Turkish Journal of Sport and Exercise /
Türk Spor ve Egzersiz Dergisi
http://dergipark.gov.tr/tsed
Year: 2023 - Volume: 25 – Issue 2 - Pages: 181-190
10.15314/tsed.1201320

Turkish Journal of
Sport and Exercise
Türk Spor ve Egzersiz Dergisi
ISSN: 2147-5652
https://dergipark.org.tr/tr/pub/tsed

# Double-pyramid and Reverse step resistance training effectiveness on physical fitness factors among female handball players

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*Ethical Statement: It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.*

*(Date Of Received): 08/11/2022 (Date of Acceptance): 17.05.2023 (Date of Publication): 31.08.2023*
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**Abstract**

Due to the necessity of resistance training for athletes conditioning, loading patterns in order to improve training outcomes have received more attention in recent decades. Accordingly, the purpose of this study was to assess the impact of 8-week resistance training performed with double pyramid (DP) and reverse step (RS) systems on some physical fitness components of elite female handball players. Thirty young female handball players are randomly assigned to the three groups of DP (age: 17.43±1.63 year, weight: 70.28±10.14 kg, fat percentage: 15.60±1.17), RS (age: 17.13±1.32 year, weight: 67.80±7.78 kg, fat percentage: 15.40±1.69), and control groups (age: 17.33±1.71 year, weight: 61.04±6.61 kg, fat percentage: 16.50±1.43). Training programs was performed for an eight-week, 3 sessions per week with loading pattern of DP or RS. Measurements including fat percentage, anaerobic power (RAST), agility (Illinois), Speed (45 meter sprint), strength (1RM), and muscle endurance (60% 1RM) are taken before and after the training course. After the training period, DP and RS groups had significant effects on the mean power, upper and lower body muscular endurance, fat percentage, agility and speed ($p<0.05$). Moreover, DP had a significantly greater improvement in upper body strength than RS groups, whereas RS revealed a significantly greater improvement in lower body strength than DP groups ($p<0.05$). Also, comparison of DP and RS groups showed a significant difference in lower and upper body muscle endurance between the two groups ($P<0.05$); While, there was not a significant difference in anaerobic power, upper and lower body strength, fat percentage, speed, and agility tests between training groups. DP resistance training appears that to have more impact in improving anaerobic power, upper body strength and speed. While, RS ones showed a greater effect on increasing the lower body strength, muscular endurance, agility and fat percentage of female handball players. Therefore, DP and RS resistance training have positive effects on physical fitness factors among elite female handball players.

**Keywords:** Resistance training, double pyramid, reverse step, loading pattern, physical fitness.

**Özet**

Sporcuların kondisyonlanması için dayanıklılık eğitim gerekliliği nedeniyle, antrenman sonuçlarını iyileştirmek için yükleme kalıpları son yıllarda daha fazla ilgi görmüştür. Buna göre, bu çalışmanın amacı, çift

piramit (DP) ve ters adım (RS) sistemleri ile yapılan 8 haftalık direnç antrenmanının elit bayan hentbolcuların bazı fiziksel uygunluk bileşenleri üzerindeki etkisini değerlendirmektir. Otuz genç bayan hentbolcu DP (yaş: 17.43±1.63 yıl, ağırlık: 70.28±10.14 kg, yağ yüzdesi: 15.60±1.17), RS (yaş: 17.13±1.32 yıl, ağırlık: 67.80±) olmak üzere üç gruba rastgele atanmıştır. 7,78 kg, yağ yüzdesi: 15,40±1,69) ve kontrol grupları (yaş: 17,33±1,71 yıl, ağırlık: 61,04±6,61 kg, yağ yüzdesi: 16,50±1,43). Antrenman programları, DP veya RS yükleme paterni ile sekiz haftalık, haftada 3 seans olarak uygulandı. Antrenman öncesi ve sonrasında yağ yüzdesi, anaerobik güç (RAST), çeviklik (Illinois), Sürat (45 metre sprint), kuvvet (1RM) ve kas dayanıklılığı (%60 1RM) ölçümleri alınır. Antrenman periyodundan sonra DP ve RS gruplarının ortalama güç, üst ve alt vücut kas dayanıklılığı, yağ yüzdesi, çeviklik ve hız üzerinde anlamlı etkileri vardı ($p<0.05$). Ayrıca, DP, üst vücut gücünde RS gruplarına göre önemli ölçüde daha fazla gelişme gösterirken, RS, alt vücut gücünde DP gruplarına göre önemli ölçüde daha fazla gelişme gösterdi ($p<0.05$). Ayrıca, DP ve RS gruplarının karşılaştırılması, iki grup arasında alt ve üst vücut kas dayanıklılığında anlamlı bir farklılık gösterdi ($P <0.05$); Antrenman grupları arasında anaerobik güç, üst ve alt vücut kuvveti, yağ yüzdesi, hız ve çeviklik testlerinde anlamlı bir fark bulunmadı. DP direnç eğitiminin anaerobik gücü, üst vücut gücünü ve hızı iyileştirmede daha fazla etkiye sahip olduğu görülmektedir. RS olanlar ise bayan hentbolcuların alt vücut kuvvetini, kas dayanıklılığını, çevikliğini ve yağ yüzdesini arttırmada daha fazla etki göstermiştir. Bu nedenle, DP ve RS direnç antrenmanlarının elit bayan hentbolcular arasında fiziksel uygunluk faktörleri üzerinde olumlu etkileri vardır.

