomized, not randomized and counterbalanced studies that aimed to observe the voluntary muscle action-induced postactivation potentiation. Seven studies were selected by two independent raters and then included in the final analysis. The studies selected for this meta-analysis included athletes or trained in strength/power subjects. The bench press exercise was performed as conditioning activity (CA), with percentages between 65 and 100% of 1RM. The current rest intervals between CA and main activity (MA) ranged from 3 to 16 minutes. The pooled estimate demonstrated small effect size for bench press throw power output (0.15 CI: - 0.02 to 0.32). There was no evidence of heterogeneity (I^2 = 0%; P < 0.001), as well as no indication of significant publication bias (Egger's test; P = 0.349). Findings, therefore, suggest that training complex, different from what was evidenced in a previous mata-analysis for upper-body activities, is not appropirated strategy to improve the upper-body power performance.

Keywords: PRISMA. conditioning activity. complex training. bench throw.

INTRODUTION

Acutely, muscle power performance is determined by several factors, among the most important are muscle physiological cross-sectional area and activation pattern (Güllich, 96). These factors may be partially affected by the muscle contraction history. Another factor that has been considered as playing a major role is the post-activation potentiation (PAP). This phenomenon has been observed by using a training strategy, initially described by Verkoshansky (1983), as training complex. It refers to a combination of strength exercises followed by plyometric activity with similar kinematic pattern. The first exercise is usually called the conditioning activity (CA), while the second (the plyometric or other type or strength/power activity) of main activity (MA).

A few possible mechanisms have been postulated to explain the post-activation potentiation. The first one is the conformational change of myosin head towards the active sites of myosin (Sweeney et al., 93), that is given by the increase in phosphorylation of myosin regulatory light chain (MRLC), caused by a combination of physiological events. As they are triggered, action potentials cross the t tubules with the dihydropyridine receptor releasing certain amounts of Ca2+, which are detected by the ryanodine receptor in sarcoplasmic reticulum. This connection will allow the output of the Ca2+ sequestered in the sarcoplasm to SR (Westerblad et. al., 02). Part of Ca2+ will bind to troponin C, but another part can bind to calmodulin. If a sufficient amount of Ca2+ (3-4 molecules) bind to calmodulin, conformational changes occur in myosin light chain, which may lead to increases in the rate of force development (Sweeney et. al., 93).

The second postulated mechanism is the increased muscle stiffness, which is supported by the evidence of a higher rate of coupling to an unchanged decoupling of crossbridges (Rassier & Macintosh, 00; Sweeney & Stull, 90), modifying the expression of the concentric muscle activity. This increased coupling of crossbridges in addition to being associated with increased active force (Sweeney & Stull, 90), results in improvement in muscle performance.

The third mechanism is associated to changes in neuromuscular activation. These changes may include increases in recruitment of large motor units, and improvements in transmission patterns, thus increasing the speed and force of muscle fibers contraction (Güllich, 96; Tillin & Bishop, 09).

Several studies have investigated the post-activation potentiation in the lower-body in activities such as jumping, sprinting or specific resistance training equipment. Kilduff et al. (2008) and McCann et al. (2010) observed that jump performance improved after using squat as conditioning activity. Similarly, Batista et al. (2007) observed improvement in knee extension peak torque after an isokinetic knee extension CA at 60°/sec. However, others found no change (Batista et al, 03; Robbins & Dochety, 05) or even a decrease in power performance (Jensen & Ebben, 03), after a CA. In addition, under specific situations such as type of conditioning activity (jumping), gender (male), individual's background (conditioned in strength and power) and with intervals between the main activity and conditioning (between 8 and 12 minutes), the PAP seems to have a notable importance for performance (Comyns et al. 06; Jensen & Ebben, 03; Kilduff et al., 07). Although there seems to be a need to further clarify this effect for upper-body activities, in a recent review and meta-analysis study by our group (Gouvêa et al., 2012) it was observed that this type of scenario provides the greatest effect size, when considering the jump height as the main dependent variable.

Studies looking at the PAP in upper-body have shown conflicting results. Cabrera et al. (2009) found a decrease in power output for bench press throw after using CA with different percent of 1RM (55, 66 and 70%). Baker and Newton (2) found a 4.5% improvement in power output after bench pressing with an CA of 65% of 1 RM. Brandenburg (2005) and Hrysomalis and Kidggel (2001) conducted similar protocols and found no significant differences in power.

Although other studies have revised the PAP (sale, 02; Tilin & Bishop, 09) none of them have systematically summarized and presented the acute effects of complex training for upper-body. Considering that the possibility of improvement in acute upper-body power output implies important values for athletes participating in determined sports (e.g. rugby, olympic throws). The purpose of this review and meta-analysis is to examine the acute effect of complex training in the performance in upper-body power.

3 METHODS

This meta-analysis was conducted according to the criteria and recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA (Liberti et al., 09).

3.1 Criteria Eligibility

Types of studies and interventions: Cross-over, randomized and not randomized and counterbalanced studies published in English or Portuguese were selected for inclusion. All studies investigated the acute effects of voluntary muscle activity-induced PAP in bench-press throw exercise. In addition, only studies that performed isotonic CA were included in this review.

Characteristics of the participants: The subjects included in these studies were male young adults with ages ranging from 18 to 33 years, involved in strength/power sport modalities and/or strength conditioning programs for more than 6 months.

Characteristics of the variables measured: The current review included studies that had power output as their main dependent variable. The power output was derived from the results obtained through the performance of bench press throw exercise.

3.2 Selection Strategy

The studies included in this review were retrieved from various databases including Medline, Scielo, Lilacs, Cochrane Library of Systematic Reviews and EMBASE. Literature search involved only full-papers published between 1986 and September 2011. The following keywords were used either independently or combined but not necessary listed in the respective mesh databases: "potentiation postactivation", "bench", "throw", "upper" and "body". Additional studies were included from either the reference lists of original articles retrieved in this search or from other review articles on this subject.

3.3 **Study Selection**

Initially, the studies were selected based on either their title or abstract. They were then read in full. Two reviewers were responsible for identifying the studies in an independent and non-blind fashion. A third experienced investigator, if needed, would be responsible to settle any disagreement between the two reviewers.

3.4 **Data extraction**

Data were analyzed based on subject's characteristics (age, years/months of experience and training status) and outcome measures (mean and, standard deviation power output, and sample size).

Data were selected from studies that used intervals between CA and MA between 3 to 16 minutes. Conditioning activity from 65 to 100% of 1 RM. Only dynamic condition activities containing concentric and eccentric phase were considered.

