The Effect of 4-week Difference Training Methods on Some Fitness Variables in Youth Handball Players

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Handball is a team sport in which main activities such as sprinting, arm throwing, hitting, and so on involve. This Olympic team sport requires a standard of preparation in order to complete sixteen minutes of competitive play and to achieve success. This study, therefore, was done to determinate the effect of a 4-week different training on some physical fitness variables in youth Handball players. Thirty high-school students participated in the study and assigned into the Resistance Training (RT) (n = 10: 16.75± 0.36 yr; 63.14± 4.19 kg; 174.8 ± 5.41 cm), Plyometric Training (PT) (n = 10: 16.57± 0.26 yr; 65.52± 6.79 kg; 173.5 ± 5.44 cm), and Complex Training (CT) (n=10, 16.23± 0.50 yr; 58.43± 10.50 kg; 175.2 ± 8.19 cm) groups. Subjects were evaluated in anthropometric and physiological characteristics 48 hours before and after of a 4-week protocol. Because of study purposes, statistical analyses consisted of a repeated measure ANVOA and one-way ANOVA were used. In considering with pre to post test variables changes in the groups, data analysis showed BF, strength, speed, agility, and explosive power were affected by training protocols (P< 0.05) as well as there is an interaction between training methods and time effect for all variables (P< 0.05). As percentage changes, findings showed there was a significant difference in squat strength, agility, speed, and explosive power (p< 0.05), but no significant difference for BF and chest strength (p>0.05). In conclusion, complex training result in advantageous effect on variables such as strength, explosive power, speed and agility in youth handball players compare with resistance and plyometric training although we also reported positive effect of these training methods. Coaches and players, therefore, could consider complex training as alternative method for other training methods.

KEY WORDS Complex Training, Resistance Training, Plyometric Training, Adolescents
INTRODUCTION

Handball is a team sport in which main activities such as sprinting, arm throwing, hitting, blocking, jumping, and pushing involve. This Olympic team sport requires a standard of preparation in order to complete sixteen minutes of competitive play and to achieve success [1]. In the handball game, the most important factors including maximal strength levels in the shortest period of time (muscular power), handball throwing velocity, and pushing are essential to obtain high sport performance levels and to help handball players in response to different offensive and defensive situations in the game [1, 2]. Since strength training improve sport performance, reduce injury rate, and provide higher motivation levels for the athletes [3], therefore, in many of team sports such as basketball, soccer, and handball, strength-based training is part of preseason programs [4]. The evidence suggests that the combination weight training and plyometric are effective. One way to combine the two forms of training is complex training or the contrast method. The effect of high load weight training and weightlifting exercises and their effect on explosive motor performance referring to this phenomenon as the contrast method [5]. On other words, the combination of plyometric training and weight training defined as complex training [6-9]. This pattern of training, used in present study, alternates biomechanically similar high load weight training exercises with plyometric exercises, set for set, in the same workout. Instance, complex training would include performing a set of squats followed by a set of jump squats. Others stated that complex training is a method in which various sets of heavy resistance exercise are followed by sets of a lighter resistance exercise [10].

Many studies have described the application of complex training [11-15]. In addition, studies have reported in the literature and have been proposed to increase muscular power by complex training [6, 7, 9, 16]. For example, Eduardo J and et al. believe that complex training increases vertical jump (VJ) and medicine ball throw (MBT) levels. They suggested this is an important part of sports conditioning that may contribute to improved performance in young basketball players [3]. An enhancement of motor performance associated with plyometric training combined with weight training or the superiority of plyometric, compared to other methods of training also has been indicated [8]. Moreover, it was indicated that dynamic athletic performance need to training strategies that train both the force and velocity components of the force velocity curve [17]. These documents suggest that both weight training and plyometric training are important. It would be noted that a specific training method in form of complex training may be a useful training strategy because of the organizational advantages of performing both types of exercise simultaneously during the same training session [8, 9, 11]. It is proposed, therefore, that complex training probably result in explosive strength improvement in youth handball players.

