Journal of Exercise Physiologyonline

June 2017
Volume 20 Number 3

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

JEPonline

Effect of Different Pre-Conditioning Activities on Repeated Sprint Ability in Professional Handball Players

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[1]Methodist University of Piracicaba, Piracicaba, SP, Brazil, [2]University Amparense, Amparo, SP, Brazil, [3]School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, SP, Brazil. [4]Faculty Adventist of Hortolândia, UNASP-HT, SP, Brazil

ABSTRACT

Germano MD, Braz TV, Sindorf MAG, Crisp AH, Cruz WA, Cunha LG, Cartarozi DF, Nunes AG, Jerônimo DP, Boreli L, Aoki MS, Lopes CR. Effect of Different Pre-Conditioning Activities on Repeated Sprint Ability in Professional Handball Players. **JEPonline** 2017;20(3):141-155. The purpose of this study was to evaluate the effects of 3 pre-conditioning interventions on sprint ability (RSA) performance in professional handball players. Seven handball professional athletes of the adult male category (22.2 ± 5.8 yrs, 81.3 ± 20.7 kg, 1.79 ± 0.10 m) were submitted to the following experimental sessions: (a) 1-repetition maximum (1RM) test on the half squat exercise and the RSA test (no previous conditioning activities); and (b) 3 pre-conditioning activities (squat exercise (SQ), plyometrics (PL), and sprints with additional load (SL). The SQ consisted of 1 series x 2 repetitions at 90% 1RM. The PL was composed by 1 set of 4 CMJ on a 50 cm barrier, and the SL was 1 sprint of 15 m with an additional load of 20% of the individual's body mass. The findings indicate a significant improvement in the mean sprint time after the SL pre-conditioning activity (P<0.001). The AG and PL pre-conditioning activities were not able to induce increment RSA performance (P>0.05). The SL pre-conditioning activity presented a greater number of responders compared to the AG and the PL pre-conditioning activities in the investigated

sample. The SL pre-conditioning activity could be used as a pre-exercise intervention that involves multiple sprints. In addition, it can also be used as an alternative warm-up method. The SQ and PL pre-conditioning activities were associated with a reduced performance in subsequent maximal sprints, although an individual response was observed within the investigated sample.

Key Words: High-Intensity Exercise, Power Development, Speed Testing, Performance

INTRODUCTION

Handball is an Olympic team sport that requires an appropriate physical training for the achievement of a high level of muscle power, which is considered essential for many key activities during the game. This is especially true in high intensity situations, acceleration, deceleration, and rapid changes in direction (2,28,29). In this regard, Chiu et al. (9) and Wilson et al. (40) have demonstrated that the muscle postactivation potentiation (PAP) is a phenomenon characterized by an acute increase in neuromuscular strength and power and, consequently, physical performance. While the physiological mechanisms involved in PAP are unclear (38), they appear to be linked to the athletes' actin-myosin interaction and increased release of calcium (Ca^{2+}) from the sarcoplasmic reticulum. Both responses alter the structure of myosin head and results in an increase in power generation of the crossbridges (30). In addition, according to Esformes et al. (14), another possible mechanism involved is the increased potential excitation of motor neurons, which favors a greater magnitude recruitment of motor units and the availability of phosphocreatine (PCr). However, since there is a fine line between the generation of PAP and the generation of muscle fatigue, which is dependent on factors such as the training status of the athletes as well as the pre-conditioning activities that involve intensity, volume, gender, and rest time (40).

Numerous studies have examined the PAP effects on strength and power using different pre-conditioning loads (38) that show improved performance in athletes is a function of using heavy load resistance exercise (e.g., 5 sets at 90% of 1 RM or 1 set at ~85% of 1RM) (2,24,33). However, not only the strength exercises have been used as PAP tool but also plyometrics (15) and sprints (2). For example, Esformes et al. (15) compared the effects of strength training and plyometrics in the vertical counter movement jump performance (CMJ) in trained subjects. The plyometric stimulus performed previously as a pre-conditioning activity consisted of 4 sets of 6 vertical jumps for a maximum of 24 jumps with an interval of 15 s between jumps. Alternatively, the stimulus through strength exercise consisted of 2 sets of 6 to 10 repetitions for the squat exercise with an intensity of 60 to 85% of 3RM and an interval of 2 min of recovery. After each pre-conditioning activity was allowed, a recovery interval of 2 min was implemented. The results showed that the strength exercise significantly increased the performance of the vertical CMJ over the plyometric exercises that showed no significant change.

