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Acute effects of strength training programs on vertical jump and technical actions in handball during preseason[1]

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Abstract

The aim of this study was to identify the acute effects of hypertrophic strength training programs on the vertical jump and technical actions in small-sided handball games during preseason. 12 senior male players (M age = 22.2 yr., SD = 3.4) participated in 3×3 and 6×6 small-sided games preceded by no strength training or upper limbs/ lower limbs/ upper+lower limbs strength training. The results showed that strength training affected the vertical jump performance and the effectiveness of some skills. The higher physiological stimuli during 3×3 games promoted the deterioration of some skills' proficiency, mainly during small-sided games with preceding strength training. The 6×6 games elicited higher cooperation and interaction between players and potentiated the vertical jump performance after strength training. Thus, when training sessions are focused on the development of skills performance, combining hypertrophic strength training with 3×3 games may be detrimental. On the other hand, coaches should use strength training before 6×6 small-sided games to develop the technical proficiency in a game context without the impairment of the vertical jump capacity and technical skills.

Handball is characterized by repeated accelerations, sprints, jumps, and repeated changes of direction that involve a great amount of body contact between players. Muscle strength and power in the pelvis and upper and lower extremities are determinant factors in specific handball actions such as the jump throw (Wagner, Pfusterschmied, Tilp, Landlinger, von Duvillard, & Muller, 2012). Consequently, the vertical jump is recognized as a useful index of the muscular ability to generate power and can be used to monitor performance as well as to provide important information about the functional ability of lower limbs under different conditions (Quagliarella, Sasanelli, Belgiovine, Moretti, & Moretti, 2010). Although muscular strength is considered a key factor in developing the vertical jump (Luebbers, Potteiger, Hulver, Thyfault, Carper, & Lockwood, 2003), the adequate inclusion of strength training units in the annual cycle of handball training is a complex issue due to the diversity of contents to be trained in a concentrated competitive schedule (Verkhoshansky, 2006). Apparently, to promote maximum performance and to diminish the possibility of injury, most strength training loads should be in the first half of the preseason (Bompa, 1993).

Hypertrophic training is commonly used during preseason to promote structural changes in the muscle morphology and cross sectional area that support greater gains in muscle strength (Verkhoshansky, 2006). However, these structural changes are slower than neural adaptations (Sale, 1988), which may be a constraint when planning a handball preseason that usually lasts from four to six weeks and demands development of physical and technical abilities in a short period of time (Issurin, 2010). Therefore, coaches should organize their weekly schedule cautiously to prevent conflicting physiological responses.

Performance in handball can be measured with scoring (e.g., goals) and performance indicators (e.g., successful or unsuccessful passes) (Hughes & Bartlett, 2002) during small-sided games. These situations can be manipulated to influence physiological, technical, and tactical stimuli (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011) and allow for functional movement behaviors to emerge (Pinder, Davids, & Renshaw,

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2012). Additionally, the variability of stimuli allows small-sided games to include action patterns similar to competition, since physiological, technical, and tactical demands of the game are strongly replicated. Therefore, small-sided games are important or development of technical skills in game-like situations and to optimize the training process during the preseason. However, small-sided games do not appear to provide significant muscle demand, i.e., specific external loads that induce neuromuscular adaptation (Zatsiorsky & Kraemer, 2006). Therefore, the preseason should include both small-sided games and strength training to maximize the players' technical and physical performance.

Regardless of the recent investigation of the acute effects of strength training (Babault, Kouassi, & Desbrosses, 2010) and acute fatigue in response to handball match play (Thorlund, Michalsik, Madsen, & Aagaard, 2008), the available literature does not describe the effects of strength training programs with different muscular solicitations (i.e., focused on upper limbs, lower limbs or both) on players' performance in game-like situations. Additionally, there is no research relating the acute effects of combining both strength training and small-sided games in technical and vertical jump performance during a handball preseason. Such information could provide coaches important information for planning short-term programs including both small-sided games and strength training. Therefore, the goal of the present study is to identify the acute effects of different strength training in the skill and vertical jump performance to handball small-sided games.

Hypothesis 1. A significant decrease in the vertical jump performance is expected immediately after the strength training.

Hypothesis 2. Greater deterioration of the vertical jump is expected after 3×3 small-sided games.

Hypothesis 3. Maximum strength training is expected to impair technical performance during small-sided games.