When outcome measures were not available in the evidence, authors were contacted to provide missing information. If authors did not provide raw data, a dimensional tool for graphic analysis (CorelDRAW®, Graphics Suite, version 12.0 for Windows) was used to extract mean and standard deviation from available graphs. In addition, analysis of inter-rater reliability of these measures is virtually perfect (ICC=1,000). When the raw data could not be obtained from the graphs, the study was not included in the analysis.

3.5 **Bias risk assessment and degree of between rater agreement**

Two reviewers worked independently on the bias risk assessment of the studies included in this review. The Jadad scale (Jadad et al., 96) was used to classify their quality level. Agreement between raters was tested by using the Kappa statistics (Sim & Wright, 05). A funnel plot graph was constructed using commercial software (STATA 10.0, StataCorp LP, College Station, USA) to assess publication bias, using the overall effect size mean of all cohorts in each individual study.

The graph was designed to express overall mean (standardized mean difference) on the X-axis while the sample size (standard error) was shown on the Y-axis. Egger's test was then used to determine if the effect mean size decreased with an increased sample (Egger et al., 97).

3.6 **Consistency of the selected studies**

To determine the heterogeneity among the studies, Cochran Q test (Cochran, 54) was used, followed by the I^2 statistics (Higgins et al., 03):

$$I^2 = \frac{(Q - df)}{Q} \times 100\%$$

Where Q is the Cochran Q test and df is the mean the degrees of freedom;

3.7 **Effect Size**

The pooled standard deviation and effects size were calculated by extracting the mean, standard deviation and sample size pre and post-treatment. Pooled analyses of the estimated ranges were developed with a fixed effects model.

This statistical analyses were performed using the same software as above (STATA 10.0, StataCorp LP, College Station, USA).

4 **Results**

The search strategy, selection and inclusion of the studies retrieved in this report are shown in figure 1.

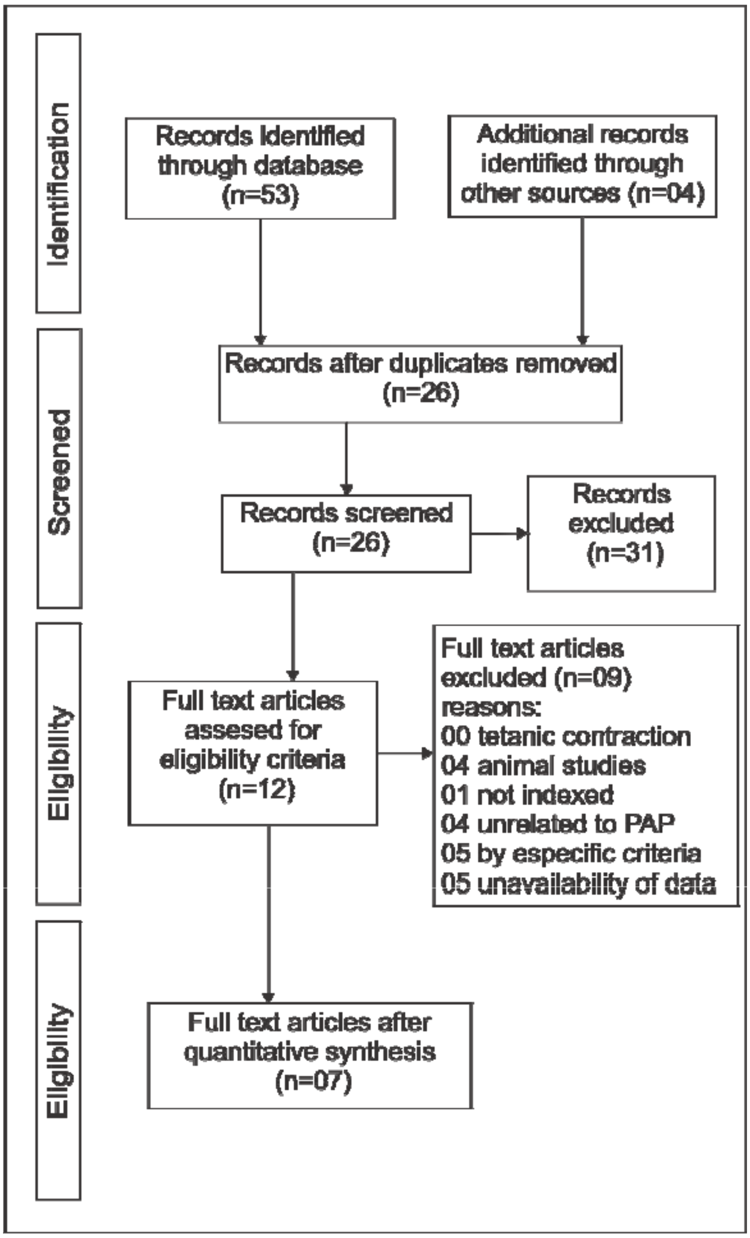

Figure 1 – Flow diagram of studies that underwent the review process.

4.1 **Characteristics of the studies selected**

Fifty-three studies were retrieved based on the above-mentioned selection strategy. Seven (with 16 cohorts) out of the 53 were selected based on inclusion and eligibility criteria (Table 1). Two of the 7 studies scored 3 points on the Jadad Scale. The remaining 5 achieved only 1 point each on this 5-point quality assessment instrument. Kappa statistics showed a perfect inter rater agreement ($r = 1.000$; $P < 0.001$).

4.2 **Subjects characteristics**

Data from a pool of 102 subjects were used in this analysis. All male subjects reported engagement in resistance training programs (with at least 6 months experience) and/or strength/power sport modalities such as rugby.

4.3 **Characteristics of the treatment**

The conditioning activity reported in the studies consisted of dynamic bench press exercise. Exercise intensity was over 65% of 1 RM. Rest intervals between CA and MA ranged from 3 to 16 min. The number of sets and repetitions ranged from 1 to 5 and 1 to 6, respectively. When throws were applied as conditioning activities, 1 to 8 trials were performed, with intensities between 30 to 55% of 1 RM.

Table 1: Studies sorted from literature.