More recently, Okuno et al (29) investigated the effects of a high intensity load in the squat exercise to induce muscle PAP in repeated-sprint-ability (RSA) in professional handball players. The athletes performed 1 set 5 x 50% 1RM, 1 set 3 x 70% 1RM, and 1 set x 90% 1RM. Before beginning the experiment, the athletes performed the RSA test which consisted of 6 sprints of 30 m with a change in direction every 15 m. The interval between sprints was

dependent on the sprint time. That is, if the subjects performed a sprint in 4 s, they were allowed to rest 16 s for a total of 20 s between effort and pauses, respectively. After the pre-conditioning activity, an interval rest of 5 min was allowed to carry out the RSA test. The results showed a significant improvement in the best time and the mean time for sprints with the pre-conditioning activity compared with the control condition (no previous conditioning activity).

The purpose of the present study was to compare the magnitude of influence of 3 types of pre-conditioning activities (SQ, squat exercise; PL, plyometrics exercise; and SL, sprints with additional load) on RSA performance in professional handball players. To date, there are no previous reports in the literature on the use of SL as a pre-conditioning activity in the PAP manifestation in handball athletes.

METHODS

Subjects

Seven professional adult male handball athletes (mean age, 22.2 ± 5.8 yrs, weight, 81.3 ± 20.7 kg, height, 1.79 ± 0.10 m, and squat 1RM = 98.6 ± 43 kg) volunteered to participate in this study. All subjects performed squat exercise, plyometrics exercises, and sprints with additional load in their regular strength training sessions. Each athlete had 5 to 7 yrs of experience in handball with 4 to 7 training sessions·wk^{-1}. The athletes were informed about the research procedures prior to signing the informed consent. The initial sample was 14 athletes, but 7 were excluded due to the following exclusion criteria: (a) less than 2 yrs of experience in handball training; (b) history of muscle injury and joint in the hip region, knee, and ankle 6 months prior to the study; (c) use of supplements or ergogenic resources; and (d) failure to attend 1 of the sessions proposed in this study. This study was approved by the Research Ethics Committee of the Methodist University of Piracicaba (19/13).

Procedures

Four experimental sessions were conducted with an interval of 48 hrs between each session. The first session was used to determine the subjects' body weight and height. Then, a warm-up was performed prior to a comfortable speed run for 3 min followed by a 2-min passive recovery and the 1RM squat exercise. To avoid the effects of fatigue from the squat exercise, there was a recovery interval of 20 min between the 1RM test and the RSA test. After the recovery, the subjects performed the same warm-up procedures again followed by the RSA test without the pre-conditioning activities. In sessions 2, 3, and 4, the subjects performed the same warm-up procedures, and were conducted in a randomized and crossover design in 3 pre-conditioning activities (SQ, PL, and SL). After the completion of each activity, there was a 5 min interval for the RSA test. The experimental procedures were carried out by the same researchers and in the same place (gymnasium of sports) and scheduled time (2:00 to 4:00 pm). All subjects already had previous experience with the procedures, especially the RSA test and the 1RM in the squat exercise. Figure 1 presents the experimental design of the study. The subjects were instructed not to engage in strenuous efforts during the research period and to maintain their regular eating routines.

