The effect of exercise order incorporating plyometric and resistance training on isokinetic leg strength and vertical jump performance: A comparative study

Article *in* Isokinetics and Exercise Science · August 2013

DOI: 10.3233/IES-130509

5 authors, including:

Uğur Dündar
Pamukkale University

Yusuf Köklü
Pamukkale University

Isokinetics and Exercise Science 21 (2013) 211–217
DOI 10.3233/IES-130509
IOS Press

The effect of exercise order incorporating plyometric and resistance training on isokinetic leg strength and vertical jump performance: A comparative study

Utku Alemdaroğlu[a,*], Uğur Dündar[a], Yusuf Köklü[a], Alper Aşci[b] and Gülin Findikoğlu[c]
[a]*School of Sport Sciences and Technology, Pamukkale University, Denizli, Turkey*
[b]*School of Sport Sciences and Technology, Hacettepe University, Ankara, Turkey*
[c]*Physical Therapy and Rehabilitation, Pamukkale University, Denizli, Turkey*

Abstract.
OBJECTIVE: To compare the order effect of a combination of plyometric and resistance training sessions on isokinetic leg strength and vertical jump performance in undergraduate students over the course of a 6-week training program.
METHODS: Twenty-four undergraduate volunteers were randomly divided into 3 groups, each group consisting of 3 female and 5 male students. The first group performed traditional combination training (TC; $n = 8$) involving plyometric training exercises at the beginning of a workout session before resistance exercises; the second group performed contrast training (CT; $n = 8$) involving alternating resistance exercises with plyometric training from set to set; the third group performed complex training (CP; $n = 8$), another form of combination training that involves the planning of several sets of resistance training repetitions, followed by plyometric exercises [16]. All groups completed a similar volume and intensity of training.
RESULTS: While all programs produced gains in vertical jump performance ($p < 0.01$) and isokinetic leg strength ($p < 0.01$, $p < 0.05$) except for quadriceps 60°/s for both legs in both genders, no between group differences were observed for any performance value.
CONCLUSIONS: The use of plyometric and resistance training within the same training session can be used interchangeably, irrespective of exercise order and gender.

Keywords: Power, plyometric training, resistance training, isokinetic leg strength, vertical jump

1. Introduction

Power is one of the most important components of physical fitness, which is the key component for optimum performance in sport that require explosive action [1,2,8,21]. For this reason, there is keen interest among researchers and sport conditioning coaches in optimal training techniques to maximize power and the transfer of power to athletic performance [8]. Coaches have used traditional weight training and plyometric exercises incorporating acceleration and deceleration of body weight and dynamic weight in order to develop power [8]. Combination training has been a popular training method, which has been used by coaches for developing power. It consists of coupling of a strength training exercise with a biomechanically similar plyometric exercise termed a complex pair [6,8,9,23].

The order of exercises within this kind of training

*Corresponding author: Utku Alemdaroğlu, School of Sport Sciences and Technology, Pamukkale University, Kinikli Kampusu, Denizli, Turkey. E-mail: utkualemdaroglu@yahoo.com.

regimen may be an important factor when establishing a resistance and power training program [10]. Traditional combination training involves power training exercises followed by resistance exercises [10,17]. Complex training involves starting a workout session with several sets of resistance training repetitions before moving on to plyometric exercises [10,17]. Finally, contrast training, refers to a workout that involves the use of exercises of contrasting loads, that is, alternating resistance and plyometric exercises set for set [17]. Most studies that have explored the effects of combining resistance and power training have examined acute responses. Training studies have also been conducted to examine and compare the effectiveness of different combination training regimes. For example, Burger et al. [5] compared the effects of two different combination training with different order of exercises on vertical jump performance. The results of this study showed that only the complex training group increased vertical jump performance. In another training study, Juarez et al. [18] compared the effects of a complex training program and a conventional training program on power and strength development in students. This study found that subjects in the complex training group showed improvement in the counter movement jump and 10 m, 15 m and 20 m run performance, whereas conventional training group subjects achieved performance gains in the 5 m run [18]. Similarly, Mathew et al. [20] reported a finding that complex training is more effective than conventional training methods for improving linear power. In another training study, Giannakopoulos et al. [15] examined isolated exercises and complex exercises in improving shoulder cuff muscular performance. The results indicated that the complex group significantly improved their muscular performance while the isolated group did not.

According to the literature, using resistance and plyometric exercises together is therefore more effective for improving power and strength than traditional training regimes. However, no study has so far reported data relating to isokinetic strength. Moreover, there is no research examining and comparing the chronic effects of the ordering of resistance exercises and plyometrics. It is thought that determining the effects of such ordering may help to inform trainers who use these exercise regimes as to how they might adapt the order of exercises and bring more variety to training sessions. Therefore, the aim of this study was to explore the effects of three different training modes on isokinetic leg strength and vertical jump performance in university students.