**Anahtar Kelimeler:** Direnç antrenmanı, çift piramit, ters adım, yükleme modeli, fiziksel uygunluk.

## INTRODUCTION

Handball is a power-speed field and one of the most beautiful sports, which has been one of the Olympic Games since the 1972 Olympics. The player's initial acceleration, jumping, and the agility to change direction, start, and stop quickly are all crucial elements of fast play (12). It requires a combination of aerobic power and anaerobic capacity that will allow the frequent repetition of short-duration high-intensity actions, interspersed with brief recovery intervals (10) Therefore, the physiological needs of this sport include aerobic fitness, strength and power, agility, and speed (20). One of the most important needs of handball is power and strength, as well as the speed of throwing, and the reason for the beauty and excitement of playing handball is due to the existence of these movements, which are performed consecutively and repeatedly during the game. One type of exercise that improves these needs is resistance training. Resistance training has been used to perform skills effectively and to endure fatigue, reduce injury, improve motor function, improve jumping, speed, muscle endurance (11), and anaerobic power (20). However, in resistance training, a combination of variables such as type of muscle activity (introverted and extroverted), training volume (number of turns and repetitions of movements) and intensity of training, type of movement selected and muscle groups involved in training, movement sequence performed, rest intervals between turns and movements, repetition speed, training frequency, range of motion and energy system involved (19 – 22,25). In addition to the above, the effectiveness of training to increase strength, muscle endurance, power, and etc. depends on the type of training system (loading pattern) used in weight training (8). Although there are different systems for weight training, the use of each of them depends on the goal and the instructor's belief in that training system. For example, some coaches believe that using different loads instead of fixed loads leads to better results. Because it is believed that using constant loads in each training session causes the desired load and tension to be applied to the muscle, but it may prevent effective training stimulation due to the use of low repetitions in each turn, limited training volume, and muscle tension time by reducing stimuli such as fatigue (23). The use of different loads, in addition to following the principle of diversity, seems to increase the volume of exercise, causing the production of various metabolites such as lactate, potassium, free phosphate and creatine, which are the factors that stimulate greater adaptation (26, 27). Therefore, in the present study, two different and common loading patterns in promoting muscle capabilities, namely RS pattern and DP pattern, were examined. In the RS pattern, the load is reduced from step to step. But the DP pattern consists of two pyramids, one of which is inverted on top of the other pyramid; as the number of repetitions decreases from the bottom to the top of the pyramid, it then increases again in the second pyramid (6). First, this training system was proposed to increase strength. Because it was believed that a training load of 80 to 85% in the final cycles would cause the application of force to occur faster and this would improve strength. However, when the final cycles are performed, the central nervous system and the muscles involved may reach the point of exhaustion,

in which case these cycles will not bring the anticipated benefits (3); fatigue in the rapidly contracting fibers will increase muscle volume instead of increasing strength (5). Now, considering that handball is a sport in the form of endurance in power, endurance in speed, endurance in jumping, etc., and since it seems that these two training methods increase strength (one of the factors of improving power performance) and muscular endurance, the present study intended to compare the effect of two DP and RS loading patterns on anaerobic power, strength, muscle endurance, body composition, agility and speed of young female handball players.

