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ORIGINAL ARTICLE

The Effect of a Combined High-Intensity Plyometric and Speed Training Program on the Running and Jumping Ability of Male Handball Players

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Abstract

***Purpose*: The aim of this study was to investigate the effect of a combined program including sprint repetitions and drop jump training in the same session on male handball players.**

***Methods*: Twenty-two male handball players aged more than 20 years were assigned into 2 groups: experimental group (n=11) and control group (n=11). Selection was based on variables "axis" and "lines", goalkeepers were not included. The experimental group was subjected to 2 testing periods (test and retest) separated by 12 weeks of an additional combined plyometric and running speed training program. The control group performed the usual handball training. The testing period comprised, at the first day, a medical checking, anthropometric measurements and an incremental exercise test called yo-yo intermittent recovery test. 2 days later, participants performed the Repeated Sprint Ability test (RSA), and performed the Jumping Performance using 3 different events: Squat jump (SJ), Countermovement jump without (CMJ) and with arms (CMJA), and Drop jump (DJ). At the end of the training period, participants performed again the repeated sprint ability test, and the jumping performance.**

***Results*: The conventional combined program improved the explosive force ability of handball players in CMJ (*P*=0.01), CMJA (*P*=0.01) and DJR (*P*=0.03). The change was 2.78, 2.42 and 2.62% respectively. No significant changes were noted in performances of the experimental group at the squat jump test and the drop jump with the left leg test. The training intervention also improved the running speed ability of the experimental group (*P*=0.003). No statistical differences were observed between lines or axes.**

***Conclusions*: Additional combined training program between sprint repetition and vertical jump in the same training session positively influence the jumping ability and the sprint ability of handball players.**

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INTRODUCTION

Handball is a strenuous contact Olympic team sport that places emphasis on running, jumping, sprinting, arm throwing, hitting, blocking, and pushing. It's a team sport which requires a high standard of preparation in order to complete sixteen minutes of competitive play and to achieve success. In this game, movement patterns are characterized as intermittent and change continuously in response to different offensive and defensive situations in which anthropometric characteristics and high levels of strength, muscle power, and handball throwing velocity are the most important factors that give a clear advantage for successful participation in elite levels of handball leagues [1]. From this, it is believed that to

improve their handball performance, elite level players must arrange specific handball conditioning with some additional resistance, as well as sprint and endurance training [2].

For Handball players, training aims to improve technical, tactical, psychological, and physical qualities. During the pre-season, training emphasizes on physical fitness improvements, whereas during the in-season period the emphasis is mainly on making tactical and technical improvements while maintaining physical fitness. Indeed, as competition matches require high energy expenditure, the training load is not increased in order to avoid excessive fatigue or the beginning of an overtraining syndrome [3]. During a handball match, players perform different types of action such as running, jumping, and tackling. Handball players require the repetition of runs alternated with short to long periods of recovery, which could be active or passive [4]. Intensity and running periods can alternate at any time according to the demands of the match. In addition, goals or decisive actions are often preceded by accelerations, sprints, bursts, jumps, and shots. Consequently, one of the aims of training is to improve the ability to perform maximal and high-intensity exercise [5]. However, little is known about the best way to improve sport specific performances in handball and whether some interference between different components of physical fitness occurs when strength, sprint, endurance, sport-specific factors, and competition are trained for simultaneously during an entire season [2,6,7].

Sprint running contributes in varying degrees to successful performance in handball; consequently, a variety of training regimes are commonly used to improve sprinting performance, including sprint drills [8] over speed training [9], sprinting against resistance [4], weight training [10], and plyometric [4]. This later has been used for many years to improve sprint performance; whereas little evidence notes that this form of training improves sprint performance [4]. In fact, plyometric is a type of training that develops the ability of muscles to produce force at high speeds in dynamic movements; these movements involve a stretch of the muscle immediately followed by an explosive contraction of the muscle. This pattern of muscle contraction is known as the stretch-shorten cycle. Plyometric exercises include vertical jumps, during which the athlete jumps as high as possible ‘‘on the spot,’’ and bounds, during which the athlete leaps as high and as far as possible, thus moving the body in the horizontal and vertical planes. It is generally accepted that the more specific a training exercise to a competitive movement, the greater the transfer of the training effect to performance [8]. To our knowledge though, there is no information concerning the effectiveness of a combined program including repeated sprint, and vertical jump concluded by technical action with ball on sprint and jumping performances in handball.