Method

Participants

Twelve male senior handball players who competed in the Portuguese second division volunteered to participate in this study. All participants were part of a team with an average of eight hours of training per week (*M* age = 22.2 yr., *SD* = 3.4; *M* height = 1.82 m, *SD* = 0.05; *M* weight 80.6 kg, *SD* = 5.38; *M* BMI = 24.4, *SD* = 1.33; *M* HR max = 195 bpm; *SD* = 10.3). The participants agreed with the protocol description and were aware of its benefits and risks. They were also notified that they could withdraw from the study at any time without any penalty. The study protocol was conformed to the declaration of Helsinki and was approved by the ethics committee of the Research Center in Sport, Health and Human Development (Vila Real, Portugal).

Procedures

The strength training was divided into four levels: no strength training, upper limbs strength training (Upper), lower limbs strength training (Lower) and upper and lower limbs strength training (Total). The small-sided games were performed in two formats: GK (goalkeeper) + 3×3 and GK + 6×6 in a handball half court. The Upper limbs strength training was performed in two formats: 3×3 and 6×6. The maximum dynamic strength (1 maximum repetition, 1RM) was assessed for each exercise (Upper: Horizontal bench press, Deltoid press, Pullover, and Wrist flexion; Lower: Squat, Leg Curl, Lunge, and Plantar flexion) (Brown & Weir, 2001). The Total strength training included two exercises from both Upper and Lower (Horizontal bench press, Squat, Plantar flexion and Wrist flexion).

The strength training protocol was performed according to the hypertrophic methods with 3 sets of 10 to 12 maximal repetitions, low speed execution (5 sec. per repetition), and recovery periods of 60 sec. (Zatsiorsky & Kraemer, 2006). To measure vertical jump height, the participants performed the squat jump, counter movement jump and Abalakov jump (Bosco, Luhtanen, & Komi, 1983). The jumping height (m) was calculated with an Ergojump (Bosco System, Globus, Italy). All games were recorded with a standard camcorder and the interrater reliability of notational analysis was inspected by calculating kappa (κ) coefficients. Four weeks before the protocol application, there was an anthropometric and dynamic maximum strength evaluation. In the following week, all participants were familiarized with the protocol procedures. The registration of the number and sequence of skills was held experimentally by the observers in a spreadsheet during the protocol familiarization. A chronological schedule of the protocol is presented in Table 1.

The first data collection (3×3+Upper) started with stretching and a low intensity run (7 km/hr.) on a treadmill for warm-up. Afterwards, the players performed two attempts for each vertical jump protocol with a 10 sec. break between trials. The best jump value was recorded. After this first vertical jump evaluation (Pre strength training, PRE ST), a 5 min. rest interval was given before initiating Upper strength training. The strength training was done on a rotary system with four stations, to optimize the recovery time between exercises and to provide the same recovery time from the last strength training exercise to the beginning of the 3×3 small-sided game. A second vertical jump evaluation took place immediately after Upper strength training (post strength training, POS ST), followed by a 20 min. interval. After this break, a 3×3 small-sided game was performed with teams alternating attack and

TABLE 1
Chronological Schedule Preceding Protocol

Week 1		Week 2	Week 3	Week 4	Week 5
Protocol presentation	Anthropometric characterization	HR max evaluation	Maximum dynamical strength evaluation	Protocol familiarization	Protocol 6 wk.
Presentation of protocol contents and standards	Weight, height and BMI assessment	*Yo-yo Intermittent Endurance Test (Level 2)*	1 RM evaluation	SSG 3×3; SSG 6×6; Upper; Lower; Total; RPE	

Note SSG = small sided games; Total = upper and lower limbs strength training; Upper = upper limbs strength training; Lower = lower limbs training.

defense per block. Small-sided games were divided in four blocks of 5 min. (1st half, 1st and 2nd blocks; 2nd half, 3rd and 4th blocks) with 2 min. intervals (20 min. of effective activity). The players were divided (following the instructions of the head coach) into two balanced teams according to their ability in passing, ball control, and game sense (Hill-Haas, *et al.*, 2011). Immediately after the small-sided games, the vertical jump was evaluated for the third and last time (Post small-sided games, POS SSG). In that same week, after a 72 hr. interval, the protocol was repeated without strength training before the games.