As in the literature has been shown that resistance and plyometric training lead to improvements of strength characteristics in team sports such as basketball players [3], several investigations also have demonstrated the positive effects of these methods [18-21]. Moreover, well-designed resistance training programs can enhance the muscular strength of children and adolescents beyond that which is normally due to growth and development. A many of studies have suggested that comprehensive resistance training programs which include plyometric exercises have been found to enhance movement biomechanics, improve functional abilities, and decrease the number of sports-related injuries in young athletes [22-25], although a concern related to youth resistance training regarded the safety and suitability of plyometric training for children and adolescents [26]. It should be noted that plyometric training is a type of training that develops the ability of muscles to generate force at high speeds in dynamic movements; this pattern of muscle contraction is known as the stretch-shorten cycle [1, 27, 28] involves a
stretch of the muscle immediately followed by an explosive contraction of the muscle [1].

Totally, many of research previously noted the effect of plyometric and complex training on different team sports and showed positive results. Despite complex training researches include acute and training studies as well as they focus on adult players, no studies were found on the effects resulting from the application of complex training in the youth handball players. Thus, given the lack of literature on the effects of complex training in the handball players, the aims of this study were to understand how youth handball players respond to short term resistance, plyometric, and complex training.

METHODS

Based on our hypothesis, the study was designed to assess the effects of three pattern of resistance, plyometric, and complex training programs on the anaerobic factors such as explosive power, maximal strength of chest and squat, mean power (MP), and fatigue index (FI), arm throwing (RT) in young male handball players, aged 16 years old. The players randomly assigned into three groups (resistance training (RT), plyometric training (PT), and complex training (CT)) were selected for this purpose. The protocols were designed in four main parts including warming-up, physical fitness training, handball specific training, and cooling down. Physical fitness training was difference among groups and the rest of session program was the same for all players in groups. Warming-up took place 10-15 minutes consist of jogging, running and stretching as well as in cooling down players did jogging, light running and stretching for 5-10 minutes. Physical fitness training which will describe in next sections (table 1) in all groups followed by handball specific training consist of technique and tactical training for 20 minute.

Thirty high-school handball players volunteered participated in this study. They have played handball in average at last for 2 years. The subjects were randomly assigned to the

Resistance Training (RT) (n = 10: age, 16.75± 0.36 years old; weight, 63.14± 4.19 kg; height, 174.8 ± 5.41 cm), the Plyometric Training (PT) (n = 10: age, 16.57± 0.26 years old; weight, 65.52± 6.79 kg; height, 173.5 ± 5.44 cm), and the Complex Training (CT) (n=10, 16.23± 0.50 years old; weight, 58.43± 10.50 kg; height, 175.2 ± 8.19 cm). All of the subjects basically were familiar with resistance training and plyometric training programs before this study and selected for high school handball team for the national competition. Athletes, parents, and coaches were informed about the purpose of the study as well as the risks associated with strength training and informed consent was obtained from all subjects and parents before the study started. The Institutional Review Board of the Faculty of Physical Education and Sport Sciences/ Razi University of Kermanshah/ Iran approved all study procedures.

Subjects were evaluated in variables forty eight hours before and after of a 4-week protocols. The following variables were assessed: body height, body weight, body mass index (BMI), body fat, chest and squat strength, explosive power, speed running, and agility, respectively. 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 was used to measure body mass to the nearest 0.1 kg. Body mass index was calculated as weight (kg) /height (m) \(^2\)). Percent body fat was evaluated by using skinfold caliper- medical (sh502 model) to measure skin fold thickness \((\Sigma SKF)\) at two body sites (triceps and calf) on the body. Following formula was used according to people <18 years old [29].

\[ \%BF = 0.735 \times (\Sigma SKF) + 1. \]

All measurements were taken by the same investigator.

After measuring anthropometric characteristics, players participated in physical fitness testing. Forty- eight hours before beginning of protocols, indirect measurement of 1RM for chest and squat strength was used. Then, the jump squat was chosen as a procedure for measuring the
explosive strength of the leg extensors; 10 meter sprint running test, T-test, and Cornish handball test were used to evaluate speed, agility, and arm throwing ability, respectively. This process was repeated forty-eight hours after last session of protocols as pre-test. We measured chest and squat strength through indirect method to determine one repetition maximum (1RM) as described in details previously [25]. In brief, before testing, all players were instructed on the proper form for squat and bench press exercises. The players were instructed to perform practice repetitions with the standard barbell. After the exercise orientation, the trainer chose a weight he estimated that the subject could lift 5 or fewer times. The test was accepted if the repetitions completed were 8 or fewer. If the subject completed more than 8 repetitions, more weight was added and the subject was retested. As Kravitz and colleagues [30] demonstrated that predicted 1RM testing provided acceptable levels of accuracy, the 1 repetition maximum (1RM) was predicted with the equation introduced by Brzycki Weight / ( 1.0278 - ( 0.0278 × Number of repetitions) ) [31]. The squat testing required the subject’s thigh to be parallel to the floor for each repetition. The bench press testing required the subject to touch his chest and return to full arm extension for each repetition.