For this reason, the main purpose of this study was to investigate the effect of a combined program including sprint repetitions and drop jump training in the same session on male handball players. The secondary purpose of the study was to investigate the effectiveness of the above-mentioned combined program on the sprinting ability of players with respect to a particular playing position.

METHODS AND SUBJECTS

Participants:

In the first part of the 2009–2010 season (September, October, and November, after the preparation phase), 22 male handball players aged more than 20 years old and having more than 10 years of training experience were enrolled. All subjects belonged to the club of “Stade Tunisien” which plays in the first league of the Tunisian Handball Federation. The participants were assigned into 2 groups: experimental group (n=11) (age: 20.18±1.32years; weight: 75.90±10.22kg; Size: 180±3.07cm and BMI: 22.90 ±3.47kg/m2), and control group (n=11) (age: 22.09±2.58 years; weight: 76.50±1.22kg; Size: 181±5.73cm and BMI: 22.63 ±3.41kg/m2). Selection was based on variables “axis” and “lines”, goalkeepers were not included.

All subjects were instructed to refrain from participation in any other form of training during the testing and training period that might affect their speed, including resistance training. All subjects were

nonsmokers and none used ergogenic aid or were users of medications known to affect cardio respiratory function during the study. The protocol of this study was in accordance with the guidelines of the Ethical Tunisian Olympic Committee, and all participants gave their written consent.

Materials:

This study was designed to address 2 questions: (a) does a combined plyometric and running-speed program performed in the same training session increase vertical-jump performance of male handball players? (b) Does this combined program affect the running speed performance in the same way for players of different playing positions? We must however emphasize that our intention was not a comparison with previously used conventional running-speed programs. We concentrated on the possible effect of two sets of additional training programs on the enhancement of explosive actions and running speed performance in elite male handball players.

The experimental group followed 2 additional training programs. The first one, applied at the first six weeks, was inspired from studies of Cometti [9] and Lehance [10]. It consisted of drop jump associated with shoots at Tuesday; and repeated sprint (10 seconds of running/20 seconds of rest) at Thursday. The second training program, applied at the second six weeks, was inspired from works of Quantaillet [11] and Lehance [10]. It consisted of drop jump associated with shoots at Tuesday; and technical actions with ball (one against one) concluded by running-speed, alternated by lateral displacement associated to running speed at Thursday. This group was compared with a control group, where participants performed the usual handball training. All training sessions were carried out by the team coaches.

For these reasons, participants were asked to report to the Sports Medicine Centre of the Ksar-Said Physical Education Institute on 2 testing periods (test and retest) separated by a training period of 12 weeks with a frequency of 2 training sessions/week. The experiment started for all subjects in the morning at 9am, 2 hours after the habitual breakfast. The testing period comprised at the first day a medical checking, anthropometric measurements and an incremental exercise test called yo-yo intermittent recovery test [12]. This later was used to determine the individual maximal aerobic speed (MAS) necessary to determine the exercise training intensities. 2 days later, participants performed at identical conditions the Repeated Sprint Ability test (RSA) [4], and performed the Jumping Performance using 3 different events: Squat jump (SJ) [10], Countermovement jump without (CMJ) and with arms (CMJA) [13] and Drop jump (DJ) [10]. At the end of the training period, participants performed again the repeated sprint ability test, and the jumping performance.

Anthropometric Characteristics:

Body height, body mass, and body mass index (BMI) were measured for each subject. The height was measured by means of stadiometry to the nearest 0.5 cm and a scale (Tanitat) was used to measure body mass to the nearest 0.1 kg. Body mass index was calculated as Wt (kg)/Ht (m^2). All measurements were taken by the same investigator.

Physical Fitness Characteristics:

Six variables were recorded for each player. These included aerobic capacity, explosive power of the lower limbs and running speed. Concerning aerobic capacity, maximal aerobic speed was determined using the yo-yo intermittent recovery test [12]. It is similar to the Yo-Yo Endurance Test, except that in the intermittent tests the participants have a short active break (5 and 10 seconds for the *intermittent endurance* and *intermittent recovery* test, respectively). The test evaluates an individual's ability to repeatedly perform intervals over a prolonged period of time, particularly required for athletes from sports such as tennis, team handball, basketball and soccer or similar sports. Use cones to mark out three lines; 20 meters and 5 meters apart. The subject starts on the middle line, and begins running 20 m when instructed by the recorded beep. This subject turns and returns to the starting point when signaled by the beep. There is an active recovery period during which the subject must walk or jog around the other cone and return to the starting point. A warning is given when the subject does not complete a successful out and back shuttle in the allocated time, the subject is removed the next time they do not complete a successful shuttle. The athlete's score is the

total distance covered before they were unable to keep up with the recording, and VO2max can be estimated by the formula: VO2 max (ml/min/kg) = distance in meter x0.0136+45.3.