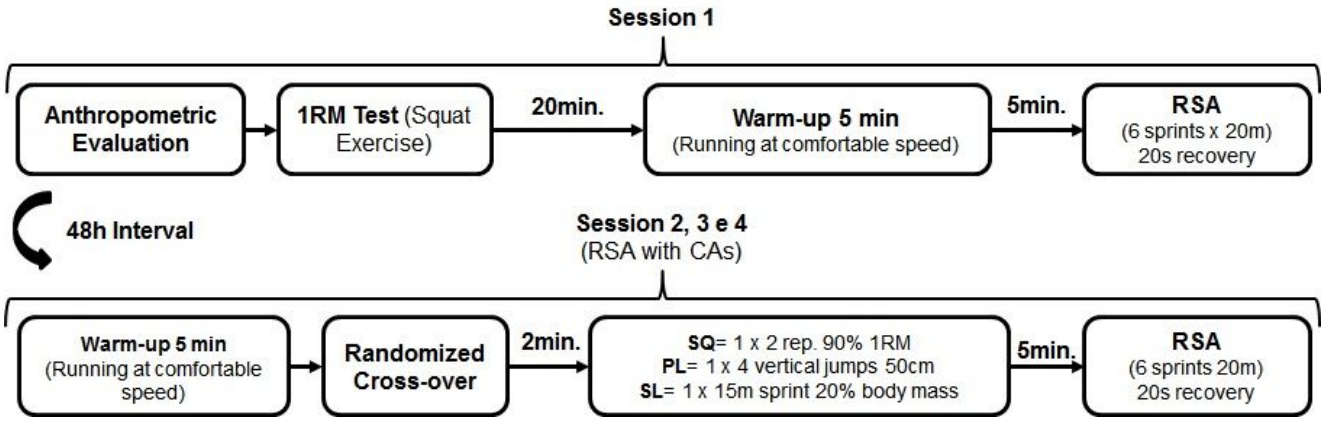

Figure 1. Experimental Design. RSA = Repeated Sprint Ability; **rec** = recovery; **CA** = pre-conditioning activity; **SQ** = squat exercise; **PL** = plyometrics exercise; **SL** = sprints with additional load; **1RM** = 1 Maximum Repetition; **s** = seconds; **cm** = centimeters; **m** = meters; **min** = minutes

Pre-Conditioning Activities

The choice of pre-conditioning activities was based on the study by Okuno et al. (29). It is noteworthy that the squat exercise with high loads and the vertical jumps are commonly used to investigate the occurence of PPA (13,18). Sprints at high intensities are part of the regular training routine of handball athletes, since, these activities are frequently required during actual matches (28). In the SQ pre-conditioning activity, the subjects performed 1 set x 2 repetitions at 90% 1RM. The movement was performed up to the 90° angle of knee flexion. In the PL pre-conditioning activity, the subjects performed 1 set of 4 CMJ on a 50 cm barrier. During the jumps, the subjects performed knee flexion approximately at the angle of 120º with subsequent extension of the knees in order to reach the maximum vertical height, with the knees remaining in extension in the phase of flight and landing. The SL pre-conditioning activity was performed by means of 1 sprint of 15 m with an additional load of 20% of each subject's body mass. During the execution of all pre-conditioning activities, the subjects were verbally encouraged to do their best. All activities were performed at the subjects' own place of competition and training.

Repeat Sprints Ability Test

The subjects performed 6 sprints (20m) with 20 s of passive recovery between each. In order to measure the time, a Speed Test 6.0 Photocell System (CEFISE®, Nova Odessa, SP, Brazil) was arranged at 2 points (0 m and 20 m). The subjects were verbally encouraged to perform all out sprints. The variables analyzed in the RSA test were the best sprint time performed (RSAbest), mean sprint time of the 6 sprints (RSAmean), and percentage sprint decrement during the test (RSAindex), which was calculated using the formula described by Okuno et al. (29): 100 – (Total Time RSA / Best Time RSA x 100), with Total Time RSA = sum of the time of the 6 sprints, and Best Time RSA = product of 6 times the RSA best. Glaister et al. (16) presented values of intraclass correlation coefficients for these variables in RSAtests: RSAbest = 0.79 to 0.91; RSAmean = 0.88 to 0.94; and RSAindex = 0.66, which demonstrates the replicability of these variables.

Statistical Analysis

The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. The mean and standard deviation (±SD) were used after the data

normality was assumed. The Student *t*-test for dependent samples was used to compare RSAbest, RSAmean, and RSAindex after the pre-conditioning activity and the control condition. A repeated measures ANOVA (2x6) with condition factors (with and without pre-conditioning activity) and sprint number (6 sprints), and a Bonferroni *post hoc* was applied when necessary. The statistical significance was set at P≤0.05. The magnitudes of the differences were examined using the standardized differences based on Cohen's d units by means of effect sizes (ES) (20). The ES results were interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; 2.0 to 4.0, very large; and >4.0, nearly perfect. The smallest worthwhile change (SWC), which was based on a small standardized effect based on Cohen effect-size principle (0.2 × between-subjects SD). According to Buchheit (6), the thresholds for trivial, small, moderate, large, and very large standardized changes (Cohen d) of <0.2, 0.2, 0.6, 1.2, and 2, respectively, means that any change of <1x, 1x, 3x, 6x, and 10x SWC can be considered trivial, small, moderate, large, and very large. This principle was used to calculate individual comparison between subjects with pre-conditioning activities of PAP (SQ, PL, and SL) in variables RSAmean and RSAbest.

RESULTS

Figure 2 shows the comparison of the mean time of the 6 sprints of 20 m the RSA test after pre-conditioning activities (SQ, PL, and SL). Only the SL induced performance increment by means of a decrease in mean sprints time (P=0.001) compared to the time observed in the Control condition. In addition, SL presented a significant difference in relation to other pre-conditioning activities, such as AG and PL (P=0.001). No difference between AG and PL was detected (P>0.05).