Vertical-Jump Height Testing was used; in brief, the athletes stand side on to a wall and reached up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips was marked or recorded. This is called the standing reach height. The athletes then stand away from the wall, and leaped vertically as high as possible using both arms and legs to assist in projecting the body upwards. The player did the test twice. In addition, peak power was calculated as following. Johnson and Bahamonde Formula was used to convert cm to watts [32]:

\[
\text{Power-peak (W)} = 78.6 \times \text{VJ (cm)} + 60.3 \times \text{mass (kg)} - 15.3 \times \text{height (cm)} - 1.308
\]

Sprint time was measured by the 10 meter fast running test. The players began with their toe on the start line. Timing began when coach counted down 3, 2, 1, and Go and ended when the subject interrupted the finish line. The best time of 2 trials was recorded. In all physical fitness, stopwatch was used to take records.

To assess agility we used T-test as described and used previously for handball and soccer players [33, 34].

Resistance training: As illustrated in table 1, group participants did perform four movements for upper and lower body. Movements were burble squat, chest press, lunge squat, and dumbbell pull over. It was used 50-60 % 1RM/8-10 repetitions/2 sets/ 3 sessions during two first weeks. When the intensity was set in 50-60 % 1RM during the first and second weeks, repatriations raise 10-12/ 3 sets/3 sessions in the third and fourth weeks. Plyometric training: These training were designed for upper and lower training as resistance training. Plyometric exercises include vertical jumps, during which the players 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. Jump squat, fast jumping into ten circles with one meter diameter, medicine ball throwing, and push up jumping. Overload principle was done by repetitions. For example, 8-10 repetitions/ 2 sets/ 3 sessions were performed during first and second weeks by participants. And, the program followed by 10-12 repetitions/ 3 sets/3 sessions in third and fourth weeks (table 1). Complex training: As described in the literature [8, 10, 11, 35, 36], complex training in this study was a combination of resistance and plyometric training. Complex training included performing a set of squats followed by a set of jump squats in the first movement. Players did four repetitions in squat as well as four repetitions in squat jump (sum of repetitions were 8 in a set); in the second movement, chest press followed by push up jumping with four repetitions in each;
lunge squat combined with fast jumping in ten circles with one meter diameter in the third movement; finally, players combined dumbbell pull over with medicine ball throwing in the last movements. The plyometric component of complex training performed immediately after the resistance training component. To equal the duration of session training as resistance and plyometric training, 8-10 repetitions/2 sets/3 sessions were performed during first and second weeks by participants. And, the program followed by 10-12 repetitions/3 sets/3 sessions in third and forth weeks.

All workouts occurred third weekly on nonconsecutive days in training groups. The duration of physical fitness training in each session was 35-50 min in all group programs. It is noted that adequate rest between sets of strength or power exercises is necessary for the recovery of the phosphagen system and recovery, in fact, may be 70% complete after 30 seconds and nearly 100% complete within 3–5 minutes [37]; in this study, 90 s–2 min and 3–5 min were considering as recovery between set and movements, respectively. Table 1 illustrates group programs in the study.

### Table 1. Resistance, polymeric, and complex training Protocols

<table>
<thead>
<tr>
<th>Group</th>
<th>Movement</th>
<th>Repetitions</th>
<th>Sets</th>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>Squat</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pull</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Medicine</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>PT</td>
<td>Squat</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pull</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Medicine</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>CT</td>
<td>Squat</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pull</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Medicine</td>
<td>8</td>
<td>2</td>
<td>3</td>
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</tbody>
</table>

### Statistical Results

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. Because of our purpose in this study concerning the effects of three programs' training and pre- post-design, statistical analyses consisted of a repeated measure ANOVA to determine if there was a significant difference in the dependent variables between the training methods and within pre and post situations. The [(pos-pre) / pre]× 100 formula and one way ANOVA were used to evaluate and compare changes percentage and differences between groups, respectively. For some variables such as agility and chest strength non-parametric Kruskal- Wallis H test was used because of non-homogeneity for variances. For statistical analysis, SPSS17 for Windows was used. P values <0.05 was considered significant.