Sprint ability was measured by the Repeated Sprint Ability test (RSA) [4]. It was assessed through 6 repetitions of maximal 2x15-m shuttle sprints (~ 6s) departing every 20 s. During the 14 s recovery between sprints, subjects had a passive standing recovery. Three seconds before starting each sprint, subjects were asked to assume the ready position and await the start signal. Strong verbal encouragement was provided to each subject during all sprints. The speed was evaluated by using 2 pairs of photocells and reflectors connected to an electronic timer (Tag Hewer, Marin, Switzerland). The photocells were placed at shoulder height and the time was given in hundredths of a second.

Jumping Performance was performed using 3 different events. For each test, subjects performed 3 trials barefoot with 60 seconds of rest between trials, and the best performance based on height was used for analysis. The jumping performance was collected by using an Optojump dispositive (Microgate SRL, Italy) connected to a personal computer, and 3 minutes of rest was used between each 2 tests [10]. Tests were squat jump (SJ) [10] in which the participant started from a stationary semi squatted position (knee angle 90°) and jumped upward as high as possible [6], Counter-movement jump (CMJ) [13], similar to the (SJ) but player started from an upright standing position and performed a very fast preliminary downward movement, flexing his knees and hip immediately after he extended the knees and hips again to jump vertically off the ground [6], and Drop jump (DJ) in which participant jumped from a bench (height 40 cm) and performed a maximal jump immediately after landing on the floor [10].

Training intervention:

The anaerobic training intervention of the experimental group consisted of combined intermittent running (10/20) and plyometric training (drop jump). The first additional training program was applied at the first six weeks. It comprised drop jumping concluded by specific position shoots at Tuesday. The height of dropping and the total number of shooting by session increased every two weeks (Table 1). At Thursday, participants performed an intermittent speed running (10/20) which had two bouts of 7 minutes 40 seconds each. Speed intensity was 100% of MAS, and 10 minutes of passive recovery were accorded between boots.

The second additional training program was applied in the second six weeks. Drop jumping associated with specific position shoots were maintained at Tuesday. Whereas, at Thursday, participants altered technical action with ball (one against one during 3 to 6s) achieved by a sprint during 4 to 7s, and lateral displacement (3 to 6s) concluded by later jumping (height 40cm) associated with sprint (7 to 4s) (fig1). Running intensity was 120% of individual MAS, and the duration of session was 2x7´40´´ with 10 minutes of passive recovery.

Statistical analysis:

Distribution normality was proved with the Kolmogorov-Smirnov test. All variables were normally distributed and therefore parametric statistics were applied. All values were expressed as means ±SD. Differences between experimental and control group, central axis and lateral axes, front basis and rear basis were tested using paired-samples T-Test. Changes from pre to post-training in squat jump, countermovement jump, countermovement jump with arms, drop jump and repeated sprint ability were given in percent (%).

Table 1: The drop jump training program (second six weeks)

week	Number of jump/session	Number of series × number of drop jump × Height of drop jump (cm)
1-2	40	10 × 20 with 10 specific position shoots/session
3-4	40	2 × 10 × 20 ; 2 × 10 × 25 with 20 specific position shoots/session
5-6	60	2 × 10 × 20 ; 2 × 10 × 25 with 30 specific position shoots/session
7-8	60	2 × 10 × 30 ; 2 × 10 × 35 ; 2 × 10 × 40 with 40 specific position shoots/session
9-10	60	2 × 10 × 35 ; 3 × 10 × 40 ; 1 × 10 × 45 with 50 specific position shoots/session
11-12	60	1 × 10 × 35 ; 3 × 10 × 40 ; 2 × 10 × 45 with 60 specific position shoots/session