Author	Sample	CA	Volume Intensity	Intervals CA and MA	MA	Results
Baker et al. 2003	16 AT Rugby	BP	1x 6 reps (65% 1 RM)	3 min	BP Throw (50 Kg)	↑ (4.5%)
Bevan et al. 2009	26 AT Rugby	BP	3x 3RM (87% 1 RM)	4, 8, 12, 16 min	8 BP Thorw (40% 1 RM)	↑ 8 min
Brandenburg 2005	8 TR	BP	1x 5 reps (100, 75 % RM)	4 min	3 BP Throw (Conc 45% 1 RM)	ND
Cabrera et al. 2009	12 TR	BP	1x 5 reps (70%, 86% RM)	4 min	3 BP Throws (55% 1 RM)	↓ 70% and 86%
Esformes et al. 2011	10 AT Rugby	BP	1x 3 RM	12 min	BP Throws	ND
Farup & Sorensen 2010	8 TR	BP	5x 1 RM	10, 15 min	BP Throws (30% 1 RM)	ND
Kilduff et al. 2007	23 AT Rugby	BP	1x 3 RM	4, 8, 12, 16 min	BP Throws (40% 1 RM)	↑ 8, 12 and 16 min

BP – bench press; Chain – with chain; Conc – Concentric; Ecc – Eccentric; AT – athletes; TR – trained; POW – power; ND – no significant difference; Isom – isometric; CA – conditioning activity; MA – main activity

4.4 **Main Effect**

When all studies were considered (1, 6-8, 17, 18, 27) Cochran's Q test and I^2 statistics analyses showed significant results (X^2 = 0.999; I^2 = 0%) indicating an absence of data heterogeneity. The pooled estimate of the effect size for upper-body power output was 0.15 (95% CI; -0.02 to 0.32) considered , "Small" under Cohen's classification (11) (Fig 2).

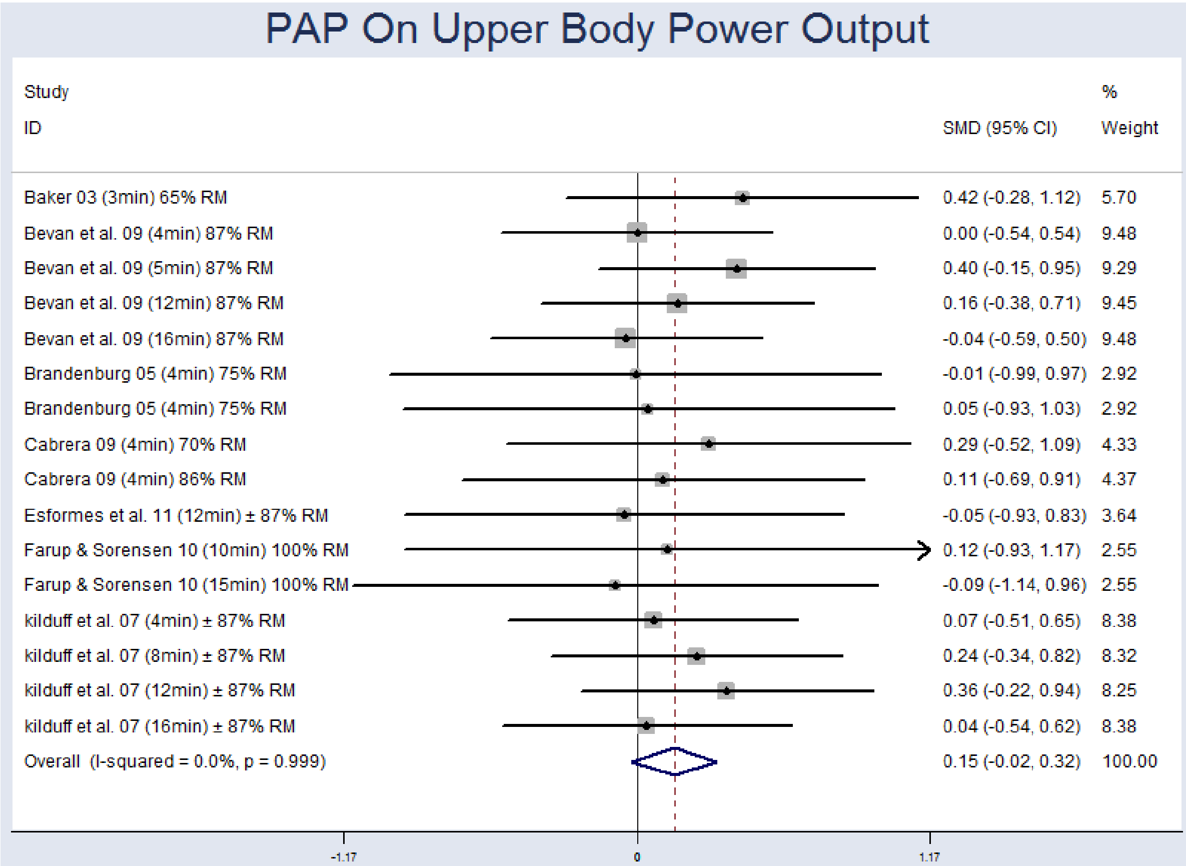

Figure 2 – Forest plot of bench-press throw power output performance

4.5 **Risk of bias within studies**

A visual analysis based on the funnel plot (Figure 3) did not show considerable data asymmetry. Egger's test did not show statistical significance P = 0.349), demonstrating a non-significant publication bias.

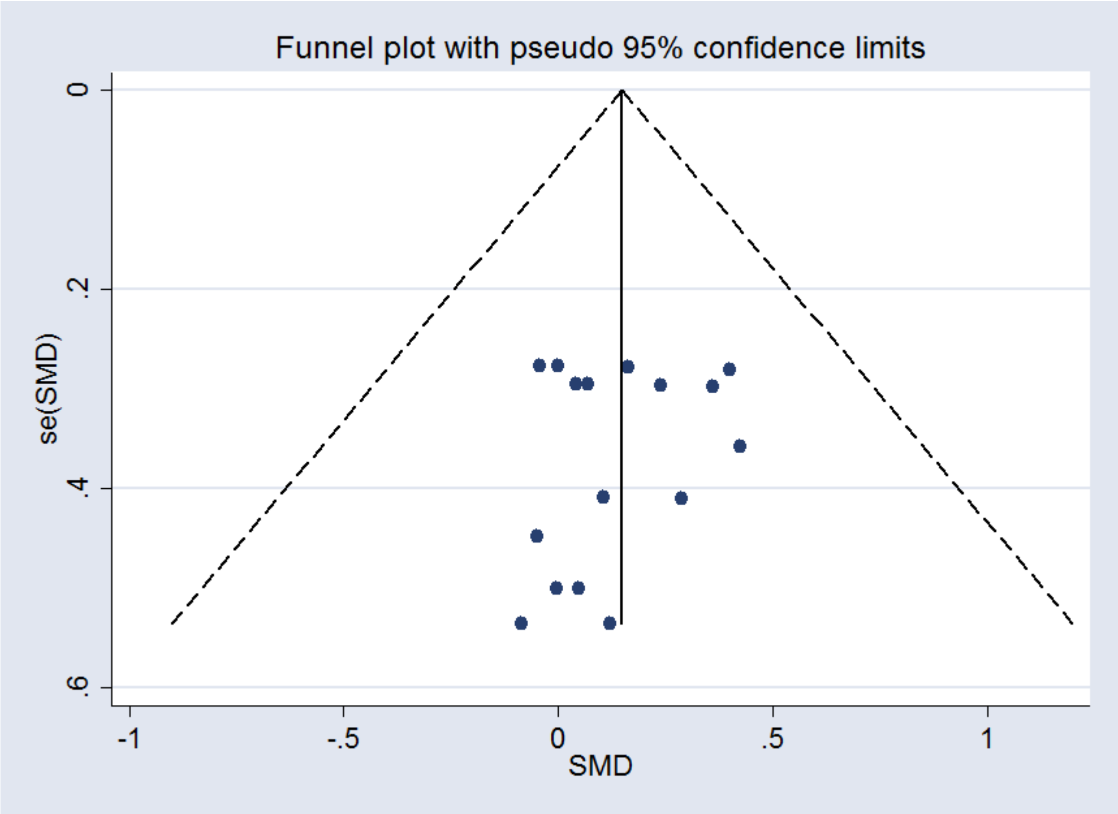

Figure 3 – Funnel plot of standardized mean difference (SMD) against standard error (SE).

