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Evaluation of Plyometric Exercise, Strength Training on Physical Capabilities

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Abstract Objectives: The aim of this study is to compare a 10-week period, in which strength training (five weeks) was followed by plyometric training (five weeks) or the other way around among handball players. Hypothesis: Performing strength training first and then plyometric training will improve lower body strength and performance more than the reverse training sequence. Methods: Thirty-six young handball players voluntarily participated in this research. Pre and post test data (running, changing direction, jumping, strength, throwing, and endurance) were compared between groups using one-way analysis of variance (ANOVA). The level of statistical significance was set at $p < 0.05$. SPSS was used for the statistical analysis. Results: The results imply that a precise training regime for plyometric and strength training in young handball players is not required. Thus, strength and conditioning training plans created for the youth handball group can be effective regardless of the training regimen. Furthermore, when boosting back squat performance is the main objective, the outcomes of the contemporary research imply that completing plyometric training before a strength-centered training phase may be useful. Conclusion: It is concluded that professionals arrange training schedules to enhance athlete compliance and concentrate on the most important results.

Keywords Polymetric Exercise, Young Athletes, Strength Training, Physical Capabilities, Evaluation

1. Introduction

Team handball is a responsive sport requiring many physical skills, including repetitive sprinting, direction change, throwing, jumping, strength, and stamina [1,2]. Meanwhile, many researches have focused on non-handball players to acquire the mentioned physical qualities [3-5], and the available handball-centered study does not particularly evaluate the influence of training regime[6-8]. Different intellectual skills have traditionally been examined in team handball intervention studies in relation to injury prevention. Additionally, multiple analyses have evaluated the impact of varying strength training regimens on athletic skills relevant to professional handball and discovered beneficial relationships between strength training and performance in sprinting, direction change, and throwing [8-10] direction (cross-over design) would produce comparable outcomes and only compared plyometrics with strength training; therefore, their analysis provides no insight into the order of training. Nevertheless, the same research suggests that using strength training, plyometric exercise, or a combination of the two can improve athletic performance [11-13].

Complex training or the contrast approach is the term used to describe combining strength and plyometric training to improve performance [14]. For a number of sports, particularly throwing sports, this training approach has been suggested [15,16]. It is demonstrated in their review that multiple researchers have evaluated how the order of training affects abilities like strength and stamina. It has been demonstrated that manipulating micro training cycles (weekly) with complicated training results in long-term alterations in the muscle's capacity to produce energy. Nevertheless, the impacts of training in either a plyometric or strength order have not yet been fully

understood [17]. Players should rotate between strength and speed training approaches throughout the similar training periods to fully utilize on the stimulatory reaction after training. This impact is more particularly on the growth in acute muscular force output that results from the contraction experience after a high energy event, such as severe strength training prior to sprinting, and can improve efficiency [18,19]. Complex training is normally carried out in a single session; nevertheless, it is usually advised that the strength training phase training intervals of two to eight weeks come before those emphasizing speed or explosiveness [20,21].

Like many other countries, handball is also famous in Jordan. The Hashemite Kingdom of Jordan's regulating organization for handball and beach handball is the Jordan Handball Federation. The Jordan Handball Federation was established in 1961 and is a member of both the Asian and International Handball Federations. The West Asian Handball Federation, the Arab Handball Federation, and the Jordan Olympic Committee are all associated with the Jordan Handball Federation. Regardless of the popularity, there is a very limited number of researches assessing the impact of polymetric and strength training on the handball players in Jordan [22]. The current research is intended to evaluate the impacts of the training regime of strength and plyometrics exercises on various intellectual skills of handball players in a training phase due to the lack of studies questioning the prevalent model of training strength before strength and agility. It was assumed that performing strength training first and then plyometric training would improve lower body strength and performance during a reverse training sequence. The assumption is based on the statement that improving the cognitive unit size and initiation before transitioning to a training phase specific to muscle contraction will improve efficiency and productivity. Before the best outcomes from plyometric training can be realized, a suitable degree of energy-generating skills must be acquired [23,24].