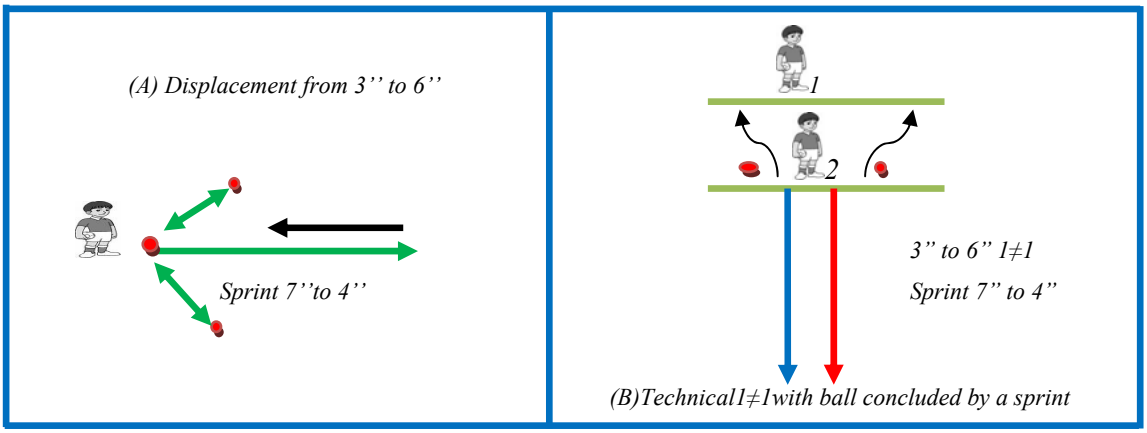

Fig. 1: Especially defensive displacement concluded with a sprint with ball (with and without defender10/20)

For Statistical analysis, SPSS 16 for Windows was used (Statistical Package for the Social Sciences, Chicago, IL). In all cases the level of statistical significance was set at $P<0.05$.

RESULTS

The findings of the study indicate that an additional combined training program between sprint repetition and vertical jump in the same training session influence positively the jumping ability of handball players (Table 2). In fact, the conventional combined program improved the explosive force ability of handball players in CMJ ($P=0.01$), CMJA ($P=0.01$) and DJR ($P=0.03$). Modification was 2.78, 2.42 and 2.62% respectively. No significant modifications were noted in performances of the experimental group at the squat jump test and the drop jump with the left leg test.

An additional combined training program modifies also the running speed ability of the experimental group ($P=0.003$). A substantial modification in the control group performance was also noted ($P=0.05$).

Table 3 shows that in the experimental group, the anaerobic training intervention manifested -1.27% and -2.31% improvement respectively in sprint for the players of the two lateral axes (right and left) and the central axis. Mean running speed increased also by -1.02% for the players of the rear basis, and by -2.41% for the players of the front basis. No significant differences were observed between axes or lines.

Table 2: Physical performances after training session of elite male handball Player [Mean (Standard deviation)]

Variable		Expérimental group (n=11)					Control group (n=11)				
		Pre-training	Post-training	%	comparison		Pre-training	Post-training	%	comparison	
					t	*P* value				t	*P* value
SJ (cm)		31.7 (2.9)	32.5 (4.1)	2.40	-1.16	NS	31.4 (5.0)	31.5 (5.6)	0.03	-0.18	NS
CMJ (cm)		33.4 (2.7)	34.2 (2.9)	2.78	-2.99	0.01	34.2 (5.9)	34.7 (6.4)	1.32	0.65	NS
CMJA (cm)		39.7 (3.8)	40.5 (4.0)	2.42	-3.04	0.01	37.7 (4.7)	38.0 (5.2)	0.96	-0.4	NS
DJ (cm)	**R**	26.3 (4.8)	26.9 (4.7)	2.62	-2.42	0.03	21.5 (4.7)	21.6 (4.3)	0.42	0.43	NS
	L	27.1 (4.9)	26.8 (4.8)	-0.39	0.32	NS	24.1 (5.4)	25.3 (5.4)	4.98	-0.53	NS
RSA (m/s)		6.1 (0.1)	6.0 (0.1)	-1. 56	3.83	0.003	6.2 (0.1)	6.1 (0.2)	-1.18	-1.94	0.05

SJ: Squat jump; CMJ: Countermovement jump without arms; CMJA: Countermovement jump with arms; DJ: Drop jump; RSA: Repeated Sprint Ability test

Table 3: Running speed performances after additional training program of elite male handball Player by axes and lines [Mean (Standard deviation)]