## METHOD

Participants. The present study was quasi-experimental with pre-test and post-test design in three experimental groups. The subjects of this study were 30 female handball players of Qazvin city who were randomly divided into three groups: DP (n=10), RS (n=10), and control group (n=10) (Table 1). The sample size was determined by the G power (Ver. 3. 1. 9. 2) software package to be 30 specified for ANOVA at the error level of $\alpha = 0.05$, effect size f= 0.25, and $\beta = 0.80$, but it was increased to 30 individuals to have the same number of subjects in each group(24). These individuals had at least four years of membership in handball teams at Iranian club League 1 level, and voluntarily participated in this study. All subjects were aware of the risks and benefits of participating in this study and signed the consent form before starting the study and all experimental protocols were approved by University of Zanjan Ethics Committee, all methods were carried out in accordance with relevant guidelines and regulations (IR.ZNU.REC.1401.007). Figure 1 presents a depiction of the recruitment and randomization process.

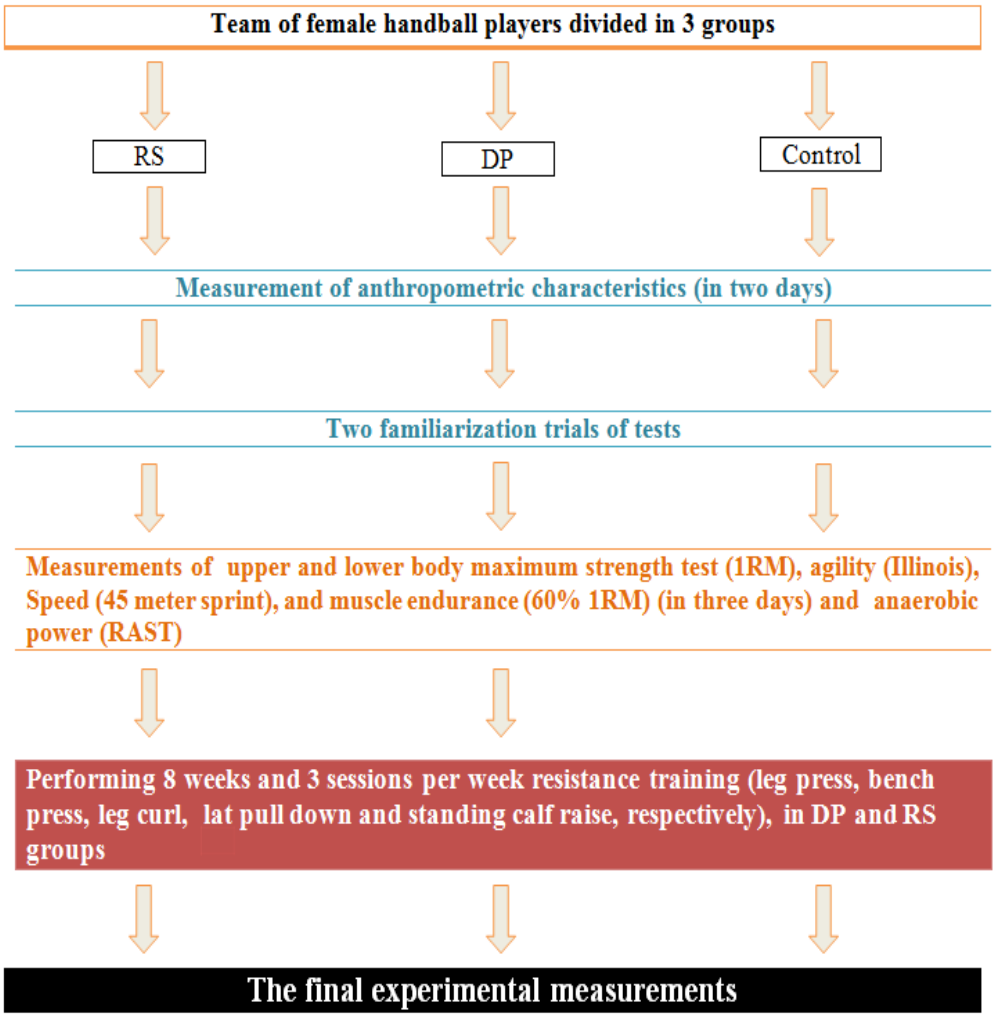


**Figure 1.**The diagram includes detailed information on the interventions received.

**Table 1.** Characteristics of the participants in the three groups of control (n = 10), DP (n = 10), and RS (n=10)

| Indices | RS group | DP group | Control group |
|---|---|---|---|
| Age (year) | 17.13±1.32 | 17.43±1.63 | 17.33±1.71 |
| Weight (kg) | 67.80±7.78 | 70.28±10.14 | 61.04±6.61 |
| Height (cm) | 169.64±5.11 | 169.54±5.93 | 169.33±3.12 |
| Body mass index (kg/m²) | 23.32±1.83 | 24.51±3.36 | 21.84±2.52 |
| Body fat (%) | 15.40±1.69 | 15.60±1.17 | 16.50±1.43 |

Study Design—Testing Procedures. After dividing the subjects into different groups, weight, height, triangular subcutaneous fat (suprailiac, triceps and thigh) and limb circumference were measured and recorded in two consecutive days. Then, within 3 days, the measurements related to the upper and lower body maximum strength test (1RM) and 60% of the maximum strength, Illinois test, RAST and 45-meter speed were recorded. Weight (with the CAMRY scale EB9003 with an accuracy of 0.1 kg), height (in centimeters), and the percentage of three-point fat (Lafayette skinfold caliper) were measured by observing all conditions and using the Jackson and Pollack equation (below) (1). Also, to determine the body mass index, the values of weight and height of the subjects were placed in the following formula (14) and body mass index was calculated in kilograms per square meter:

Density = 1.10938 - (0.0008267 × SSF)

+ (0.0000016 × SSF) – (0.0002574 × Age)