2. Materials and Methods

2.2. Research Design

Lower limb strength was measured using a dual empty weight back squat with loads of 15 kg, 25 kg, and 35 kg. The subject began by standing with a barbell on the trapezius muscle of the neck. Then they bend their knees to 90 degrees and immediately extend their hips and knees without lifting them off the floor. Using a rod-mounted linear encoder, the thrust velocity at each load was averaged around 1 ms-1.27 to determine the training weight and was chosen because this velocity was found to produce the highest power. The optimal condition was used for further studies after each weight was subjected to three repetitions with 5- minute rest between each repetition.

The two criteria used to judge shooting ability are the set shot from 6.5 meters (the penalty kick) and the three-step shot from 6.5 meters from the goal. Participants are asked to throw a normal- weight handball with as much force as possible toward the handball agreement before testing.

Before the post-test, the random sampling method was used to compare the effects of strength training and plyometric training on the physical capabilities of young handball players. The first group started a 10-week plyometric training period (five weeks), followed by five weeks of strength training, while the second group did the reverse training. Before switching the training regimen, the various physical capacities were evaluated after five weeks and again after 10 weeks (post-test). No additional control groups were included since the study is only interested in the impact of the training regime within a training phase.

2.2. Materials and Methods

After a standard seven-minute warm-up, each rider completed a variety of mechanical and cognitive skills test, including throwing, lower body strength and power, change of direction, running, and endurance.

A 27-meter run with two pairs of wireless photovoltaics was used to assess running ability. Participants began from a distance of 0.3 m behind the first beams, which were set at a height of 0.3 m. To prevent participants from pushing their arms or legs forward to achieve faster times, the last pair of beams were placed 0.7 m high. Participants completed three sprints, followed by 4 minutes of rest. For further tests, only the fastest possible time was evaluated [13]. Mohamed et al. [25] used handball-specific tests to assess the directional change.

Counter-movement jump was used to assess the explosive force of the lower extremity. For each jump of movement, there is a target. A Doppler radar gun with a 10-degree field of view was used to measure the ball's maximum velocity with an accuracy of 0.117 meters per second. The radar gun was placed one meter from the target at the height of the ball during launch. Three attempts were made for each test and the best one was selected.

In accordance with the guidelines provided by Bangsbo et al. [26], the Yo-Yo Level 1 Intermittent Recovery Test (Yo-Yo IR1) was utilized for the purpose of evaluating endurance and performance. The Yo-Yo IR1 accurately assesses a person's capacity to run repeatedly and continuously by simulating normal team handball performance. Each participant was given the first five trials in a random order, but each subject completed the trials in the same order for each testing session. The Yo-Yo IR1 test is always administered at the conclusion of the assessment to prevent fatigue from affecting other tests. Before and after the various tests, subjects were only permitted to consume water. The specifics of each training phase's plyometrics and strength training programs are shown in Tables 1 and 2.

Table 1. Plyometrics training program per training phase

Training method	Training phase					
	One	Two	Three	Four	Five	Six
Jumps on two legs without bending the knees	6 x 22	6x 22	6 x 22	6 x 26	6 x 26	6x 26
Jumps on two legs while bending knees	6 x 12	6 x 12	6 x 12	6 x 12	6 x 16	6 x 16
Hop fast and briefly on one leg	4 x 12	5 x 12	6 x 12	6 x 12	5 x 16	5 x 16
Jumps on one leg as high as you can	5 x 12	5 x 12	6 x 12	6 x 12	6 x 12	6 x 12
Sprint while still standing	6 x 22m	7x 22m	7x 22m	7x 22m	4 x 6 x 22m	
From the laying start position, sprint quickly						4 x 6 x 12m
Training method	Seven	Eight	Nine	Ten		
Jumps on two legs without bending the knees	4 x 32	5 x 32	6 x 23	6 x 22		
Jumps as far as you can on two legs while bending your knees	4x 22	4 x 22	5 x 22	5 x 22		
Hop quickly on one leg	4x 22	4x 22	4x 22	4x 22		
Jumps on one leg as high as you can	4x 22	4x 22				
Jump without a ball			4 x 17	4 x 17		
From the laying start position, sprint	6x 35m	6x40m				
Sprint from 5m sideways			7x 35m	7x40m		