For the RSAbest, when investigating individual results, 6 of the 7 subjects achieved the minimal difference (MD) improvement to the SL pre-conditioning activity, so that 3 subjects had a small effect, 1 subject had a moderate effect, and 2 subjects had a large effect. On the other hand, only 1 subject had a negative effect (large effect). In the PL pre-conditioning activity, 4 out of the 7 subjects achieved the MD improvement, so that 3 subjects had a small effect and 1 subject had a large effect. However, 2 subjects showed a negative effect (small and moderate effect, respectively) and 1 subject did not reach MD. Finally, in the SQ pre-conditioning activity, 4 out of the 7 subjects achieved the MD improvement, so that 3 subjects had a small effect, 1 subject had a moderate effect, 2 subjects had a negative effect (small and moderate effect, respectively), and 1 subject did not reach MD.

For the RSAmean, when investigating individual results, 4 out of the 7 subjects achieved the minimal difference (MD) improvement to the SL pre-conditioning activity, so that 1 subject showed a small effect, 2 subjects had a moderate effect, and 1 subject had a large effect (Figure 3). However, 1 subject did not reach the MD and 2 subjects demonstrated a negative effect (small effect). In the PL pre-conditioning activity, no subject reached the MD. However, 4 subjects showed negative effects, so that 2 subjects had a small effect and 2 subjects presented a moderate effect. Finally, in the SQ pre-conditioning activity, 3 out of the 7 subjects achieved the MD improvement, so that 3 subjects had a small effect, 1 subject did not reach the MD, and 3 subjects showed a negative effect (1 subject had a small effect and 2 subjects had a moderate effect, respectively). Importantly, in the comparison between RSAbest and RSAmean, the RSAmean variable appears to be more impaired, demonstrating individually greater potential for fatigue.

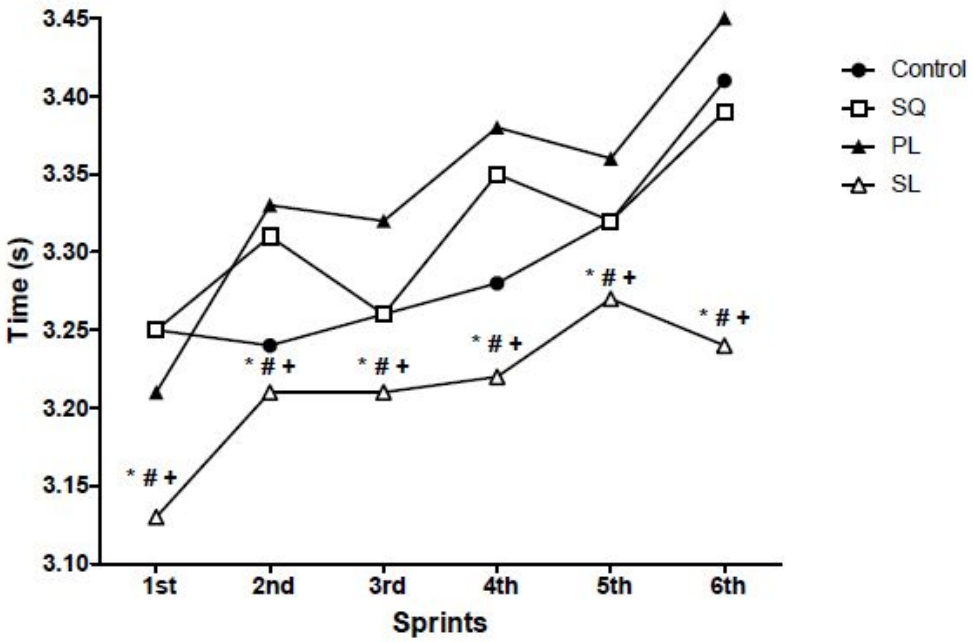

Figure 2. Mean and Standard Deviation of the Mean Time (s) of the 6 Sprints of 20 m. Values of the Control Condition and Experimental Pre-Conditioning Activities. * = Significant difference SL x Control P<0.001. **#** = Significant difference SL x SQ P<0.001. **+** = Significant difference SL x PL P<0.001.