DISCUSSION

This meta-analysis examined the effect size pooled of PAP-induced increment on bench press performance. Despite the overall effect being positive, the current result suggests that complex training caused only a small effect on improving bench-press throw power output.

Based on the inclusion and eligibility criteria, seven studies (with 16 treatments cohorts) were selected and then subjected to the assessment of their bias publication risk and methodological quality level. A subsequent analysis that involved a visual interpretation of the funnel plot graph did not detected data asymmetry, indicating no presence of possible outliers. A second and quantitative analysis of the funnel plot characteristics using the Egger test, confirmed absence of significant publication bias.

The degree of agreement between assessments performed by two independent reviewers was classified as very high since the Kappa correlation coefficient was 1.0 (P = 0.000). Based on Landis and Koch's proposal (Jadad el al., 96) this inter-reviewer reliability for quality rating analysis could be classified as "perfect". In addition to previous research that reported its validation (Higgins et al., 03) these findings also suggested that the Jadad scale seems to be an appropriate tool to assess methodological quality rating.

Because of the methodological characteristics of study designs, PAP studies do not use double blind model. For that reason, the maximum score five of the scale was not attained. Although even the studies with higher ranking in this review being considered low quality, this is probably due to a methodological limitation of the scale in evaluating studies with characteristics similar to those of PAP. Moreover, the main cause of the studies classified as score "1" is non-randomization, which may not represent differences in effect size when compared with the randomized trials. Benson and Hartz and Concato et al. (2000; 2000) performed a meta-analysis comparing randomized to nonrandomized studies, investigating the same topics. The results were remarkably similar for both designs. Therefore, the inclusion of nonrandomized studies with designs, bias is not important.

Evidence suggests that the PAP can be influenced by the subject's training background or sport modality that involves exclusive strength and power (Chiu et al., 03; Rixon e al., 07). Theoretically this type of sample has higher percentages of fast-twitch fibers, where PAP is speculated to be more pronounced (Hamada et al., 00). This possibility can be addressed to the enzyme kinase regulatory myosin light chain specific gene expression, that may have greater regulation of the expression in fast-twitch fibers (Stull et al., 11; Zhi et al., 05). This may turn such fibers more susceptible to phosphorylation of myosin regulatory light chain, increasing the sensitivity of contractile proteins to $Ca2+$. Another point would be assuming potentiation to be mediated by neural aspects, where there is an increase in the activation of type II motor units. This increase may be associated to the use of autonomic protection reserves (Güllich, 96; Tillin & Bishop, 09) that is triggered by reductions in synaptic failures. In this case, both the amount of pre-synaptic transmitters and the sensitivity of post-synaptic receptors are increased, besides possible reductions in failures in axonal bifurcation points along the afferent nerve fibers (Güllich, 96; Tillin & Bishop, 09).

In addition, even in a sample of trained subjects there seems to be a large inter-subject variability (Jo et al., 10; Till & Cooke, 09), and the reason why some subjects are more susceptible to PPA remains unclear. In this review although the confidence intervals vary widely in some studies, it is clear the overlap of the deviations when considering the studies as a whole (see Figure 2). Furthermore, although there is homogeneity among the studies' samples, the clinical effect of the complex training was not observed in the power produced.

Higher levels of muscle-tendon stiffness may represent a more rapid transfer of power from the muscle tendon unit to the bone (Wilson et al., 94). Some authors have reported improvements in performance when conditioning activities were performed at intensities above 80% of 1 RM (Bevan et al., 09). Opposing these findings, other authors reported improvements in performance with intensities below 80% of 1 RM (Baker, 03; Cabrera et al. 09; Saez Saes de Villarreal, 07). The highest percentages of conditioning activities may represent a more rigid, but do not necessarily represent absolute gains in power output (Comyns et al., 07). In general, the main activities are carried out with stretch shortening cycle exercises. Within this context a structure with greater capacity for distension produces better results compared to a stiffer muscle tendon unit (Wilson et al., 91). Furthermore, only studies that performed complex training in the lower-body estimated muscle tendon stiffness, thus making it difficult infer to studies that aimed at upper-body actions (Comyns et al., 07). Therefore, the studies included in this review performed conditioning activities from 65 to 100% of 1 RM.

The coexistence of fatigue and PAP was also questioned by a few authors (Bevan et al., 09; Kilduff et al., 07; Sale, 02; Tilin & Bishop, 09), suggesting that the time interval between the conditioning and main activity seems to be one of the key variables to determine success in power performance. However, the longer time interval after a conditioning activity, not only illustrates a further damping of the effects of fatigue, but also the effects of PAP (Bevan et al., 09; Kilduff et al., 07; Sale, 02). Data in the literature regarding the PAP in the upper-body are conflicting. Among the findings the authors reported significant improvements in performance (Baker, 03; Farup & Sørensen, 10), others found no changes (Hrysomallis & Kidgell, 01) and some observed even deleterious effects (Bevan et al., 09; Kilduff et al., 07) at rest intervals of less than 3 minutes. Resting intervals over 3 minutes have shown conflicting results with studies showing improved performance (Bevan et al., 09; Farup & Sørensen, 10; Kilduff et al., 07) while others no significant changes (Ebben et al., 00; Esformes et al., 11). In addition, when intervals are longer than 16 minutes, PAP seemed to be attenuated with no change in performance (Bevan et al., 09; Farup & Sørensen, 10; Kilduff et al., 07).

In summary, two basic scenarios can be described: (a) in the initial stages there is a predominance of the effects of fatigue after the conditioning activity. In these early stages the physiological mechanisms such as decreased release and sensitivity of myofibrillar calcium (Westerblad et al., 10) and the breakdown of phosphocreatine (which consequently will lead to increased intracellular inorganic phosphate (Pi)), may induce to a decreased capacity of crossbridges to generate force (Westerblad et al., 02; Westerblad et al.,10); (b) after very long rest intervals after the conditioning activity both potentiation and fatigue tend to dissipate, with no change in performance. Thereby, this review included data only from rest intervals between activity and the main conditioning from 3 to 16 minutes.