Table 2. Strength training program per training phase

	Training phase					
Exercise	**One**	**Two**	**Three**	**Four**	**Five**	**Six**
Squats	4 x 8	4 x 8	4 x 8	4 x 8	4 x 9+3.7kgs	5 x 9+3.7kgs
Sprint starting from a static posture	6 x 22m	7 x 22m	7 x 22m	7 x 22m	5 x 6 x 22m	
From the laying start position, sprint						4x 6 x 12m
Exercise	Seven	Eight	Nine	Ten		
Squat	4 x 8+7kg	5 x 12+8kg	5 x 12+8kg	5 x 12+8kg		
From the laying start position, sprint	6 x 25m	6 x 10m				
Sprint from 5m sideways			7 x 25m	7 x 10m		

2.3. Participants

The research was carried out at a private university in Jordan. The university's permitted existing ethical guidelines for sports and exercise research were followed. Thirty-six female young handball players willingly participated in the current research. The participants were aged between 15-18 years, with body weight below 62 kg, a maximum body height of 180 m, training experience of at least 6 years, and a minimum of one year of strength and plyometric training experience. The team engaged in three training sessions, lasting 60 minutes each, and played two competition games weekly on average. The study's protocol was clearly explained to the participants before it began. All respondents were provided with written precise 0.075 mm linear encoder at the waist that was used to measure height by counting the pulses at 10 ms intervals. Each condition received three, with a 30-second break in between each one.

2.4. Statistical Analysis

Body measurements and pre-test performance data were compared between groups using a one-way analysis of variance (ANOVA). A post hoc comparison with the lowest mean difference was used for peer review. In addition, the mean difference in each performance parameter from pretest to posttest in each training group was determined for comparison with other investigations and for the relative difference between the two groups. The intraclass correlation coefficient (ICC) for each specific test was greater than 0.8, indicating high reliability. The significance threshold was set at $p = 0.05$ or higher. Statistical analysis was performed with SPSS software.

3. Results

With arm swing, the counter movement jump was (F = 12.9, p 0.001, 2 =0.410) without arm swing (F = 7.9, p 0.001, 2 = 0.311), change in direction (F 10.9, p 0.001, 2 = 0.401), with a significant main effect of time (+ 6.9%, 8.8%, and 5%). In addition, the weight changed significantly over time in the strength test (F = 6.0, p = 0.012, 2 = 0.201), in the throwing tests (F = 0.90, p = 0.37, 2 = 0.040), in the yo-yo test (F = 3.11, p = 0.079, 2 = 0.110), and in the sprint test (F = 0.02, p = 0.899, 2 = 0.002). The training team did not exhibit a significant main effect in any of the tests (F 1.0, p 0.2, 2 = 0.03) (see table 3). Performance on the aptitude test was significantly improved between the pre- and mid-tests in the strength-plyometrics training group, but there were no significant changes between the middle test and the post-test (2%). Pre-to-mid-test results were found for the counter movement jump without arm swing (+9%, +7%), the counter movement jump with arm swing (+6%, +5%), the change of direction (+5.5%, +6.5%), strength (+14%, 11%), endurance (12%, 9%), sprint (-0.1%, +0.3%), throwing-standing throw (+0.1, +0.2%), and running throw (+1.2%, +0.9%) (see table 4).

Table 3. Performance mean

performance tests	time	weight	running distance	F	p	η2
countermovement jump with arm swing	+6.9 %			12.9	< 0.001	0.410
countermovement jump without arm swing	+8.8%			7.9	< 0.001	0.311
change of direction	+5%			10.9	< 0.001	0.401
strength test		+39%		6.0	0.012	0.201
Yo-Yo IR1 test			+10.5%	3.11	0.079	0.110
sprint over 30 m	+0.08%			0.02	0.899	0.002
throwing tests				0.90	0.37	0.040