In the two following weeks, the protocol was exactly the same except in this case, the strength training units that preceded the 3×3 were Lower and Total strength training conditions, respectively. In Weeks 4, 5, and 6, the protocol was the same; however, strength training and 6×6 small-sided games were performed by 12 participants, so four players each used one of the strength training stations. The strength training included four exercises. The first three stations were organized on a rotary system (four players took part in each one of the strength training stations = 12 players) and the fourth station was simultaneously performed by all the players. The exercises of Upper, Lower, and Total strength training are described in the first paragraph of the procedures section (Upper: horizontal bench press, deltoid press, pullover, and wrist flexion; Lower: squat, leg curl, lunge, and plantar flexion; Total: horizontal bench press, squat, plantar flexion, and wrist flexion). The small-side games took place in an indoor court with a total area of 400 m^2 (325.5 m^2 of playable area). The games were played according to the International Handball Federation official rules and the ball used was size three for senior males (60 cm diameter, 475 g). To avoid intensity disruptions, all penalty infractions were considered as goals to the attacking team. In addition, to prevent subjectivity in rules interpretation, a single referee was selected and maintained during the whole protocol. The offensive actions were recorded within three shooting zones (Zone A: area between the midfield and 9 m line; Zone B: central zone area between the 9 m and 6 m lines; Zone C: wing shooting zone). All actions were assigned to ball possessions and analyzed using the percentage per 100 ball possessions (Kubatko, Oliver, Pelton, & Rosenbaum, 2007; Sampaio & Janeira, 2003).

Measures

The notational analysis of offensive technical actions included passes and catches (with and without success), set shots and jump shots (with and without success) and technical errors. The interceptions and goalkeeper actions were the considered defensive actions. Data reliability was high (ICCs > .90).

Analysis

The data are presented as means and standard deviations. All data sets from technical indicators and vertical jump performance were assessed for outliers and assumptions of normality. A repeated-measures ANOVA was performed to identify inferential differences in vertical jump performance (PRE ST, POS Stand POS SSG) according to the number of players, type of strength training, and time of testing effects. When appropriate, the Scheffé *post hoc* test was used for multiple comparisons. Effect size (ES) was presented as eta squared and interpreted by the follow criteria: significant but weak (ES ≤ 0.04), moderate (0.04 < ES ≤ 0.36) and strong (ES > 0.36) (Tabachnick & Fidell, 2007). The vertical jump performance was also presented as percentage of height variation, with the Pre strength training (PRE ST) performance being considered as the baseline.

All analyses were performed using Statistica Version 8 (Statsoft, Tulsa USA) and alpha was set at .05.

Results

The vertical jump values according to the number of players, type of strength training and test session are presented in Fig. 1. Significant differences were found in the triple interaction between the test session, number of players, and type of strength training (Table 2). Also, differences were identified in the main effect of test session, and in the interaction between test session and number of players. Overall, the vertical jump performance decreased after all types of strength training, with higher values after the 6×6 small-sided games. However, Figs. 1, 2, and 3 show that after 3×3 small-sided games there was a decrease in vertical jump per-