Moderate amount of research on post-activation potentiation in the upper-body reported significant improvements in performance. However, the magnitude of these improvements does not seem to be clinically relevant. Although the effect size value of the current meta-analysis was positive, its magnitude is considered “small” (pooled ES = 0.15). This result suggests that even in athletes the effects of PAP in the upper-body may not be evident. However, no deleterious effect was observed in power output and considering that the warm up prior to any activity is part of the daily routine of an athlete, one should carefully personalize strategies that can be tested and incorporated into the sporting environment.

In conclusion, further studies on complex training should be carried out including other independent variables such rest interval between CA and MA, intensity of CA, number of sets of CA, type of CA, intensity of MA, number of sets of MA and type of MA.

Further to studying the possible effects of conditioning activities over performance, it is also very important to understand the underlying physiological, biochemical and biomechanical mechanisms that explain such results. Understanding this phenomenon will permit coaches to better prescribe activities that may elicit improvements in performance.

PRACTICAL APPLICATIONS

Current results suggest that complex training is not an efficient strategy to acutely improve bench-press throw power output performance. Based on what is known now, there seems to be no significant additional benefit in using complex training when the target is the upper-body type of activity.

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CONCLUSÃO GERAL

O treinamento complexo supostamente pode levar a melhoras no desempenho de membros superiores e inferiores. Essa mudança no desempenho pode ser devido a sobreposição dos efeitos da PPA sobre os da fadiga. Entre os mecanismos associados estão o aumento da rigidez da unidade músculo-tendinosa, a fosforilação da cadeia leve regulatória de miosina e alterações na ativação neuromuscular.

Um dos principais achados desta dissertação de mestrado foi que quando se manipula os intervalos entre ação condicionante e principal, diferentes resultados são encontrados. Para os intervalos de 0-3 minutos os efeitos da fadiga são presentes e fazem com que a magnitude dos resultados tome direção e efeito negativos. No entanto para intervalos de 8-12 minutos os efeitos são positivos, demonstrando um efeito benéfico para altura do salto.

Resultados para o segundo documento não suportam a ocorrência de PPA em membros superiores. Diversos fatores podem ter influenciado a magnitude do efeito para o desempenho de potência no exercício de supino arremessado. Tal como, diferenças das características musculares dos sujeitos e até mesmo alguma limitação no método utilizado.

Mais pesquisas são necessárias para confirmar e elucidar o nível de contribuição dos mecanismos que são postulados induzirem a PPA. Em adição, os achados revelam que uma adequada manipulação do treinamento complexo pode gerar mudanças benéficas no desempenho.

APÊNDICE A

Lista de Checagem dos estudos:	Batista et al., 03 SIM	Batista et al., 03 NÃO	Jensen et al., 03 SIM	Jensen et al., 03 NÃO
1 - O estudo podem ser classificados como ensaios crossover?	x		x	
2- Foi escrito em língua inglesa ou portuguesa?	x		x	
3 - O estudo tem caráter agudo?	x		x	
4 - As ações musculares condicionantes são de natureza voluntária?	x		x	
5- Os indivíduos são homens adultos com idades entre 18 e 33 anos?	x		x	
6- São atletas de atividades natural de força e/ou potência ou são treinados em força?	x		x	
7- Contém salto, supino e/ou são atividades principais?	x		x	

APÊNDICE B

AUTOR, ANO	RANDOMIZAÇÃO		ADEQUADO		DUPLO CEGAMENTO		ADEQUADO		HÁ PERDAS OU NÃO SÃO DESCRITAS		TOTAL
KOVACEVIC ET AL., 2010	não	0		0	não	0		0	não	1	1
ESFORMES ET AL., 2010	sim	1	sim	1	não	0		0	não	1	3
CHATTONG ET AL., 2010	sim	1	sim	1	não	0		0	não	1	3
TILL ET AL., 2009	sim	1	sim	1	não	0		0	não	1	3
KHAMOUI ET AL., 2009	sim	1	sim	1	não	0		0	não	1	3
HOUGH ET AL., 2009	sim	1	sim	1	não	0		0	não	1	3
WEBBER ET AL., 2008	sim	1	sim	1	não	0		0	não	1	3
KILFUFF ET AL., 2007	não	0		0	não	0		0	não	1	1
ROBBINS ET AL., 2005	sim	1	sim	1	não	0		0	não	1	3
JONES ET AL., 2003	não	0		0	não	0		0	não	1	1
YOUNG ET AL., 1998	não	0		0	não	0		0	não	1	1
MCCANN ET AL., 2010	sim	1	sim	1	não	0		0	não	1	3
VILLAREAL ET AL., 2007	sim	1	sim	1	não	0		0	não	1	3
KILDUFF ET AL., 2008	não	0		0	não	0		0	não	1	1
BATISTA ET AL., 2011	sim	1	sim	1	não	0		0	não	1	3
GOURGOULIS ET AL., 2003	não	0		0	não	0		0	não	1	1

APÊNDICE C

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RJSP-2012-0082	The Effects of Rest Intervals on Jumping Performance: A Meta-Analysis on Postactivation Potentiation Studies [View Submission]	30-Jan-2012	30-Jan-2012	SE: Drust, Barry EIC: Nevill, Alan Under Review

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ANEXO A

The Effects of Rest Intervals on Jumping Performance:
A Meta-Analysis on Postactivation Potentiation Studies

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Running title: Rest intervals in complex training
Keywords: Complex training, PRISMA, Performance

Abstract

The purpose of this review and meta-analysis was to examine the extent and quality of current research on the acute effect of rest interval on strength/ power performance, determined by jump height performance. This manuscript was conducted according to the criteria and recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA. Criteria eligibility included cross-over, randomized, not randomized and counterbalanced studies, and all were aimed at observing the voluntary muscle action-induced postactivation potentiation. Fourteen studies were selected by two independent raters and then were included in the final analysis. The rest intervals analysis involved ranges from 0-3, 4-7, 8-12 and equal or greater than 16 minutes. The results demonstrated medium effect sizes for rest intervals 0-3min and 8-12 (-0.25 CI: -0.51 to 0.01 for 0-3min and 0.24 CI: -0.02 to 0.49 for 8-12min, respectively) and a small effect for other rest intervals (0.15 CI: -0.08 to 0.38 for 4-7min, and 0.07 CI: -0.21 to 0.24 for 16min or more). There was no evidence of heterogeneity for any sub-groups tested ($I^2 = 0\%$; $P<0.001$), as well as no indication of significant publication bias (Egger's test; P=0.179). Based on these results, the rest intervals between 0-3 minutes have a detrimental effect on jump performance as opposed to ranges between 8-12 minutes which have a beneficial effect on jump performance. Findings therefore suggest that the training complex is a viable strategy to improve the strength/power performance of the jump.