SSF = Total subcutaneous fat at three points (suprailiac, triceps and thigh)

Percentage of fat = [4.95 ÷ body density - 4.5] × 100

Body Mass Index (BMI) = Weight (kg) ÷ Height raised to the power of 2 (square meters)

**Dynamic strength and endurance tests**

All subjects participated in a two-session explanatory training program prior to the measurements to get familiar with the training equipment and learn the correct movement techniques. The maximum strength of the subjects was measured using the 1RM test by McGuigan method (14); thus, before the test and after general warm-up, 5 repetitions with 30% (2 minutes rest), 4 repetitions with 50% (2 minutes rest), 3 repetitions with 70% (3 minutes rest), and 1 repetition with 90% (3 minutes rest) were performed to warm up. After performing the last turn with 90% of 1RM, the load was added in the next rounds with the feedback of the subjects based on the amount of weight shifted to obtain 1RM (2.5 to 10 kg after each successful attempt). To obtain 1RM, after determining 90% of 1RM, three test steps were performed and 4 minutes rest was considered between each attempt.

After determining the subjects' 1RM, 60% of their 1RM in each movement was calculated individually and they were asked to perform the maximum repetition with that calculated weight (60% of 1RM). The number of repetitions performed was considered as local muscle endurance.

**Anaerobic power measurement (RAST)**

RAST test was used to measure anaerobic power with lactic acid. In this test, the subjects had a complete rest for 3 minutes before the test. To perform this test, the player performed a distance of 35 meters 6 times with a 10-second break between repetitions, and then according to the time obtained from each 35 meters, the power of each repetition was obtained according to the following formula (2).

Power = [weight × (distance)2 / (time)3]

Fatigue index = maximum power – minimum power / (total time of six repetitions)

**Speed test**

After familiarization, subjects performed a maximal, linear 45-m sprint after a 25-min profound, individual warm-up on an outdoor tartan surface. The subject had to repeat the sprint test twice with at least 4 min of recovery between tests. subjects were encouraged to complete the sprints as fast as they could. Consistent verbal support was given to the players during each sprint. The test was performed from an

individually chosen standing position with the subjects front foot one meter behind the start line. Players were instructed to adopt a forward lean and start voluntarily. Test scores were recorded by recording the test run time in seconds and tenths of a second from start to finish (using a Citizen stopwatch) (13).