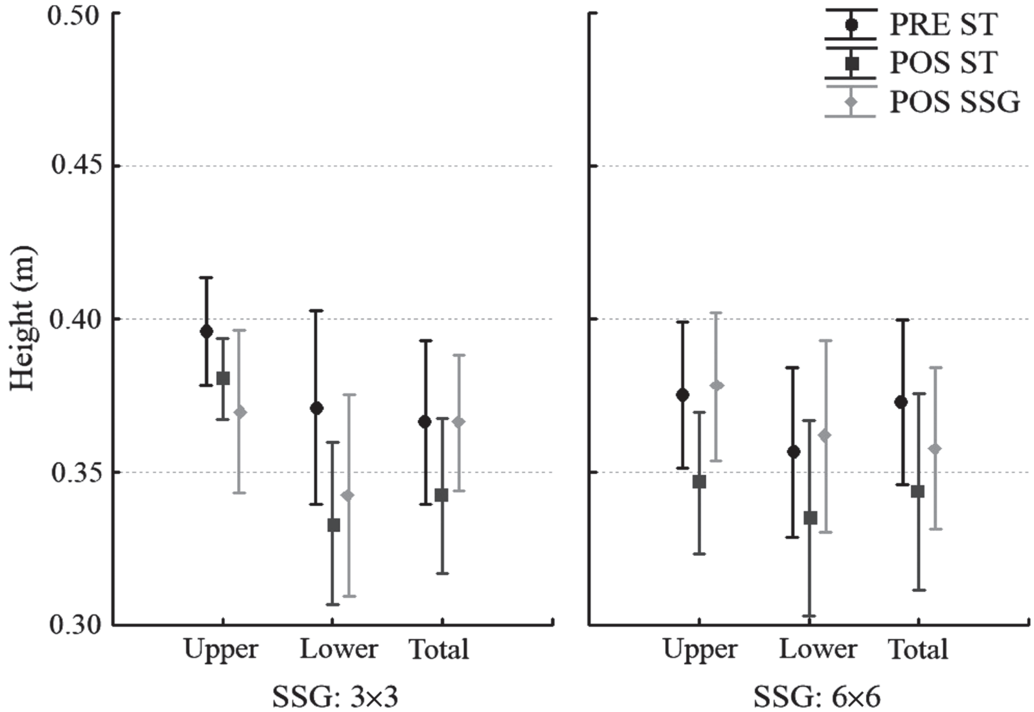

Fig. 1. Results from interaction Players × Strength Training × Moment for squat jump values. Lower = lower limbs strength training; POS SSG = Post small-sided games; POS ST = Post strength training; PRE ST = Pre strength training; Total = upper and lower limbs strength training; Upper = upper limbs strength training.

formance when the game was preceded by Upper or Lower strength training.

According to Fig. 4, the percent change in vertical jump performance from baseline recorded after the 6 × 6 small-sided games (POS SSG) was lower than those after strength training (POS ST). Compared to baseline, the vertical jump performance increased after 6 × 6 small-sided games when there was precedent Upper and Lower strength training. However, after the 3 × 3 games there was a decrease from the vertical jump baseline after Upper strength training (squat jump and countermovement jump) and Lower strength training (countermovement jump and Abalakov jump).

The 6 × 6 games promoted a higher percentage of passes than the 3 × 3 games (17.21 ± 5.14 successful and 0.59 ± 0.22 unsuccessful versus 9.33 ± 2.10 successful and 0.24 ± 0.18 unsuccessful, respectively). Also, the 6 × 6 games elicited a higher percentage of successful catches than the 3 × 3 games (17.10 ± 5.25 and 9.15 ± 1.93, respectively). The percentage of unsuccessful set shots was higher in 3 × 3 games compared to 6 × 6 games (0.64 ± 0.31 and 0.33 ± 0.19, respectively).

TABLE 2

Analysis of Variance to Assess Differences in Vertical Jump Performance by Number of Players in Small-sided Games, Type of Strength Training, and Time of Testing

Source	*MSE*	*F*	*df*	*η2*	95%CI
Test session (T)					
SJ	0.013	48.8‡	22	0.82	0.61, 0.88
CMJ	0.009	34.1‡	22	0.76	0.50, 0.84
AJ	0.011	67.6‡	22	0.86	0.70, 0.91
T × Players (P)					
SJ	0.002	7.5†	22	0.41	0.07, 0.59
CMJ	0.002	8.3†	22	0.43	0.08, 0.61
AJ	0.003	10.1‡	22	0.48	0.13, 0.64
T × P × Strength training					
SJ	0.002	9.1‡	44	0.45	0.18, 0.57
CMJ	0.0001	3.3*	44	0.23	0.01, 0.37
AJ	0.001	5.1‡	44	0.32	0.06, 0.46

$^{*}p < .05$. $^{\dagger}p < .01$. $^{\ddagger}p < .001$.