Table 4. Improvements in performance percentage through all training stages

plyometrics-strength training group				
physical capabilities	pre-test to mid-test		mid-test to post-test	
	percentage of change (%)	p	percentage of change (%)	p
change of direction	+5.5%	< 0.05	< 2%	0.003
Counter movement jump without arm swing	+9%	< 0.05	< 2%	0.011
Counter movement jump with arm swing	+6.9%	< 0.05	< 2%	0.011
strength	+14%	< 0.05	< 2%	0.003
endurance	+12%	< 0.05	< 2%	0.003
sprint	+0.1%	0.001	< 2%	0.011
throwing (standing throw)	+0.1%	0.001	< 2%	0.003
throwing (running throw)	+1.2%	0.003	< 2%	0.011
strength-plyometrics training group				
physical capabilities	pre-test to mid-test		mid-test to post-test	
	percentage of change (%)	p	percentage of change (%)	p
change of direction	+ 6.5%	< 0.05	< 2%	0.003
Counter movement jump without arm swing	+7%	< 0.05	< 2%	0.011
Counter movement jump with arm swing	+5.9%	< 0.05	< 2%	0.011
strength	+11%	< 0.05	< 2%	0.003
endurance	+9%	< 0.05	< 2%	0.003
sprint	+0.3%	0.001	< 2%	0.011
throwing (standing throw)	+0.2%	0.001	< 2%	0.003
throwing (running throw)	+0.9%	0.003	< 2%	0.011

4. Discussion

In this research, the training phase for combined strength and plyometrics training programs was compared for the order of influence on several physical skills in young female handball players. The key conclusions were that over the course of five weeks, maximum jumping height, directional shift, and strength all increased, but throwing velocity, stamina, and sprinting skills did not alter much. No influence of training regime was discovered, in contrast to the major hypothesis. An influence of the training regime promoting the capability of the groups trained during that time was only discovered when the variability in performance for the counter movement jump and strength skills was determined from the before-middle and middle-end: strength or plyometric exercises.

The sequential training program combined with strength training and plyometrics, which encouraged changes that help to improve lower-body muscular power, can be used to explain the improvement in maximum counter movement jump height and strength. Following a 10-week complex training program, significant progress (20%) is discovered in counter movement jump performance in young female handball players [8]. Young athletes have fairly recent experiences with structured strength and plyometric training, allowing them to expand strength and energy more quickly [27]. Furthermore, as demonstrated by the improvement in strength and counter movement jump performances from the before to middle of the test in this research, the elevation in the shift of direction capacity from pre- to mid-test might be attributed to this improvement in strength and explosive strength of the limbs.

In contrast to previous treatments that reported improved sprint performance with strength training, plyometric exercise [16,28] or both, [8,16] neither group showed a significant improvement in sprint performance. Although the processes underlying our findings are uncertain, it is conceivable that the technical and sequential nature of running may be more difficult to produce significant improvements compared to jumping or strength activities. In fact, according to recent research, improvements in jumping activities are almost always greater than in sprinting tasks. Impedance performance is predicted. These results that are comparable with research found that a resistance band program that focuses on specific throwing motions improves throwing speed compared to a program that focuses on general motions [29].

In contrast to the plyometric strength group, running distance (as measured by the yo-yo IR1 test) was improved from pretest to average in the plyometric strength training group. Determining the cause of these findings is difficult, but it is possible that plyometric training can improve muscle and tendon stiffness, leading to more energy-efficient movements [30].

The percentage change by calculation revealed the impact of the training regime [30]. The group that began with a plyometric training program (the first five weeks of the training phase from start to intermediate trial) increased in height, indicating that plyometric training outperformed strength training in improving jumping ability of the last group. Due to similar strength/speed patterns and body movements, plyometric manipulations are the most effective way to increase jump height. The data supports the training privacy hypothesis. The group that started strength training had a similar outcome: strength increased in the first five weeks but decreased in the later stages of plyometric training. It is noteworthy that both groups had similar strength during the first half of treatment. In contrast, the plyometric strength training group did not continue to gain strength over the next five weeks. Contrary to conventional wisdom, this research on strength development is the only variable that responds positively when starting a training course with a treatment phase focused on plyometrics.

5. Conclusions

The results imply that strength and conditioning training plans created for handball guys can be effective regardless of the training regimen. Although main objectives of the research were met, some drawbacks and areas still need more investigation. Additionally, the primary focus was placed on strengthening the lower body's muscle groups. Therefore, the outcomes might vary if comparable procedures were used on the upper body. The results may vary depending on the context, and readers should know that they only apply to young female handball players. The male athletes were not involved in this research; therefore, future research should be performed on both genders to assess any gender differences in polymetric-strength training programs on performance effectiveness. Future studies should examine how the training regime affects advanced trainees. To completely explain the impacts of the training regime, longer treatments, more exact measurements, and an analysis of putative mechanistic components are needed.

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Competing Interests

The authors declare that they have no competing interests.

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