Experimental group (n=11)	RSA (m/s)					
	Pre-training		Post-training		%	
Players of central axes (n=3)	6.1 (0.1)		5.96 (0.05		-2.31%	
Players of lateral axis (n=8)	6.2 (0.1)		6.07 (0.14		-1.27%	
	t	-0.28	t	-0.72	t	-2.46
	Sig	NS	Sig	NS	Sig	NS
Players of rear bases (n=5)	6.15 (0.10		6.02 (0.06		-1.02%	
Players of front bases (n=6)	6.12 (0.13		6.06 (0.15		-2.41%	
	t	1.17	t	0.59	t	1.98
	Sig	NS	Sig	NS	Sig	NS

RSA: Repeated Sprint Ability test; NS: non-significant

DISCUSSION

Our findings indicate that an additional combined training program between sprint repetition and vertical jump positively influence the jumping ability of handball players. This confirms earlier studies showing that concerning the results obtained for the drop jump, it is well known that this performance depends mainly on muscle stiffness [6,14]. It is also known that combined running speed and vertical jump training increases the muscle stiffness as well [15].

In fact, relevant literature has shown that vertical jump is improved through various types of training methods, such as resistance training [16-18], depth jump [19], jumping (stretch shortening cycle) exercises [5,16-18,20], and a combination of plyometric exercises and electro stimulation [19]. It has been demonstrated that explosive-type resistance training is more effective in improving vertical jump, compared to high-resistance training [5. 20].

Vertical jump was also considered crucial for the handball player performance. It was a complex movement that greatly depends on inter-limb coordination [1] on muscle fiber type and stiffness [21] and occasionally on maximum strength. depending on the level of the athlete's performance [22].

Training intervention manifested significant changes; improvements in countermovement jump, counter-movement jump with arms and drop jump with the right leg. No significant changes were noted in squat jump and drop jump with the left leg. This could be attributed to the fact that no program was sufficient to cause the adequate adaptations on the muscle-tendon unit in the same training session. These adaptations could be attributed either to neuronal factors or to the optimal transfer of the strength gain to running performance [3].

However, it has also been reported that resistance training does not always result in enhancement of vertical jump, which is affected by other factors such as learning effect [23] training status [24] and volume of training [25]. Several studies have reported that combined programs including resistance and explosive unloaded tasks such as throwing, jumping, and punching in the same training session may improve muscular strength and the velocity of execution on the selected task [5,7,17,26-30]. Improvements were attributed either to neural adaptations or to a learning transfer.

Our findings noted also that running velocity was increased in the experimental and control group. Our data are in accordance with relevant studies in the literature [6,9,11] which reveals that running velocity can be improved following several types of training interventions, such as sprint training without external resistance, towing, over speed [28], and specific plyometric (speedbound) exercises [8]. This may be attributed to the type of the muscle fibers [31]. In fact, in high velocity movements, like a handball game, units are preferentially recruited [32]. It is demonstrated that in power athletes (sprinters, throwers, jumpers and weight lifters) the size of the glycolytic fibers (IIx type), is approximately the triplicate of the oxidative

glycolytic fibers (IIa type), despite the fact that the overall distribution of the slow and fast twitch fibers is proportional in the muscles of the lower and upper extremity. Since stabilization of this distribution occurs in very early age and the activation is frequent in sports like handball [33], it is possible that the combination of these two factors explained the increase of the RSA performance of both groups.

Some limitations of this study are acknowledged. Firstly, players showed many difficulties in maintaining exercise intensities during training sessions. Secondly, handball is a very complex sports activity where successful performance depends on other motor abilities namely the ability of cortical regulation of movement, explosive strength (of throwing type in particular) and basic strength of the trunk. Thirdly; handball team success was a multidisciplinary process including morphological, physical, technical, tactical, psychological aspects and their relationships. Throwing is considered as one of the most important technical skills in competitive team handball as it is a major determinant of all actions taken by the players [3]. Studying the effects of the additional combined training program sprint repetition and vertical jump on ball velocity would be useful.

CONCLUSION

This study has shown that anaerobic performances were increased in-season by a specific combined training program based on intermittent/force10/20 runs at high intensity and sprint repetitions and vertical jump in the same session associated with specific technical actions. These results seem particularly interesting for handball players because improvements in physical qualities are often emphasized before the beginning of competition. After this period, the objective of coaches is to maintain the level of physical qualities. The results obtained after the experimental period have chown that anaerobic capacity can be also developed during the competition season. However, this study shows that improvements in physical qualities are also possible during a 12 week period. Nevertheless, it is not appropriate to directly link physical performance to a handball team's performance. Performance in handball is determined by the players' technical, tactical, Physiological, and psychological/social characteristics, and these factors are closely linked to each other.

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