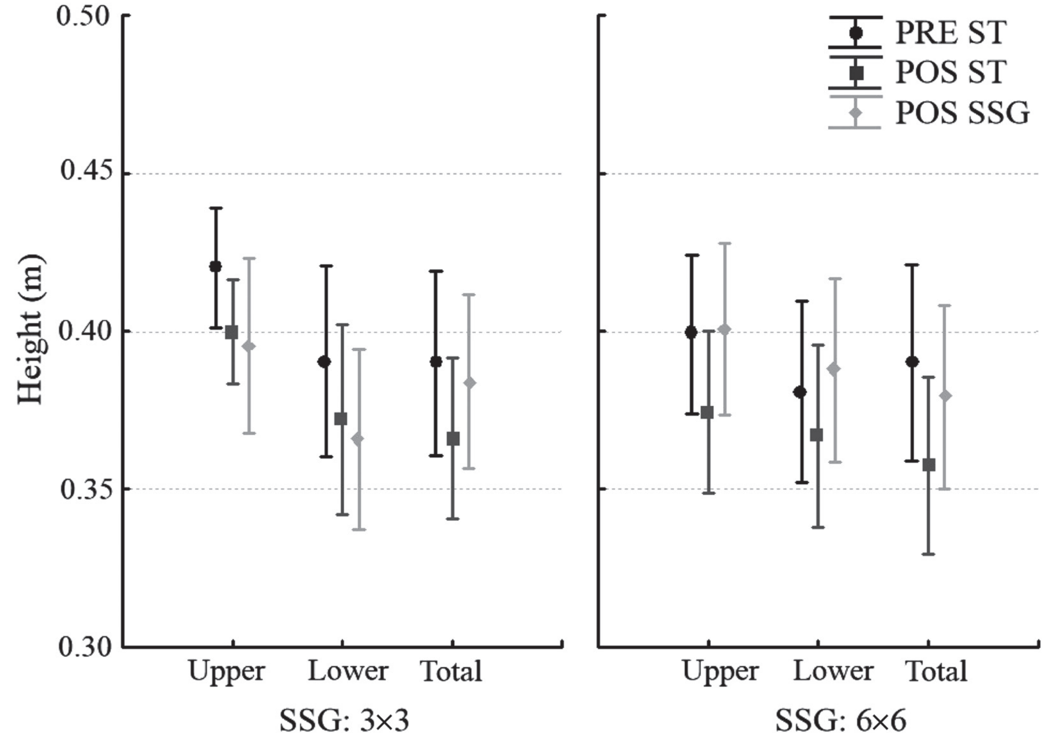

Fig. 2. Results from interaction Players × Strength Training × Moment for counter movement jump values. Lower = lower limbs strength training; POS SSG = Post small sided games; POS ST = Post strength training; PRE ST = Pre strength training; Total = upper and lower limbs strength training; Upper = upper limbs strength training.