**Agility test**

Illinois test was used to measure agility. This test was performed in a space of 10 by 5 meters and 8 cones and a stopwatch were used to perform it. The distance of the cones from each other (4 cones in the middle of the ground) was set at 3 meters and 30 centimeters. The athlete first lay on the ground facing forward (head towards the starting point) and, as instructed by the coach, quickly got up from the starting point (start) and started running at maximum speed in the direction of movement shown in the following figure. After passing through the cones and passing the end point, the stopwatch was stopped and the elapsed time was recorded as the athlete's record (Figure 2) (21).

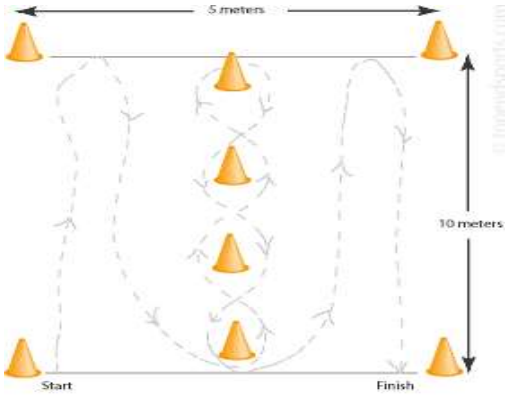


**Figure 2.** Details of the Illinois test (agility)

**Resistance training program**

After performing the initial measurements, the subjects were trained for 8 weeks using the two selected loading patterns. Two training protocols were designed for the subjects; the first group practiced using DP protocol (80% (4), 85%(3), 90%(2), 95%(1), 95%(1), 90%(2), 85%(3), 80%(4)), in which they did 4 repetitions the first time with 80% of 1RM, and after this stage the training load was increased progressively, i.e. 5% was added to the training load at each stage. After reaching one movement at a load of 95%, the load decreased and the number of repetitions increased to reach the initial stage rate of 80% with 4 repetitions. In total, each muscle was trained 8 times in the DP protocol (figure 3)(4).

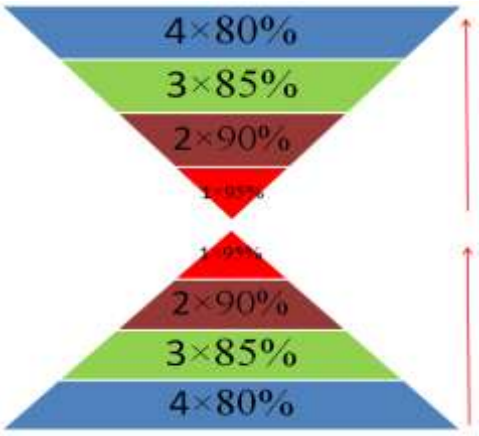


**Figure 3.** Dubble Pyramide Loading Pattern (DPLP)

The second group practiced using the RS protocol (90%(2), 75%(10), 60%(15), 90%(2), 75%(10), 60%(15)) in which after performing one turn with 90% of 1RM, and 2 repetitions in the next two turns, the repetition increased, but the load decreased. At the beginning of the fourth turn, the load increased again, so that it reached 90% of its value, i.e. 2 repetitions. The next two steps, as before, the load decreased and the repetitions increased (75% of 1RM with 10 repetitions and 60% of 1RM with 15 repetitions, respectively). After each exercise, the subject rested for 2.5 to 3 minutes (figure4) (1).

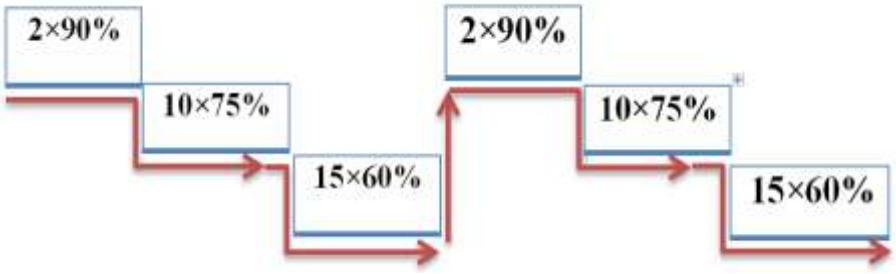


**Figure 4.** Reverse Step Loading Pattern (DPLP)

Subjects performed leg press, bench press, leg curl, lat pulldown and standing calf raise, respectively, for 8 weeks and 3 sessions per week; so that all the muscles active in these movements were trained in each session. In each training session, the researcher supervised the subjects and once every two weeks, the maximum strength or maximum repetition (1RM) test was taken from the subjects, and according to the amount of weight shifted, a new program was given to the subject to observe the principle of overload.