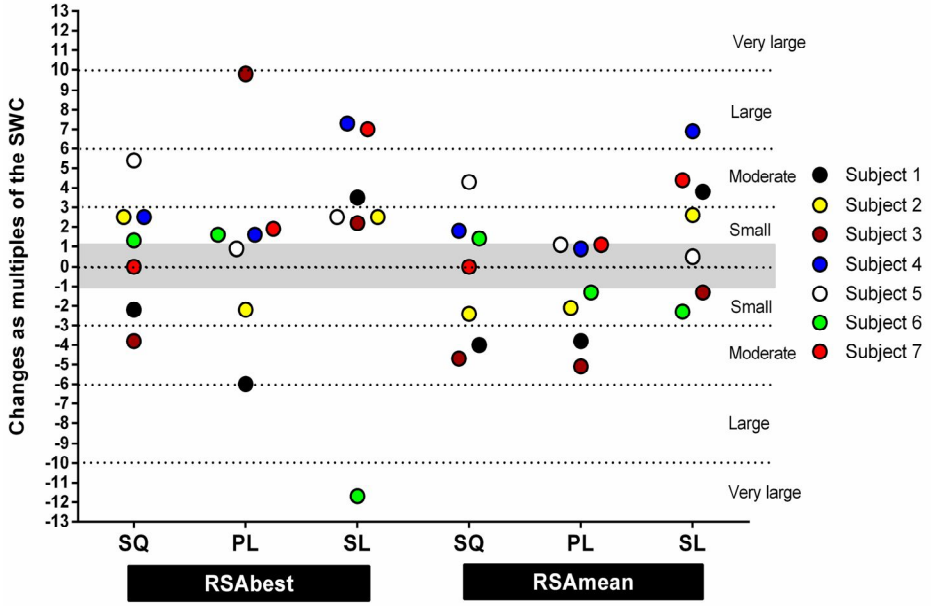

Figure 3. Individual Comparison Between Subjects After the Experimental Pre-Conditioning Activities. Change as Multiple of the Smallest Worthwhile Differences (SWC) for the Best Sprint Time Ever (RSAbest) and Mean Time of the 6 Sprints (RSAmean). Thresholds changes of 1×, 3×, 6×, and 10× SWC can be considered small, moderate, large, and very large (6). The grey area represents the zone of the smallest worthwhile change (**SWC**). For the variable RSAbest and RSAmean the SWC was calculated by multiplying the standard deviation of the subject x 0.2 (20) giving ± 0.032 s and 0.037 s, respectively. **SQ** = squat exercise; **PL** = plyometrics exercise; **SL** = sprints with additional load.

Table 1 presents the mean value of the variables observed in the RSA test (RSAbest; RSAmean; and RSAindex). No significant differences (P>0.05) were found in any of these variables in the pre-conditioning activities and the control condition.

Table 1. Mean and Standard Deviation of Variables RSAbest, RSAmean and RSAindex after No Previous Conditioning Activity (Control) and Experimental Conditioning Activities (SQ, PL, and SL).

Conditions	Control	SQ	PL	SL
RSAbest (s)	3.20 ± 0.16	3.18 ± 0.25	3.20 ± 0.17	3.14 ± 0.22
RSAmean (s)	3.29 ± 0.19	3.31 ± 0.30	3.36 ± 0.25	3.25 ± 0.25
RSAindex (s)	2.72 ± 0.93	4.11 ± 2.04	5.08 ± 6.02	3.57 ± 2.15

RSAbest = best sprint time ever; **RSAmean** = mean time of the 6 sprints; **RSAindex** = percentage sprint decrement during the test; **Control** = without pre-conditioning activity; **SQ** = squat exercise; **PL** = plyometrics exercise; **SL** = sprints with additional load

Table 2 shows the ES values for the variables: RSAbest; RSAmean; and RSAindex in the pre-conditioning activities conditions and the control condition. Although no significant difference was found between the averages for these variables (Table 1), ES for the variable RSAindex in comparisons to Without x SQ was considered moderate (ES = 0.87).

Table 2. Calculation of the Effect Size (ES) for the Variables RSAbest, RSAmean, and RSAindex in the Comparison Between No Previous Conditioning Activity (Control) and Experimental Conditions Activities (SQ, PL, and SL).