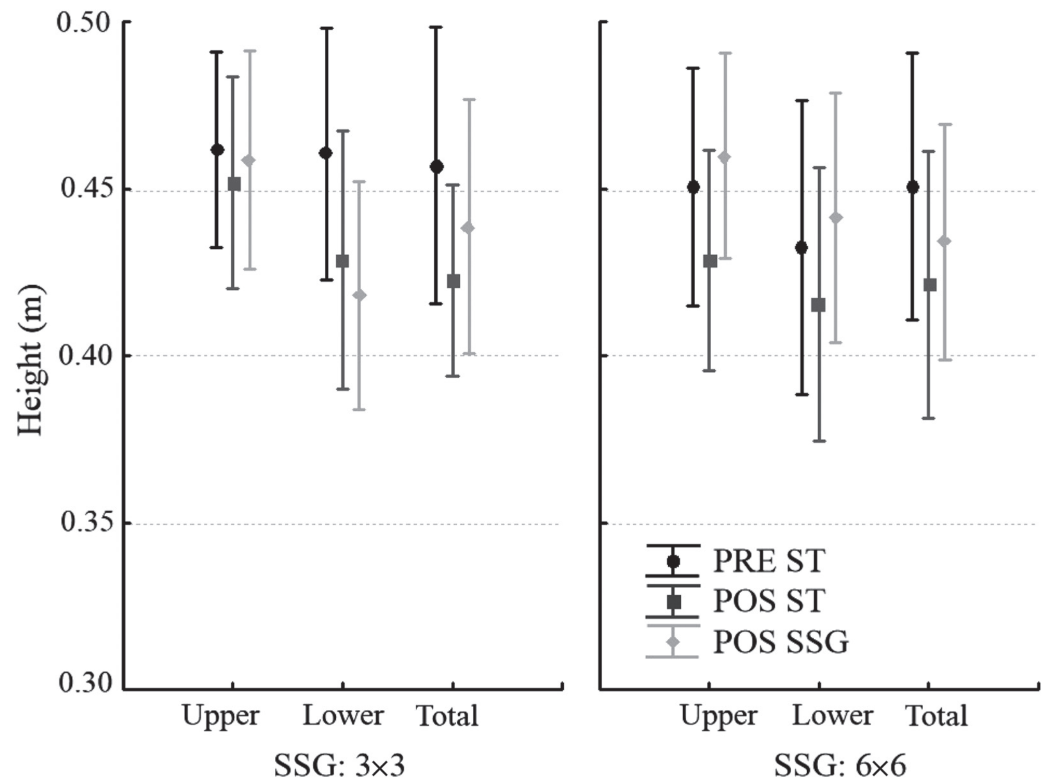

Fig. 3. Results from interaction Players × Strength Training × Moment for Abalakov jump values. Lower = lower limbs strength training; POS SSG = Post small-sided games; POS ST = Post strength training; PRE ST = Pre strength training; Total = upper and lower limbs strength training; Upper = upper limbs strength training.

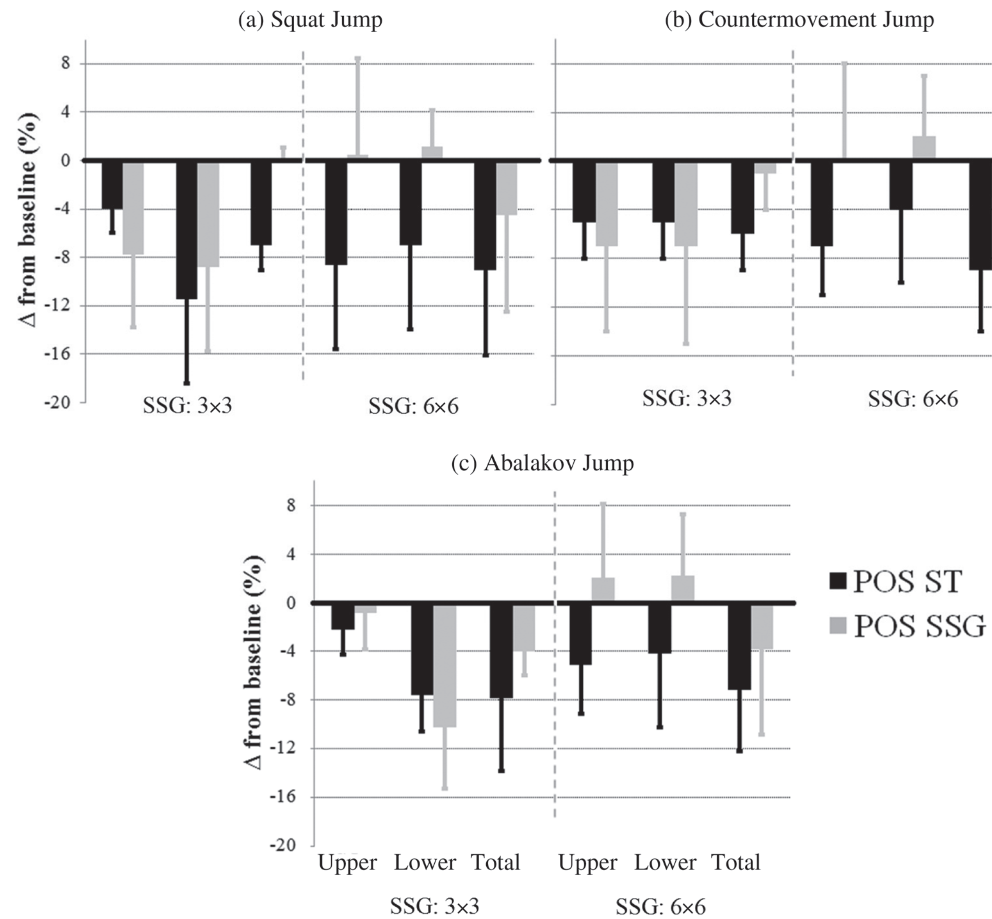

Fig. 4. Percentage (%) of the height variation from the baseline pre-strength training (PRE ST) to the interaction Players × Strength Training × Moment. POS SSG = Post small-sided games; POS ST = Post strength training; 3 × 3 and 6 × 6 indicate number of players.

Statistically significant differences were identified in the percentage of technical errors between 3 × 3 and 6 × 6 games after Total strength training (0.12 ± 0.08 and 0.01 ± 0.01, respectively). The percentage of interceptions was higher in the 6 × 6 games (0.41 ± 0.21) compared to 3 × 3 games (0.10 ± 0.09). The percentage of goalkeeper actions increased in the second halves of both types of small-sided games (first half, 0.95 ± 0.33; second half, 1.34 ± 0.51) and it was higher when preceded by Upper (1.45 ± 0.67) or Lower strength training (1.21 ± 0.43). Finally, the number of players influenced the number of shots per shooting zone, with a higher number of shots in the wingers' position (zone C) being recorded in 3 × 3 compared to 6 × 6 small-sided games (28.08 ± 12.28 and 12.84 ± 3.77, respectively).