Introduction

In the early seventies, Verkhoshansky (1983) proposed that when maximal strength exercises (now known as conditioning activity – CA) preceded plyometric drills that had similar motor activity, this main activity (MA) would be significantly improved. Currently, this strategy better known as complex training (CT) (Jensen & Ebben, 2003) has been applied to activities other than plyometrics and used by coaches and athletes to improve strength and power performance. However, other authors (Hough, Ross, & Howatson, 2009; A.V. Khamoui et al., 2009; Kilduff et al., 2007) demonstrated a reduction in performance, which might have been associated to fatigue due to the pre-stimulus. The underlying mechanisms responsible for a CA-induced improvement in performance have been termed as post-activation potentiation (PAP) (Hamada, Sale, & Macdougall, 2000).

Several studies (Batista, Coutinho, Barroso, & Tricoli, 2003; Comyns, Harrison, Hennessy, & Jensen, 2006; Jensen & Ebben, 2003) have been conducted to determine the time when the mechanisms of fatigue succumbed to those associated to the PAP. Nevertheless, due to the differences between the studies' experimental conditions, there is no available consensus that indicates the best interval between a conditioning activity and the main motor task.

Although CT has been widely used in the athletic field, there have been several issues regarding to variables that possibly affect PAP occurrence such as the rest interval between CA and MA, which need to be resolved. Thus, there is a need to better understand the recommended dose for the several training variables involved in the CT method in order to make ~~a~~ more efficient use of such a strategy. The aim of this review and meta-analysis was to examine the acute effects of the different interval ranges between the stimulus and the main activity in order to find out what is the most effective stimulus to provoke significant positive results in jumping performance.

Methods

This meta-analysis was conducted according to the criteria and recommendations by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement – PRISMA (Liberati et al., 2009).

Criteria Eligibility

Types of studies and interventions: Cross-over, randomized, not randomized and counterbalanced studies that were published either in English or Portuguese were selected for inclusion. All studies needed to aim the acute effects of isotonic voluntary muscle action-induced PAP on jumping performance.

Characteristics of the participants: Subjects included in the studies were young male adults, aged between 18 to 33 years, involved in strength/power sport modalities and/or strength conditioning programs for more than six months.

Characteristics of the variables measured: The current review included studies that had jump height (JH) as their main outcome dependent variable. Jumping performance obtained in different models such as drop, squat and counter movement jumps were all considered for the analysis. These are all considered good indirect indicators of power performance.

Selection Strategy

The studies were retrieved from various databases including Medline, Scielo, Lilacs, Cochrane Library of Systematic Reviews and EMBASE. Literature search involved only complete papers published from 1961 to January 2012. The following keywords were used either independently or combined but not necessary listed in the respective mesh databases: "postactivation potentiation", "strength", "power", "complex training", and "PAP". Additional studies were included from the reference lists of papers retrieved in the search strategy.

Study Selection

Initially, the studies were selected based on either their title or abstract content. They were then read in full. Two reviewers were responsible for identifying the studies in an independent and non-blind fashion. A third experienced investigator, if needed, would be responsible to settle any disagreement between the two reviewers.

Data extraction

Data were analyzed based on subject's characteristics (age, years/months of experience and training status), rest interval between CA and MA, study's sample size and the outcome measure jump height (jump height mean, and standard deviation).

Rest interval analysis included four arbitrary different subgroups in which the effects of the ranges from 0 to 3, 4 to 7, 8 to 12 and 16 or more minutes were independently examined.

When detailed results outcome measures were not available, authors were contacted to provide missing information. If authors did not provide raw data, a dimensional tool for graphic analysis (CorelDRAW®, Graphics Suite, ver 12.0 for Windows) was used to derive mean and standard deviation from available graphs. When data could not be obtained from the graphs, the study was not included in the analysis.

Bias risk assessment and degree of between rater agreements

Two reviewers also worked independently on the bias risk assessment of the studies included in this review. The Jadad scale (Jadad et al., 1996) was used to classify their methodological quality level. Agreement between raters was tested using the Kappa statistics (Sim & Wright, 2005). Assessment of bias publication was performed through a visual analysis of a funnel plot graph (STATA 10.0, StataCorp LP, College Station, USA) that involved overall effect size mean of all cohorts in each individual study. This graph was designed to express overall mean on the X-axis while the sample size (standard error) was presented on the Y-axis. Egger's test was then used to determine if the mean effect size decreased with an increased sample (Egger, Smith, Schneider, & Minder, 1997).

Consistency of the selected studies

The analysis of the heterogeneity among the studies involved the application of the Cochran Q test (Cochran, 1954) that was followed by the I^2 statistics (Higgins, Thompson, Deeks, & Altman, 2003):

$$I^2 = \frac{(Q - df)}{Q} \times 100\%$$

Where Q is the Cochran Q test and df the degrees of freedom;

Effect Size

The pooled standard deviation and effect size were calculated by extracting the mean, standard deviation and sample size pre and post-treatment. Pooled analyses of the estimated ranges were developed with a fixed effects model. Statistical analyses were performed using commercially available software (STATA 10.0, StataCorp LP, College Station, USA).

Results

The search strategy, inclusion criteria and eligibility of studies included in this review are presented in Figure 1.

****Figure 1 near here****

Characteristics of the studies selected

Based on the above-mentioned selection strategy, 469 studies were retrieved. Fourteen (with 36 cohorts) out of the 469 were selected based on inclusion and eligibility criteria (Table 1). Eight of the 14 studies scored 3 points on the Jadad Scale. The remaining 6 achieved only 1 point each on this 5-point quality assessment instrument. Kappa statistics showed a perfect inter rater agreement ($r = 1.000$; $P < 0.001$).

Subjects characteristics

Data from a pool of 193 subjects were used in this analysis. All male subjects reported engagement in resistance training programs (with at least 6 months experience) and/or strength/power modalities such as rugby, volleyball, soccer.

Characteristics of the treatment

The conditioning activities reported in the studies consisted of dynamic leg press, knee extension, dead lifts and squat exercises. Exercise intensity was over 80% of 1 repetition maximum. Rest intervals ranged from 0 to 360 min. The number of sets and repetitions ranged from 1 to 6 and 1 to 7, respectively. When jumps were applied as conditioning activities, 1 to 8 trials were performed being done with their body mass of individuals or additional weights.