Conditions	Control x SQ		Control x PL		Control x SL	
Variables	ES	Magnitude	ES	Magnitude	ES	Magnitude
RSA best	0.09	Trivial	0.00	-	0.31	Small
RSAmean	0.08	Trivial	0.31	Small	0.18	Trivial
RSAindex	0.87	Moderate	0.54	Small	0.51	Small

RSAbest = best sprint time ever; **RSAmean** = mean time of the 6 sprints; **RSAindex** = percentage sprint decrement during the test; **Without** = without pre-conditioning activity; **SQ** = squat exercise; **PL** = plyometrics exercise; **SL** = sprints with additional load; **ES** = Effect Size

DISCUSSION

The purpose of the present study was to verify the effect of different pre-conditioning activities on the repeated sprints ability in professional handball players. The main finding of this study was that the SL pre-conditioning activity was effective in improving performance in the RSA test by means of a significant decrease (P=0.001) in the time of the 6 sprints when compared to other pre-conditioning activities (SQ and PL) and control pre-conditioning. Interestingly, the SQ and PL pre-conditioning activities had no significant potential to performance increment (P>0.05) (Figure 2).

However, it is important to note that individual responders did exist within the sample. For the RSAbest variable, the individual analysis supports the finding that the SL pre-conditioning activity presented greater effectiveness, due to the fact that 6 out of the 7 subjects achieved the MD improvement. The AG and PL pre-conditioning activities showed lower number of subjects who responded positively (4 subjects) (Figure 3). This finding shows large individual variations in responses, and may indicate the highly individual nature of the PAP response. On the other hand, the RSAmean variable presented greater individual potential for fatigue generation in detriment to RSAbest, given that in the SQ and the PL pre-conditioning activities, there were 3 and 4 subjects that presented negative effects respectively, while the PL pre-conditioning activity did not show a positive effect in any of the subjects and SQ only induced a positive effect in 3 subjects. Additionally, for the RSAmean variable the SL pre-conditioning activity, 4 subjects responded positively while 2 subjects responded negatively.

In addition, the pre-conditioning activities did not induce significant changes in performance related to the RSAbest, RSAmean, and RSAindex variables versus control condition (Table 1). However, although these activities did not present any significant differences for these variables investigated, the ES scores for the AG activity were considered moderate (ES = 0.87), which may represent a greater potential for muscle fatigue.

While there are numerous studies (23,31,34,36) that have examined the effectiveness of pre-conditioning activity on subsequent strength and power output in both upper and lower body, the results are conflicting. In particular, some researchers (23,31,34) have reported that the preload stimulus might induce fatigue mechanisms. In other studies, researchers (1,10,36) have shown a positive influence on performance. This conflict in the literature may in part be explained by the methodological differences in training status of the subjects, the pre-conditioning activity, intensity, and volume, as well as gender and the recovery time between the pre-activity and the actual activity (19,24). Thus, it is clear that the study design must take into consideration these concerns (19). For example, Gullich and Schmidtbleicher (17) indicated that their recovery interval after each pre-conditioning activity prior to performing the RSA test was 5 min versus 3 min. They verified that the 5-min recovery intervals positively affected the PAP generation compared to the 3-min recovery interval. But, strangely, there is no uniform agreement about the optimal recovery time between the preload stimulus and subsequent explosive activity with studies reporting recovery periods ranging from 0 to 18 min (4,8,22).

It is reasonable to assume that performance in the RSA test might be a useful indicator for success in handball players, and therefore coaches and athletes should take into account strategies that improve this ability (29). Buchheit et al. (5) found that the execution of repeated shuttle (2 to 3 sets of 5 to 20 m) and explosive strength activities increased the RSA test performance. The back squat is the most widely studied pre-conditioning activity used to elicit a PAP effect on sprinting (18). The majority of research has assessed the effects of back squats performed at heavy loads (70% 1RM) on distances ranging between 5 and 100 m with no effect (12), enhanced performance (8,26,35), and mixed results (2,11,41). In the present study, the SQ protocol (1 set x 2 repetitions 90% 1RM) did not present a significant potential to increase performance compared to the Control situation, without a pre-conditioning activity. The magnitude of ES was trivial for the RSAbest (ES = 0.09) and RSAmean (ES = 0.08) variables. This result is not in agreement with the majority of the studies that used squatting exercises as a pre-conditioning activity. Okuno et al. (29) reported a performance increment, on a sample similar to the present study, using SQ as a pre-

conditioning activity. These authors observed a significant increase in RSAbest (ES = 0.54 moderate) and RSAmean (ES = 0.41 small) when compared the pre-conditioning activity (1 set x 5 repetitions 50% 1RM; 1 set x 3 repetitions 70% 1RM; 5 sets x 1 repetitions 90% 1RM, with 2 min of interval between sets) compared to the control condition. This discrepancy in the results might clearly be explained by the methodological differences in the experimental design. The athletes of the present study performed a volume of repetitions lower than the volume proposed by Okuno et al. (29), which seems to have been insufficient to generate PAP and performance increment. Therefore, a higher volume represented a higher dose-response that, consequently, resulted in an increase in performance. In addition, the RSA test performed by Okuno et al. (29) was 6 sprints of 30 m with a change of direction every 15 m, which is different from the RSA test proposed in the present study.