Discussion

The purpose of this study was to identify the acute effects of hypertrophic strength training programs on the vertical jump and technical actions in small-sided handball games during preseason training. Generally, the results showed that the vertical jump capacity was impaired immediately after the strength training, with a greater deterioration found after 3 × 3 games. Additionally, it was found that technical proficiency was affected when strength training preceded the 3 × 3 games.

The first hypothesis was supported, since the results showed that vertical jump decreased after all types of strength training, probably explained by the neuromuscular process and the elastic and contractile capacity of the muscle structure (Komi, Nicol, & Marconnet, 1992). It is also related to the hypertrophic strength training methodology used in this study. In fact, this strength training methodology can increase blood lactate concentrations up to 10 to 13 mmol (Mero, Leikas, Knuutinen, Hulmi, & Kovanen, 2009), impair the muscular contraction and the acute capacity of the stretch/shortening cycle to generate muscular torque (Rodacki, Fowler, & Bennett, 2002). These symptoms play a crucial role on the reducing the lower limbs' strength and power, which may explain the deterioration of the vertical jump performance after strength training.

The results showed that vertical jump absolute values increased after 6 × 6 games when compared to the Post strength training values. Previous studies have demonstrated that high-threshold fast motor units are

TABLE 3

Analysis of Variance to Assess Statistical Differences in Percent of Technical Actions by Number of Players in Small-sided Games, Type of Strength Training and Half (Only Statistically Significant Differences Are Presented)

Source	*MSE*	F_{16}	η^2	95% CI
Number of players				
Passes (successful)	16.78	28.5‡	0.64	0.27, 0.78
Passes (unsuccessful)	0.042	24.7‡	0.61	0.23, 0.76
Catches (successful)	17.23	27.3‡	0.63	0.26, 0.77
Set shots (unsuccessful)	0.061	16.3‡	0.51	0.12, 0,69
Interceptions	0.035	22.4‡	0.58	0.20, 0.74
Half				
Goalkeeper actions	0.083	11.9†	0.69	0.28, 0.79
Number of players × Strength training				
Technical errors	0.001	3.65*	0.41	0.00, 0.59
Strength training × Half				
Goalkeeper actions	0.029	4.1*	0.43 strong	0.00, 0.61

*$p < .05$. †$p < .01$. ‡$p < .001$.

recruited during maximal intensity actions such as the vertical jump (Kubo, Morimoto, Komuro, Tsunoda, Kanehisa, & Fukunaga, 2007). In fact, vertical jump height is considered an important indicator of the lower limbs' muscle power and it has been used to assess lower extremity function and to measure power development, because of its high reproducibility (Slinde, Suber, Suber, Edwen, & Svantesson, 2008). Also, strength training research has shown that performing maximal (or near maximal) muscular contractions can produce short-term increases in maximal force due to phosphorylation of myosin light chains resulting from the initial muscle activity and excitability of alpha-motoneurons, resulting in a greater contractile performance after previous muscular activity (Sweeney, Bowman, & Stull, 1993). Thus, maximal voluntary contractions can improve the acute muscle peak torque and the explosive muscle performance. In contrast, vertical jump capacity was impaired after 3×3 games when preceded by Upper strength training (squat and counter movement jumps) and Lower strength training (countermovement and Abalakov jumps). One of the possible reasons is that small-sided games with a higher number of players have lower physiological demand, because the addition of more players lowers %HRmax, blood lactate concentrations, and perceived exertion (Hill-Haas, *et al*., 2011). Strength training using high loads promotes acute muscular fatigue; however, it was already found that 60 min. after hypertrophy strength training, lactate concentrations and the ability to generate force returned to levels close to those recorded before the strength training (McCaulley, McBride, Cormie, Hudson, Nuzzo, Quindry, *et al.*, 2009). The time gap between the strength training and game situations, the apparently recovery of the ability to generate power, and the 6×6 game play may have potentiated the vertical jump performance. Indeed, the agility, sprint, and jump capacity decline after playing a soccer 3×3 game (Hill-Haas, *et al*., 2011). Considering that sprint capacity depends on the stretch/shortening cycle of muscle function in upper and lower musculature and its relation with vertical jump height (Maulder & Cronin, 2005), the general impairment of the vertical jump performance after 3×3 games with preceding strength training may be explained by the decrease of both limbs' muscle power. So, Hypothesis 2 was supported. Interestingly, despite the acknowledged importance of lower limbs when performing jumping actions, upper extremity strength is also important in jump throws, due to trunk rotation and lower extremity force (Fleck, Smith, Craib, Denahan, Snow, & Mitchell, 1992). Apparently, the high intensity promoted by 3×3 games resulted in vertical jump decreases and did not allow recovery from fatigue induced by Upper and Lower strength training.