2. Methods

2.1. Subjects

Twenty-four recreationally trained undergraduate students participated in this study voluntarily. The subjects were randomly divided into 3 groups (each group consisting of 3 female and 5 male students); TC ($n = 8$; age: 21.6 ± 2.3 years; height: 172.3 ± 9.0 cm; body mass: 67.8 ± 13.1 kg), CT ($n = 8$; age: 21.9 ± 2.6 years; height: 173.5 ± 8.8 cm; body mass: 69.0 ± 14.7 kg), CP ($n = 8$; age: 21.3 ± 2.1 years; height: 173.2 ± 7.0 cm; body mass: 68.6 ± 13.7 kg). All subjects had experience of resistance training and plyometric training. Subjects were informed about possible risks and benefits of the study and gave informed consent to participate in this study.

2.2. Procedures

The duration of study was 10 weeks. The 2-week pre-study training period served as an adaptation period to weights and plyometric exercises for the subjects all of whom performed a 2-week adaptation resistance and plyometric training regime including 4 strength training sessions and 2 plyometric training sessions. The selected adaptation training exercise load was 65% of 1RM and in each exercise, 3 series of 10 repetitions were carried out in resistance training. Plyometric training consisting of 3 exercises with 2 series of 6 repetitions. After the adaptation training period, anthropometric measurements (height and body mass) were carried out for all of the subjects, followed by the vertical jump test, isokinetic test and 1RM test (leg curl, split squat and leg press) in order to determine the training workload. After the pre-test period, subjects were divided into the 3 experimental groups to undertake their 6-week program of TC, CT or CP training. The subjects participated in 2 training sessions per week. During the program they were not involved in any other physical activity. For each session, they performed a thorough warm-up consisting of 10 minutes of jogging and then 5 minutes of exercise involving fast leg movement (e.g. skipping, carioca) over short distances of 5 to 10 m (3–5 times) with 2-min passive recovery time. Subjects then performed resistance exercises (split squats, leg presses and leg curls) according to the protocol set out in Table 1 and plyometric exercises (split jumps, squat jumps and front tuck jumps) according to the protocol presented in Table 2. The procedure was applied in line with Fletcher et al. [14].

Table 1
Resistance training protocol

Week		Training day 1	Training day 2	% of 1RM
1	Adaptation training	3 × 10	3 × 10	65
2	Adaptation training	3 × 10	3 × 10	65
3	Pre-test			
4		3 × 6	3 × 6	85
5		3 × 6	3 × 6	85
6		3 × 6	3 × 6	87.5
7		3 × 6	3 × 6	87.5
8		3 × 6	3 × 6	90
9		3 × 6	3 × 6	90
10	Post-test			

Table 2
Plyometric training protocol

Week		Training day 1	Training day 2
1	Adaptation training	2 × 6	2 × 6
2	Adaptation training	2 × 6	2 × 6
3	Pre-test		
4		3 × 8	3 × 8
5		3 × 8	3 × 8
6		3 × 10	3 × 10
7		3 × 10	3 × 10
8		3 × 12	3 × 12
9		3 × 12	3 × 12
10	Post-test		

2.3. Isokinetic leg strength

Before the isokinetic test, subjects performed a 5-minute warm-up on a bicycle ergometer. Measurements were taken using an Isomed 2000 (Ferstl GmbH, Germany) isokinetic dynamometer. The test was performed in a sitting position; stabilization straps were secured across the trunk, waist, and distal femur of the tested leg. The extensor and flexor muscle of each leg were concentrically measured at 60°/s (10 repetitions) and 180°/s (10 repetitions). Verbal encouragement was given to the subjects during the measurement procedure. Before the test, the subjects were allowed 5 trials.

2.4. Vertical jump measurements

Vertical jump performance was measured using a portable force platform (Newtest, Finland). Subjects performed countermovement jumps (CMJ) and squat jumps (SJ) according to the protocol described by Bosco et al. [3] Before testing, subjects performed self-administered submaximal CMJs and SJs (2–3 repetitions) as a practice and specific additional warm-up. They were asked to keep their hands on their hips to prevent any influence of arm movements on the vertical jumps and to avoid coordination as a confounding variable in the assessment of the leg extensors [4]. Each subject performed 3 maximal CMJs and SJs, with approximately 2 minutes' recovery time in between; they were asked to jump as high as possible. The highest jump was recorded in centimeters [4].

2.5. Training interventions

The present study consisted of three training interventions (see Table 3). To equate the total amount of work for each of the training sessions, a thorough calculation was carried out. Definitions of training regimes were taken from Janz et al. [17].

1. Traditional combination training (TC): the TC group performed traditional combination training, *involving power training exercises at the beginning of a workout session followed by resistance exercises [10].* This group performed three resistance exercises 5 minutes after three plyometric exercises. Both the plyometric exercises and the resistance exercises were performed with 1-min rests between sets and 2-min rests between exercises [17].
2. Contrast training (CT): the CT group performed contrast training, alternating resistance exercises with power training from set to set [10]. This training mode included the following pairs of exercises: split squats – split jumps; leg presses – squat jumps; leg curls – front tuck jumps. While 1-min rest interval was used between exercise pairs, 2-min was given when passing to the next exercise group [17].
3. Complex training (CP): the CP group performed complex training which *consisted of planning of several sets of resistance training repetitions followed by power exercises [10,26].* The same pairs of exercises used in contrast training were also used in this training mode. The subjects in this group performed the plyometric exercises after finishing the resistance pair sets. 2 minute rest intervals were given both between pairs and between exercises, and 1 minute rests were granted between sets for each individual exercise [17].