Another important factor is that the SQ pre-conditioning activity for the variable RSAindex presented values that are considered of a moderate effect. This shows that this pre-conditioning activity negatively impacted the athletes through fatigue mechanisms, and that it was possibly responsible for the incapacity in the generation of PAP. This potential of fatigue observed may be related to the pre-activation attempt, since both processes coexist for a few moments after the muscle contraction (18). Okuno et al. (29) did not find a significant difference in the comparison between the control condition and the experimental pre-conditioning activity for the RSAindex, which suggests that the execution of a greater volume of muscular work was probably effective in the generation of PAP. The primary explanation for the difference in results is the training status of subjects, due to the fact that the athletes used in the study by Okuno et al. (29) were players of the Brazilian handball national team and, therefore, represented a highly trained sample. Although the athletes in the present study were professionals in the modality and with great experience of training and games (5 to 7 yrs), the disputed competitions were of state level. This disparity in the status of the subjects might be observed by the presented values of 1RM. The athletes in the present study presented 98.6 ± 43 kg 1RM in the squat exercise, while the athletes of Okuno et al. (29) presented 193 ± 27 kg. This may, in part, explain the greater ability to resist fatigue and to generate PAP by the athletes in the Okuno and colleagues' study (29) when compared to the subjects in the present study who responded with moderate magnitude to fatigue. However, a limitation in the study by Okuno et al. (29), as highlighted by the authors, was to have only investigated the strength exercises as a pre-conditioning activity, as in handball other activities such as sprints and jumps at high intensities are also often carried out in the game.

McBride et al. (27) assessed the effects of 1 set of 3 repetitions of back squats using a load of 90% of 1RM on sprint ability in male NCAA Division III football players. The recovery time after the pre-conditioning activity and before the test was 4 min. Sprint times were assessed over 10, 30, and 40 m with a significant improvement reported over 40 m. No significant diference was found for 10 and 30 m. Lim and Kong (25) investigated the effects of heavy (90% 1RM) back squats on 10, 20, and 30 m performance 4 min post warm-up in well-trained male track athletes. No significant difference was observed in any of the sprint distances. The response reported only at greater distances may represent a specific characteristic of dose-response from squat exercise at maximal sprints. Possibly, the PAP was not observed in the present study due to this factor, since the sprints were performed using a 20 m distance. Seitz et al. (35) involved rugby league players performing 20 m sprints after 1 set of 3 repetitions of back squats using a load of 90% of 1RM. A significant improvement in sprint

time, average velocity, and average acceleration was found after a 7-min recovery period compared with baseline values. Likely, the recovery time of 7 min after the pre-conditioning activity and prior to the maximum test provided a greater restoration of PCr and ATP muscle storage and, therefore, had a positive impact on performance. On the other hand, the 5-min recovery in the present study appears to have been insufficient to cope with fatigue and, as a result, to improve subsequent sprint performance (24).

Regarding plyometrics, there is a growing interest in assessing its use in eliciting PAP at maximal sprints of 5 to 20 m (7,19). It has been suggested that plyometric exercises have a greater biomechanical specificity to sprinting (e.g., similar ground contact times to the acceleration phase) compared with conventional strength training. The PL (1 set of 4 CMJ on 50 cm barrier) did not present significant potential to improve performance in comparison to the control condition. The magnitude of ES was small for the RSAmean variable (ES = 0.31). Till and Cooke (37) investigated whether 5 repetitions of double leg tuck jumps combined with a dynamic warm-up could improve 10 and 20 m sprint performance. No significant change in performance was found after 4, 5, and 6 min compared with a dynamic warm-up alone. Byrne et al. (7) assessed the acute effects of a dynamic warm-up combined with depth jumps on subsequent 20 m sprint performance. Depth jumps were performed from a predetermined “optimal height” 1 min before completing a 20 m sprint. The authors reported a significant reduction in 20 m time compared with a dynamic warm-up only. The use of an optimal height that is individualized may have been responsible for the positive results observed. The subjects in the present study performed the jumps at a standardized height, which is a limitation since the different athletes have different characteristics inherent of the actual match.