**Statistical analysis**

To compare the physiological changes after 8 weeks of resistance training between the three groups, one-way analysis of variance (ANOVA) and Bonferroni post-hoc test were used for pairwise comparison. Dependent t-test was also used for within-group comparison between pre-test and post-test stages. All data analysis was performed using SPSS software version 22. Significance level in this study was considered 0.05.

**RESULT**

The values for Paired Sample 't' test the control group showed that no significant difference was observed in any of the pre and post tests; while the values for Paired Sample't' test for the DP group showed a significant improvement in fatigue, anaerobic power, upper body strength, lower body muscle endurance, upper body muscle endurance, fat percentage, agility and speed ($P < 0.05$), while no significant difference was observed in any of the pre and post tests lower body strength. The values for Paired Sample't' test for the RS group indicated that this group had a significant improvement in anaerobic power, lower body strength, lower body muscle endurance, upper body muscle endurance, fat percentage, agility and speed. While no significant change was observed in fatigue and upper body strength indices. Paired comparison, obtained from one-way analysis of variance and Bonferroni post hoc test between DP and RS groups showed that after the training period, a significant difference was observed between lower body muscle endurance and upper muscle endurance of DP and RS groups, while there was no significant difference in indices of anaerobic power, upper and lower body strength, fat percentage, agility, and 45-m speed. The results of paired comparison of the DP and the control groups confirmed a significant difference in the indices of anaerobic power, upper body strength, fat percentage, agility and 45-m speed; while no significant difference was observed between the DP and the control groups in lower body strength, lower body muscle endurance and upper body muscle endurance. Also, based on the results of paired comparison between the RS and control groups, a significant difference was observed in lower body strength, upper body muscle endurance, lower body muscle endurance, fat percentage, agility and 45-m speed. While no significant difference was observed in upper body strength (Table 2 and Figure 5).

**Table 2.** Changes in physical fitness factors and limb circumference before and after double pyramid and reverse step resistance training among the three groups

| Group | DP group | | RS group | | Control group | |
|---|---|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test | Pre-test | Post-test |
| Lower body muscular endurance (reps) | 16.60±1.89 | 18.10±1.66* | 17.00±1.98 | 23.40±2.23*¥ | 16.70±1.15 | 16.80±1.31 |
| Upper body muscular endurance (reps) | 15.90±1.28 | 17.20±1.31* | 17.10±1.19 | 21.80±2.97*¥ | 16.50±1.17 | 16.70±1.05 |
| Upper body strength (kg) | 28.50±6.25 | 35.00±6.66* | 25.00±5.27 | 28.00±5.86 | 28.00±5.86 | 27.00±6.74 |
| Lower body strength (kg) | 102.00±8.56 | 104.00±10.48 | 96.30±3.19 | 102.50±4.08 | 103.00±8.88 | 103.50±8.18 |
| 45-m speed (s) | 8.10±0.61 | 7.63±0.52* | 7.93±0.03 | 7.11±0.62* | 7.58±0.64 | 7.85±0.54 |
| Agility (s) | 19.56±0.85 | 19.05±0.84* | 19.80±1.01 | 19.01±0.94* | 19.51±1.19 | 19.16±1.05 |
| Fatigue index (watts per second) | 6.40±1.26 | 5.27±1.43* | 5.28±1.01 | 5.07±1.23 | 5.06±1.54 | 5.88±1.48 |
| Average power (w) | 554.16±74.37 | 606.8±74.04* | 547.90±61.64 | 573.76±56.8* | 592.88±74.39 | 573.12±81.32 |

*: Significant difference between pre-test and post-test values (P<0.05)
¥: Significant difference between double pyramid and reverse step groups (P<0.05)
DP = Double Pyramid, RS= Reverse Step