### Results

As repeated measures ANOVA analysis showed, the variance-covariance matrices are equal across all levels of the between subjects factor in the all depended variables (P > 0.05). The assumption of compound symmetry, also, has been met so that Mauchly's test of sphericity showed not significant (P > 0.05). The Levene's Test of Equality of Error Variances provided the test of the assumption of homogeneity of variance for the between-subjects factor (training methods) (P > 0.05).

### Table 2. Comparison of variables test results in RT, PT, and CT groups. All data presented as mean ±SD.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>P-value</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>RT</td>
<td>31.43</td>
<td>28.07</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>PT</td>
<td>32.05</td>
<td>28.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>32.43</td>
<td>28.07</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td>Speed</td>
<td>RT</td>
<td>10.23</td>
<td>11.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>PT</td>
<td>10.23</td>
<td>11.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>10.23</td>
<td>11.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td>Explosive</td>
<td>RT</td>
<td>11.45</td>
<td>12.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>PT</td>
<td>11.45</td>
<td>12.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>11.45</td>
<td>12.56</td>
<td>0.001</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Data analysis showed all variables including body fat, chest and squat strength, speed, agility, and explosive power were affected during time from pre to post test. There was, therefore, a significant difference in over time between pre
and post mean of above variables (P< 0.05) (table 2 and figures 1-7).
There is an interaction between training methods and time effect (from pre to post test) for chest and squat strength, speed, agility, and explosive power (P= 0.001, P= 0.000, P= 0.021, P= 0.000, P= 0.004, respectively). However, there was no an interaction between training and time effect in body fat (p> 0.05) (table 2 and figures 1-7). In contrast, no a significant difference between three groups after training methods was reported by repeated measure ANOVA analysis (P> 0.05). Then, percent changes was assessed and as figure 9 illustrates, One Way ANOVA analysis showed there was a significant difference in squat strength, agility, speed, and explosive power (p= 0.002, 0.000, 0.020, 0.012 respectively) but no significant difference for BF and chest strength (p>0.05). For details see table 2 and figure7.
Figure 5. Speed- 10 meter (s) from pre to post-test. + Significant difference from pre to post (p< 0.05). RT= Resistance Training; PT= Plyometric Training; CT= Complex Training.

Figure 6. Explosive power (W) from pre to post-test. + Significant difference from pre to post (p< 0.05). RT= Resistance Training; PT= Plyometric Training; CT= Complex Training.

Figure 7. Changes percent from pre to post in all variables. + Significant difference between CT and RT groups (p< 0.05). *Significant difference between CT and PT groups (p< 0.05). NS: No significant difference between groups after training methods (p>0.05).

RT= Resistance Training; PT= Plyometric Training; CT= Complex Training.
DISCUSSION

The purpose of this study was to identify the effects of difference training methods on some physical fitness factors including chest and squat strength, explosive power, speed, and agility in youth handball players. Our results showed that all training methods, resistance, plyometric, and complex training affected mentioned variables significantly after 4-week training. Although resistance and plyometric training have been shown effectiveness for team sports such as basketball, soccer as well as handball players previously [3, 38, 39], complex training has been not documented in handball players in the literature. For example, it was reported that the positive effects from the application of resistance and plyometric methods, reporting higher increases in the explosive strength indicators [3].

In our study, chest and squat strength increased from pre to post. It is possible that the non-statistically significant trend for improvement in chest strength from resistance and plyometric training methods to complex training method could reflect role of movement combination and amplify of neuromuscular adaptations in complex training because results showed 22.61 % increase due to complex training; in contrast, we reported a significant increase from pre to post and our results showed a significant increase in complex training (17.25%) compare to resistance and polymeric training (4.95 % and 8.66 %, respectively) for squat strength. Previously, studies have been shown that both resistance training and plyometric training are typically recommended for adults as well as in children and adolescents training-induced gains in strength and power are indeed possible following participation in a resistance training program [26, 38]. Therefore, based on our results, we could indicate that changes in motor performance skills resulting from the performance of combined resistance training and plyometric training are greater than with either type of training alone [38]. In literature, weight training has been shown as a prerequisite to plyometric training. It means after a specific period of preparation, such as 4-6 weeks of weight training, after several weeks or months of sprint and resistance training, after developing a strength base, or after gaining experience in basic jump base and weight training, plyometric training should suggest [9]. Based on these documents, our subjects selected and they became familiar with the technique and had experience in strength training.