****Table 1 near here****

Main Effect

When all studies (Baker, 2003; Deutsch & Lloyd, 2008; Esformes, Cameron, & Bampouras, 2010; Gourgoulis, Aggeloussis, Kasimatis, Mavromatis, & Garas, 2003; Jensen & Ebben, 2003; Jones & Lees, 2003; A. V. Khamoui et al., 2009; Kilduff, et al., 2007; Kilduff et al., 2008; Mitchell & Sale, 2011; Saez Saez de Villarreal, Gonz, lez-Badillo, & Izquierdo, 2007; K. R. Weber, L. E. Brown, J. W. Coburn, & S. M. Zinder, 2008; Warren B. Young, Andrew Jenner, & Kerrin Griffiths, 1998) were pooled (36 cohorts from 14 studies), Cochran's Q test and I^2 statistics analyses showed significant results ($X^2 = 0.978$; $I^2 = 0\%$) indicating an absence of data heterogeneity. In order to provide a better understanding of the influence of rest intervals on the PAP occurrence, subgroup analyses involving different interval ranges were subsequently performed.

Rest interval

When a subgroup analysis was performed for different ranges of rest intervals between conditioning activity and main activity, the pooled estimate of the effect size for the rest interval range 0 to 3 min was - 0.25 (95%CI; -0.51 to 0.01) (Fig. 2). There was no evidence of data heterogeneity ($I^2 = 0\%$; $X^2 = 0.977$; $P < 0.001$) when 9 treatments cohorts of 6 studies were considered.

****Figure 2 near here****

For the rest interval range from 4 to 7 min, the pooled estimate of the effect size was 0.15 (95% CI; -0.08 to 0.38) (Fig. 3). Data did not present heterogeneity ($I^2 = 0\%$; $X^2 = 0.997$; $P < 0.001$) for 10 cohorts of 10 studies included in this analysis.

****Figure 3 near here****

The pooled estimate of the effect size for the rest interval range from 8 to 12 min was 0.24 (95% CI; -0.02 to 0.49) (Fig. 4). There was also no evidence of data heterogeneity ($I^2 = 0\%$; $X^2 = 0.977$; $P < 0.001$) for 8 cohorts of 5 studies analyzed. Finally, for the range that included rest intervals longer than 16 min, the pooled estimate of the effect size was 0.01 (95% CI; -0.21 to 0.24) (Fig. 5). Similar to the other rest interval ranges, there was no evidence of data heterogeneity ($I^2 = 0\%$; $X^2 = 0.935$; $P < 0.001$) for 9 cohorts of 5 studies.

****Figure 4 near here****

****Figure 5 near here****

Risk of bias within studies

A visual analysis based on the funnel plot (Figure 6) did not show a considerable data asymmetry. In addition, an absence of statistical significance in the Egger test ($P = 0.179$) evidenced a non-significant publication bias.

****Figure 6 near here****

Discussion

The present study analyzed the magnitude of PAP-induced increment on jump performance as well as the influence of manipulating one specific variable that may have an impact on the treatment effects. The current results support the hypothesis that complex training constitutes an effective method of inducing increases in vertical jumping performance of young males engaged in either strength/power sport modalities or resistance training. Furthermore, the manipulation of the rest interval that precedes the main activity performance seemed to affect PAP magnitude and jump height.

Evidence has attributed changes on PAP magnitude to the manipulation of complex training variables other than the rest interval that precedes the main activity (Kilduff, et al., 2007; Kilduff, et al., 2008). These variables were not included in the meta-analysis due to limited data available in the literature. When data were available, the depth of analysis did not fit the established inclusion criteria. Therefore, the rest interval between conditioning activity and main activity constituted the main focus of the review analysis.

Based on the inclusion and eligibility criteria, eleven studies (with 29 treatment~~s~~ cohorts) were selected and then subjected to the assessment of their bias publication risk and methodological quality level. A subsequent analysis that involved a visual interpretation of the funnel plot graph did not detect~~ed~~ data asymmetry, indicating no presence of possible outliers. A second and quantitative analysis of the funnel plot characteristics using the Egger test, confirmed absence of significant publication bias.

The rate of agreement between assessments performed by two independent reviewers was classified as very high since the Kappa correlation coefficient was 1.0 ($P = 0.000$). According to Landis and Koch's proposal (Jadad et al., 1996), the current inter-reviewer reliability for quality rating analysis was classified as "perfect". In addition to previous research that reported its validation (Higgins, Thompson, Deeks, & Altman, 2003), these findings also suggested that the Jadad scale seems to be an appropriate tool to assess methodological quality rating.

Considering that the studies reviewed did not use double-blind models due to the characteristics of the subject under investigation, the scores obtained by some of these studies did not reach more than 3 out of five points, which is within the criteria used by the Jadad scale. In addition to this fact, the average quality level was even more reduced due to the non-randomized features of the five out of eleven selected studies. Therefore, although average quality level was classified as LOW, such an analysis should also consider the applicability of the Jadad Scale to the characteristics of these studies. Moreover despite the great debates about the randomization of the included studies, evidence supports that there is no difference in the size of the effects between randomized and nonrandomized studies (Benson & Hartz, 2000; Concato, Shah, & Horwitz, 2000)

Conflicting findings are found when it comes to the intensity of the conditioning activity. Villareal et al. (2007) and Comyns et al. (2007) found better results with jump intensities above 80% 1RM. These findings may be associated to higher levels of muscle-tendon stiffness, which would reduce the transfer time of the strength of the bone muscle-tendon unit (Till & Cooke, 2009). This way, it would explain improvements in some variables in the jump, but not absolute additions in jump height, as evidenced by Comyns et al. (2007), that found an increase in stiffness and ground reaction force but not in the jump height. In addition, other findings revealed no differences for intensities lower than 40% as compared to largest than 80% of 1 RM (Parry et al., 2008; Weber, Brown, Coburn, & Zinder, 2008). Thus, intensities between 80 and 100 % of 1RM were chosen based theoretical physiological concepts from different authors based on other evidences rather than just performance (Hamada, Sale, MacDougall, & Tarnopolsky, 2000; Tillin & Bishop, 2009)

The number of sets and repetitions may play an important role in generating PAP. Obviously the higher the volume the greater the stimulus imposed fatiguing the muscle. As discussed by some authors, fatigue possibly coexists with PAP (Comyns, et al., 2006; Kilduff, et al., 2007), so a balance between the volume, intensity and resting interval time is needed to generate the beneficial effects of PAP (Sale, 2002). However, a consensus on what is the optimal volume has not been established yet.

Studies selected for the current review used similar volume to those that observed a potentialization effect inducing a positive jump performance result (Gourgoulis, et al., 2003; Saez Saez de Villarreal, et al., 2007).