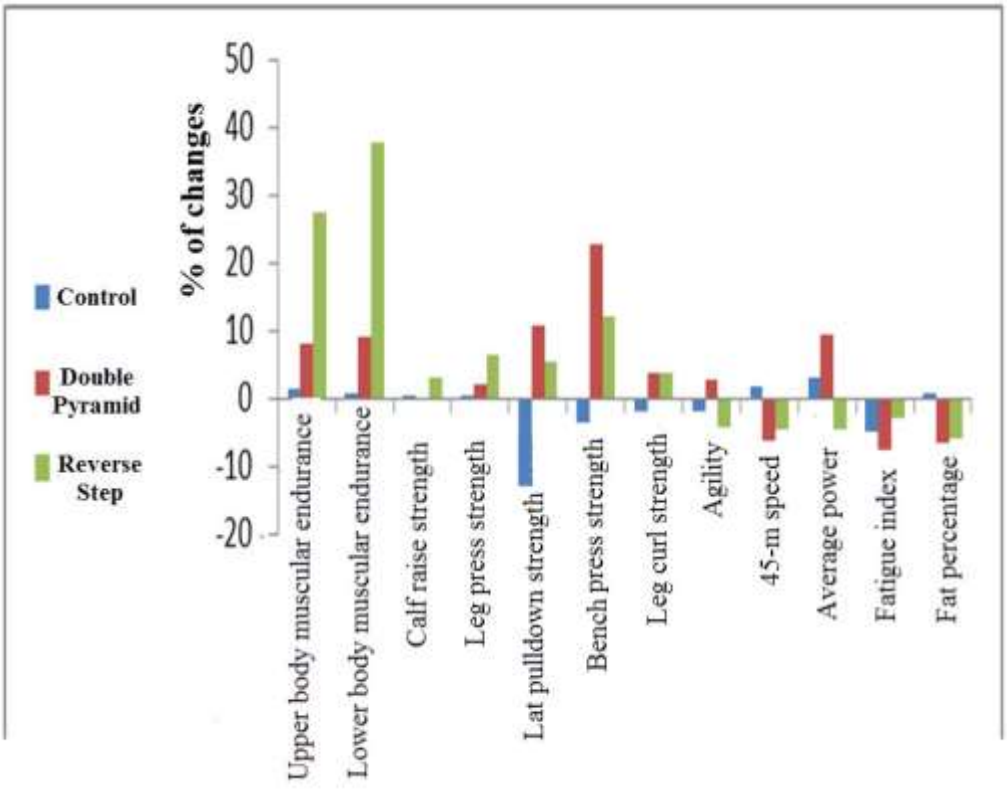


**Figure 5.** Percentage of changes in physical fitness factors among the three (control, DP and RS) groups.

## DISCUSSION

The main purpose of this study was to investigate the effect of two weight training loading patterns (DP and RS) on some physiological abilities of elite female handball players. The research findings indicated that the type of loading pattern used is an influential factor on the factors required for handball (strength, endurance and speed). Intra-group comparison of data showed that in the DP loading group, lower body muscular endurance in leg press movement (9.03%), chest press muscular endurance (8.17%), agility (2.67%) and mean anaerobic power (9.50%) improved significantly from before to after the test; while the intra-group comparison showed a significant decrease for fat percentage (6.73%), fatigue index (8.17%) and 45-m speed (6.15%). Intra-group comparison of RS loading pattern showed a significant decrease of average power (-4.71%), fat percentage (-5.84%), agility (-4.15%), and 45-m speed (-4.61%) from before to after the test. However, a significant improvement was observed in maximal lower body strength in leg press movement (6.43%), lower body muscular endurance (37.64%), and upper body muscular endurance (27.48%); no significant change was observed in the control group before and after the test. The results of the present study showed that both types of RS and DP loading pattern are effective on muscle endurance and have significantly increased the upper and lower endurance of young female handball players after eight weeks. The pairwise comparison of the groups was significant for lower body muscular endurance and upper body muscular endurance and showed that there was a significant difference in lower body muscular endurance index in control, DP, and RS groups; there was a significant difference in upper body muscular endurance index of DP and RS groups. Comparison between means showed that the RS loading pattern is more effective than other loading patterns. A comparison of RS and DP groups showed that the RS loading pattern would increase muscle endurance more than the DP loading pattern due to the high repetitions in 4 stages of this DP pattern. Because according to the theory of strength and endurance continuity, the higher the repetition with medium load, the better effect will have on muscle endurance (15). The results of the present study are consistent with the results of Hosseini et al. who used 8 weeks of resistance training with a DP pattern and RS on 22 wrestlers (14) and are inconsistent with the results of Weiss (28).