Speed and agility also, improved result from RT, PT, and CT methods. The 10 meter and T-test records reduced after 4-week training. Our results do agree with other studies. For instance, Maio Alves JMV et al [39] found a reduction in sprint times over 5 and 15 m after complex and contrast training (CCT) program. The authors suggest that CCT could induce performance increases in 5- and 15-m sprint. They investigated the short-term effects of CCT on jump, sprint, and agility abilities of soccer players for 8 weeks. The results found by the above referred authors and our results suggest that resistance, plyometric, and complex training methods are useful practices to improve 10 meter speed running and agility activities. Since there was a significant difference between groups, these training methods could be suitable alternative in training programs. It should be considered that there is a significant increase to complex training effects on agility and speed performance compare to resistance and plyometric training (-5.05 % vs. -2.09 % and -1.92 % in speed; -3.83 % vs. -0.53% and -0.41 % for agility) (see figures 5, 6 and 9).

Also, explosive power in youth handball players, in the present study, significantly increased after application of RT, PT, and CT methods. Since combining weight training and plyometric training for explosive power and improved performance are more advantages, Santos EJ and Janeira MA [3] reported the significant increases in the height of the different jumps Squat jump (SJ) (A), countermovement jump (CMJ) (B), Abalakov test (ABA), which proved the complex training efficacy and these authors believed that these findings show the quality of the training program design. They also indicated several factors may have contributed to the changes in vertical jump (VJ), including a better synchronization of body segments, increased...
coordination levels, and a greater muscular strength/force. Maio Alves JMV and et al, in addition, reported a significantly increase for jump performance without countermovement (SJ) and jump performance with countermovement (CMJ), after application of CCT program. Also, similar effects of plyometric and complex training on maximum vertical jump height were shown in a previous study [35]. In our study, as mentioned about speed and agility, there was a significant difference between complex with plyometric and resistance trainings. These results suggest effectiveness of weight training and plyometric training combination in form of complex training; so that Ebben reported the effectiveness of complex training in male division I college football players [8]. In our study, complex training led to 13.43 % increase in explosive power in youth handball players; however, resistance and plyometric training result in 5.48 and 6.37% increase, respectively. These data show importance of complex training versus resistance and plyometric training.

We observed a significant increase in squat, speed, agility, and explosive power following different training methods; so that the main program was complex training. Previously, it was reported that the best results would be attained when a combination of heavy and light loads are implemented within the one workout. By performing heavy loads before light power exercises there is greater activation and preparation for maximal effort in the lighter load [10]. Complementary, it was indicated that simultaneous mastering of large external loads (e.g. weight) and small loads (e.g. body weight), it is possible to produce better neuro-muscular adaptation and reported that combining exercises of large and small loads can achieve great training effect [35]. Let us considering high and low load in complex training. As plyometric and resistance programs in this study show, the load is the same in all repetitions; in contrast, players must overcome to high load then low load (without load) in complex training. It should be noted that we have designed complex training according to following definition stated various sets of groups/ complexes of exercises performed in a manner in which several sets of a heavy resistance exercise are followed by sets of a lighter resistance exercise [10]. In result, our results maybe show Chu' claim that he has stated the power increases achieved through complex training are up to three times more effective than conventional training programs [10]. Our results, therefore, showed 2-3 times increase in variables such as squat strength, speed, agility, and explosive power induced by complex training compare with resistance and plyometric training. In some studies significant increase has been related to muscle mass and hypertrophy after long-term program such as 10 week [35]; because of short-term programs in present study, however, it is not reasonable that we considering a role of performance improvement. Why we observed a significant increase in variables, probably excitation of central nerve system (CNS) plays a main role; because results of studies suggest that performing exercises of a large load can increase the excitation of a CNS [36]. On other hand, CNS is the important factor for muscle force development not only by the amount of the muscle mass involved, but also by the degree to which individual muscle fiber activated. By activating more motor units, increased discharge frequency and synchronization of muscular units, allows the creation of maximal muscle force [35].

In summary, results of present study suggest that complex training result in advantageous effect on variables such as strength, explosive power, speed and agility in youth handball players compare with resistance and plyometric training although we also reported positive effect of these training methods. Since resistance and plyometric training methods lead to a significant improvement and have positive effect on study variables after a short term program and complex training involve both components of resistance and plyometric training in one session, it should be considered as main alternative program method in training by coaches and players in team sport especially for handball players.

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