Bonfim et al. (3) examined whether depth jumps from a height of 0.75 m would improve 50 m sprint performance. Athletes were instructed to react as quickly as possible once they made contact with the ground. Sprints (50 m) were performed 5, 10, and 15 min after the depth jumps. A significant improvement was reported after 10 and 15 min compared with baseline values. The recovery time also seems to strongly influence the generation of PAP with the use of PL as a pre-conditioning activity. The 5-min recovery time was not sufficient to induce performance increment, which was the case in the present study. Turner et al. (39) compared the effects of a plyometric protocol consisting of alternating leg jumps with use of 10% body mass overload. Plyometric trained subjects performed 20 m sprints (with 10 m splits) before, immediately, and 2, 4, 8, 12, and 16 min after the conditions. A significant improvement in performance was observed after 4 and 8 min with the use of overload compared to the control group that performed low intensity efforts (walking activities). From these results, it is resonable to speculate that the high volume of jumps during technical and tactical actions inherent to handball provided great neuromuscular learning to the athletes over the years. Hence, the performance of only 1 series of 4 CMJ with intensity of 50 cm was not enough to increase the magnitude of muscle activation, and it is possible that the use of overload may be an efficient alternative.

Recently, Iacono et al. (21) assessed the effects of vertical and horizontal drop-jump-based post-activation potentiation (PAP) protocols on neuromuscular abilities in tasks such as jumping, sprinting, and change of direction (COD) in professional handball players. The subjects completed 2 experimental trials involving a standardized warm-up, and then baseline CMJ or 25 m (12.5m + 12.5 m and 180° COD) shuttle sprint assessment, followed

by either a preload stimulus of 3 sets of 5 plyometric vertical alternate single-leg drop-jumps (VDJ) or 3 sets of 5 plyometric horizontal alternate single-leg drop-jumps (HDJ). After performing 1 of the 2 conditions, the jumps and sprints were re-tested after 8 min of passive recovery. The authors observed that the HDJ positively affected sprints performance with change of direction, while the VDJ positively affected the performance of the CMJ jumps. Both protocols seem to be effective to induce PAP in professional handball athletes. However, another recent study by Iacono et al. (22) compared the effects pre-conditioning stimuli on explosive activities of trained young athletes of handball and basketball. The athletes performed a standard warm-up, which consisted of 7 CMJ and 7 sprints of 20 m. After the standard warm-up, the athletes performed 1 of 3 types of conditioning activities: (a) 3 sets of 10 repetitions of double-leg drop jumps (PAPD); (b) 3 sets of 5 repetitions of alternate-one-leg drop jumps (PAPO); and (c) walking control (CON). A significant reduction in explosive performance was observed at each time-point in both groups. A negative PAP effect occurred with the 20-m sprint in PAPO at 16, 24, and 30 min, and in PAPD at 30 min compared to CON. The authors concluded that there was a negative effect on PAP on subsequent explosive performance in the young team sport players.

Finally, the SL protocol was effective in the generation of PAP in RSA in the current study. The athletes performed 1 sprint of 15 m with an additional load of 20% of the individual's body mass, which seems to have been an excellent load for the potentialization and decrease of the time of sprints. In this regard, the literature has reported that additional loads might induce PAP due to the increase in the pool of motor neurons and increase in the amount of neurotransmitter release, which favors the work of the contractile machinery. However, up to now, there are no reports using additional loads during sprinting in professional handball players. Hence, it is reasonable to speculate that the SL pre-conditioning activity was the only activity that induced a large recruitment of type II motor units, which is preferably responsible for the generation of PAP in the investigated sample.

Athough it is important to point out that the small number of subjects in this study is a limitation in the data gathering process, the choice of the individual analysis seems to be an excellent alternative for visualization and interpretation of the data, especially for the great variation among the subjects in performance after different pre-conditioning activities, which makes it necessary for coaches to perform their own in "research" to determine the suitability of specific protocols for their individual athletes.

CONCLUSIONS

The findings in the present study suggest that the SL pre-conditioning activity may be used as a pre-exercise intervention before activities that involve multiple sprints and short periods of rest. In addition, this intervention can also be used as an alternative warm-up method in order to maximize physical performance (e.g. muscle power). On the other hand, SQ and PL pre-conditioning activities were associated with reduced performance in subsequent maximal sprints. Thus, these interventions should be avoided as a warm-up tool for handball athletes, although some individuals showed improved performance within the sample. These outcomes have several practical applications, since strength and conditioning coaches can plan training sessions using such intervention in order to maximize performance. However, it is important to consider the great variability and sensitivity of individual response to different pre-conditioning activities.

ACKNOWLEDGMENTS

The authors thank the handball team, their athletes, and the place assigned to carry out the study.

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