The results showed that the DP loading pattern improved the upper body strength and the RS loading pattern increased the lower body strength, which can be attributed to the fact that the lower body muscles have better muscular endurance than the upper body; therefore, a weakness of the step pattern that these exercises cause muscle fatigue and decrease muscle strength as they use maximum loads in first stages and decrease loads in the later stages (4), has less effect in the present study and this improves lower body strength. This is contrary to the results of Hosseini et al. on increasing the strength of the upper body with a step loading pattern (14), which can be attributed to the difference in the type of exercise of the subjects (handball versus wrestling); because wrestling athletes have good upper body muscular endurance, and this has led to the RS pattern resist against fatigue and consequently involve more movement units as well as larger movement units (according to the size principle), which improves upper body strength. More increase of upper body muscles in the DP pattern compared to RS and inconsistency of these results with Hosseini et al. may be due to less strength of upper body muscles of female handball players. While most wrestlers have good lower body strength, this is why, according to the principle of first size, female handball players with less upper body strength are more improved. As expected from the DP pattern (due to the use of high training loads), it has improved strength. Probably because most wrestlers have high body strength, the DP scheme has not been able to increase their strength. Other possible reasons for the difference in increase in upper and lower body muscle strength can be the use of smaller upper body muscle mass than the lower body (22). Comparison of the RS group and control group showed a significant increase in strength in the RS group, which may be due to this reason. In the RS loading pattern, maximum weights are used in the first periods of training, which causes muscle overcompensation and stimulates the increase of strength by calling more movement units (9). Studies also show that when the athlete is tired, more movement units are used, so the continuation of the muscle activity of these stimuli increases strength, which is true in the DP and RS loading pattern (26).

The results of the present study showed that both types of loading patterns had a significant effect on agility and speed index. A two-by-two comparison of the DP and RS groups with the control group at 45-m speed and agility test was significant. These results are consistent with the significance of the maximum strength of the leg muscles and are consistent with the results of Hosseini et al. However, Johns et al. showed that high-speed high-intensity training with moderate load was more effective than speed training with low-

speed training (16). This is inconsistent with the results of the present study, because the RS has a better average in speed and agility.

The results of the present study showed that the resistance training program with a DP and RS loading patterns had an effect on the average power and as a result, a significant increase was observed after eight weeks of training. A pairwise comparison between the groups showed that there was a significant difference in the average power only between the DP group and the control group, which is in line with the results of Kotzamanidis et al., who effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players (18) and inconsistent with the results of Hosseini et al., which may be due to the different levels of readiness of athletes.

Another finding of the present study showed that both types of DP and RS loading patterns had a significant effect on body composition and reduced the percentage of subcutaneous fat. Comparison of the means indicated that RS group exercises were more effective on the fat percentage of young handball players, which may be due to the endurance nature of the RS model to the DP. The results of this study are consistent with Faramarzi and Kargarfard (7, 17) and are inconsistent with Hosseini's results, which may be due to the gender difference and difference of athletes' fields. The results are inconsistent with the results of Hermassi who used eight weeks of heavy resistance training for male handball players (13), which can be attributed to the intensity and different patterns of weight training, as well as the different genders of the subjects.

## CONCLUSION

The results of this research showed that, in general, resistance training is effective in improving the anaerobic power of young elite female handball players. But, when comparing the DP and the RS pattern and normal handball exercises, the DP pattern is more effective than the RS pattern. Considering this issue, handball coaches can use resistance exercises, especially DP resistance exercises, in order to improve the explosive performance of handball players. Also, both patterns are effective for improving speed and agility. In addition, it seems that using the DP pattern is more effective for improving upper body strength, and the RS pattern is more effective for improving lower body strength, lower body muscular endurance, agility, and reducing body fat percentage.

### Acknowledgement

We sincerely thank and appreciate the cooperation of all the athletes who helped us with their effective participation in this study.

### Conflict of Interest

There is no any conflict of interests among the authors.

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