Evidence suggests that the experience in strength and power activities may influence the generation of PAP (Chiu et al., 2003; Rixon, Lamont, & Bemben, 2007). Indeed, it has been shown that PAP was most effective when type II fibers constituted a greater percentage of the muscle under investigation (Hamada, Sale, & Macdougall, 2000). PAP effectiveness would occur due to an increased sensitivity of the fast twitch white muscle fibers to the contraction-induced myosin light chain phosphorylation (MLCP) (Moore & Stull, 1984). This justifies our decision to include only the studies that included trained subject or athletes.

In addition, current findings confirm that training status influences the PAP occurrence and effectiveness at least when jump performance constitutes the main activity studied. A mean pooled overall estimate of the effect size that involved 165 subjects, indicated a small or non-existing change on performance when data analysis was performed for rest interval between CA and MA (0.05: CI; -0.07 to 0.18).

Subgroups analysis though, generated different effects. The pooled estimate of the effect size for rest interval range from 8 to 12 min (0.24: CI; -0.02 to 0.49) indicated a medium improvement, while ranges from 4 to 7 min (0.15: CI; -0.08 to 0.38) and from 16 min or more (0.01: CI; -0.21 to 0.24) indicated a small improvement on jump performance. This classification is based on Cohen (1992). When subgroup analysis only involved the range from 0 to 3 min, the pooled effect size (-0.25; CI: -0.51 to 0.01) did tend to emphasize a decrease in jump performance, indicating a harmful effect.

Although a possible effect inter-individual discussed in the literature, increase the variability of results (Jo, Judelson, Brown, Coburn, & Dabbs, 2010; K. A. Till & C. Cooke, 2009), at different cutoff points of rest interval produces magnitude distinct of results. According to other studies (Comyns, et al., 2007; Jensen & Ebben, 2003; Kilduff, et al., 2008) intervals less than 3 minutes long can produce significant reductions in performance. This may be associated to a poor phosphocreatine resynthesis (Young, Jenner, & Griffiths, 1998), which would impact the phosphagenic system to properly regenerate energetic substrate for the main action. In the 4 to 7 interval range and above 16 minutes or more, data are consistent with other findings (Cabrera, Morales, Greer, & Pettitt, 2009; Comyns, et al., 2006) where no performance difference was obtained after conditioning action. This probably occurred simply because the effects of fatigue equaled those of PAP, for ranges 4 to 7 minutes, while 16 minutes and above effects dissipated.

Current research indicates a medium effect size for the performance of jump height (0.24 CI: 0.02 to 0.49) when the recovery intervals between 8 and 12 minutes. These findings corroborate those of other authors (Cabrera, et al., 2009; Comyns, et al., 2006; Kilduff, et al., 2008) that clearly showed the possible window of time where the values of PAP outweigh fatigue, thus contributing for improving performance.

This ergogenic effect may be possible by aforementioned MLCP, where part of the released calcium by the sarcoplasmic reticulum in the stage of conditioning activities will bind calmodulin and stimulate a higher sensitivity crossbridges to calcium, thus improving the ability of the sarcomere to produce force in a smaller unit of time (Sweeney & Stull, 1990). Other aspects associated with neural mechanisms have also been postulated as to increase recruitment and synchronization of motor units and to decrease pre-synaptic inhibition (Cabrera, et al., 2009). Nevertheless, these mechanisms still need to be investigated in environments similar to daily sports in order to make causal inferences more secure and improve external validity of the experiments.

Conclusion

In conclusion, the results of this study indicated that an interval range of 8 to 12 minutes seems to be the best rest interval between conditioning activity and jumping performance, as compared to the other interval ranges compared here. In addition, more studies are needed to investigate other variables not specifically addressed here, as well as number of sets, intensity and type of conditioning activity. A combination of activity intensity, rest interval, characteristic of the main activity and level of training also play an important role in determining the acute effect on performance.

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Table 1. Studies retrieved from the literature search strategy

Study	Subjects	CA	Volume Intensity	Interval CA between MA	MA	Results Jump Height
Kilduff et al. 2007	23 ATL rugby	Squat	1 x 3 RM	15s, 4, 8, 12, 16 and 20 min	CMJ	ND
Kilduff et al. 2008	20 ATL rugby	Squat	3 x 3 RM (87% 1RM)	15s, 4, 8, 12, 16 and 20 min	8 CMJ	↓ (15 s) ↑ (8 min)
Jones & Lees 2003	8 TRA	Squat	1 x 5 rep (85% 1 RM)	3, 10 and 20 min	3 CMJ 3 DJ	ND
Esformes et al. 2010	13 ATL power	Squat	1 x 3 RM	5 min	3 CMJ	ND
Villarreal et al. 2007	12 ATL volleyball	Squat	4 x 7 rep (± 82,5% RM) 6 x 7 rep (± 88% RM)	5 min and 6 h	CMJ DJ	↑ (5min, 6h)
Mitchell et al. 2011	11 ATL rugby	Squat	1 x 5 RM	4 min	5 CMJ	↑
Crewther et al. 2011	9 ATL	Squat	1 x 3 RM	15s, 4, 8, 12, and 16 min	CMJ	↑ (4, 8, 12 min) ↓ (15s, 16 min)

ATL – athletes; CA – conditioning activity; CMJ – countermovement jump; DJ – drop jump; MA – main activity; ND – no significant difference; rep – repetitions; RM – repetition maximum; s – second; ↑ – significant increment in jump height; ↓ – significant decrement in jump height; TRA – trained

Table 1. Studies retrieved from the literature search strategy (continued)

Author	**Subjects**	**CA**	**Volume Intensity**	**Interval CA between MA**	**MA**	**Results Jump Height**
Webber et al. 2008	12 ATL Power	Squat	1 x 5 rep (85% 1RM)	-	7 CMJ	↑
Till et al. 2009	20 ATL soccer	Deadlift	1 x 5 RM	7 min	3 CMJ	ND
Khamoui et al. 2009	16 TRA	Squat	1 x 2, 1 x 3, 1 x 4, 1 x 5 (85% 1 RM)	5 min	6 CMJ	ND
Young et al. 1998	10 TRA	Squat	1 x 5 RM	4 min	3 CMJ +19Kg	↑
Gourgoulis et al. 2003	20 TRA	Squat	5 x 2 rep (20, 40, 60, 80 and 90% 1 RM)	±20min	2 CMJ	↑
Jensen & Ebben 2003	10 ATL Power	Squat	1 x 5 RM	10s, 1, 2, 3 and 4 min	CMJ	↓ (10s)
Deutsch & Lloyd 2008	8 TRA	Squat	1 x 3 RM	10 min	CMJ	ND

ATL – athletes; CA – conditioning activity; CMJ – countermovement jump; MA – main activity; ND – no significant difference; Rep – repetitions; RM – repetition maximum; s – second; ↑ – significant increment in jump height; ↓ – significant decrement in jump height; TRA – trained.