The 6×6 small-sided games promoted more successful and unsuccessful passes, successful catches, and interceptions, suggesting higher interaction between the players in the same playable area. The higher number of passing possibilities in 6×6 games likely facilitated the occurrence of successful catches and passes. On the other hand, it appears that the reduction of the ratio area per player and the consequent proximity between players caused a higher number of unsuccessful passes and interceptions. In contrast, the small-sided games with a reduced number of players seem to decrease the available choices for the player with the ball, while the 6×6 games appear to facilitate the cooperation between players. Previous research has found that the addition of players increased the number of skills per team, while reducing the number of players has been related to the increase of individual contacts with the ball (Hill-Haas, *et al*., 2011). The small-sided games with smaller number of players reduced the possible solutions for the player with the ball and consequently the possibilities of cooperation. As a consequence, the tendency of the player is to solve these constraints using *ad hoc* solutions. In summary, it is possible that the higher physiological stimulus and the increase of individual actions promoted by 3 × 3 games may not allow maintenance of technical skill proficiency. In fact, the present study showed that the number of unsuccessful set shots was higher in 3 × 3 games, which supports the idea that high intensity game situations may be counterproductive in terms of playing performance. Hypothesis 3, a deterioration of the technical performance during small-sided games, was thus partly supported: only the 3 × 3 games resulted in the impairment of some technical skills.

The number of shots in the wingers' zone (zone C) was higher during 3 × 3 games, suggesting that players tend to search for unoccupied areas in the lateral corridors when the number of players was lower. In fact, it has been shown already that small-sided games with a smaller number of players have different tactical requirements (Hill-Haas, *et al*., 2011). The greater distances travelled when the ratio area per player is higher make the game pattern less predictable. In accord with previous research (Hill-Haas, *et al*., 2011), it may be suggested that the relation between the individuals' workout profiles and skills performance should be the target of future investigations to help clarify these results.

The 3 × 3 games preceded by Total strength training induced a higher number of technical errors. High intensity exercises like strength training and small-sided games with a smaller number of players can increase peripheral and central fatigue, as well as impair motor skills outcomes and decision-making (Knicker, Renshaw, Oldham, & Cairns, 2011). Together, these fatigue-related symptoms seem to affect the skill performance as shown by the increase in technical errors observed in current study when the 3 × 3 small-sided game was preceded by Total strength training. The acute muscular fatigue elicited by the Lower and Upper strength training may have affected the lower and upper limbs' capacity to generate power during both small-sided game formats, which supports the higher occurrences of unsuccessful jump shots.

Short-term planning in team sports requires that coaches understand the acute effects of combining strength and technical-tactical training. This study provided new evidence on how strength training may be combined with court training (small-sided games). Coaches usually consider the preseason as a specific period for development of technical-tactical skills but also to increase the players' strength and muscle mass. These findings highlight the importance of selecting adequate court training exercises after a hypertrophic strength training session. When the aim is to develop technical abilities, coaches should not use 3 × 3 games after a hypertrophic strength training session. On the other hand, placing the strength training before 6 × 6 small-sided games seems to be a correct strategy to develop the technical proficiency in a game context without the impairment of the vertical jump capacity and technical skills.

This study had limitations that could be eliminated in further research. Due to the constraints of competitive schedules, it was not possible to apply a long-term protocol involving a higher number of players. Consequently, the number of strength training sessions combined with small-sided games was not as frequent as deemed desirable. Future research should focus on the effects of other types of strength training (e.g., neural adaptations and power) on the players' performance, preferentially during the complete annual cycle or training.

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