2.6. Statistical analysis

All data are reported as means and standard deviations. Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk test. A three-way mixed analysis of variance was used to examine the statistical significance between and within the group and time measures, as well as between genders, for isokinetic strength and for vertical jump per-

Table 3
Training protocol

Training groups	Exercise 1	Exercise 2	Exercise 3	Exercise 4	Exercise 5	Exercise 6
TC	Front tuck jumps (P)	Split jumps (P)	Squat jumps (P)	Leg curl (R)	Split squat (R)	Leg press (R)
CT*	Front tuck jumps (P)	Leg curl (R)	Split jumps (P)	Split squat (R)	Squat jumps (P)	Leg press (R)
CP#	Leg curl (R)	Front tuck jumps (P)	Split squat (R)	Squat jumps (P)	Leg press (R)	Squat jumps (P)

TC: Traditional combination training; CT: Contrast training; CP: Complex training; P: Plyometric exercise; R: Resistance exercise; *CT group performed one set Leg Curl and after then one set front tuck jumps. When the finished three sets, subjects pass the next pair (Split squat and split jumps); #CP group performed the plyometric exercises after finishing the resistance pair sets (Three sets leg curl after then three sets front tuck jumps).

Table 4
Changes in isokinetic strength and jump performance between pre- and post-test for female

	TC			CT			CP		
	Pre-test	Post-test	%	Pre-test	Post-test	%	Pre-test	Post-test	%
Hamstring right 60°/s (Nm)	118.0 ± 20.4	136.6 ± 15.2**	15.8	115.6 ± 19.1	123.3 ± 20.5**	6.7	114.6 ± 9.8	123.0 ± 22.6**	7.3
Hamstring left 60°/s (Nm)	95.3 ± 16.1	111.3 ± 8.3**	16.8	94.33 ± 11.0	119.0 ± 13.2**	26.2	103.6 ± 4.1	110.6 ± 12.5**	6.8
Quadriceps right 60°/s (Nm)	122.0 ± 36.0	122.6 ± 28.0	0.5	127.3 ± 35.6	136.3 ± 43.8	7.1	152.3 ± 23.4	157.0 ± 19.9	3.5
Quadriceps left 60°/s (Nm)	116.0 ± 18.3	125.6 ± 33.8	8.3	127.3 ± 22.5	133.3 ± 22.2	4.7	154.0 ± 18.6	162.0 ± 14.0	5.2
Hamstring right 180/s (Nm)	85.6 ± 13.6	90.0 ± 9.0**	5.1	93.6 ± 19.0	95.6 ± 13.4**	2.1	89.6 ± 7.5	101.6 ± 10.7**	13.4
Hamstring left 180/s (Nm)	78.0 ± 24.0	80.3 ± 16.2**	2.9	88.6 ± 20.1	92.0 ± 19.9**	3.8	84.0 ± 8.5	95.0 ± 19.0**	13.1
Quadriceps right 180°/s (Nm)	91.6 ± 18.5	94.0 ± 24.2*	2.6	112.3 ± 33.4	118.3 ± 31.8*	5.3	111.3 ± 21.3	123.6 ± 12.0*	11.1
Quadriceps left 180°/s (Nm)	92.3 ± 24.3	98.0 ± 26.8**	6.2	101.3 ± 34.6	113.6 ± 28.0**	12.1	112.6 ± 14.1	125.6 ± 4.9**	11.5
Squat jump	19.0 ± 1.7	24.6 ± 1.1**	29.5	21.0 ± 1.0	23.0 ± 3.0**	9.5	22.0 ± 4.3	23.0 ± 6.5**	4.5
Counter movement jump	21.3 ± 5.7	27.0 ± 3.0**	26.8	24.0 ± 1.7	27.3 ± 1.5**	13.8	22.6 ± 6.5	24.0 ± 6.0**	6.2

Data are presented as Means ± SD. The test was carried out using a isokinetic dynamometer. TC: Traditional combination training; CT: Contrast training; CP: Complex training. * Significant difference ($p < 0.05$) between pre- and post-test within group. ** Significant difference ($p < 0.01$) between pre- and post-test within group.

Table 5
Changes in isokinetic strength and jump performance between pre- and post-test for male

	TC			CT			CP		
	Pre-test	Post-test	%	Pre-test	Post-test	%	Pre-test	Post-test	%
Hamstring right 60°/s (Nm)	164.0 ± 23.7	174.5 ± 25.9**	6.4	160.4 ± 33.5	164.9 ± 23.9**	2.8	159.8 ± 25.7	169.0 ± 20.1**	5.8
Hamstring left 60°/s (Nm)	156.0 ± 42.0	167.9 ± 28.3**	7.6	147.6 ± 29.0	167.2 ± 27.2**	13.3	154.6 ± 30.0	176.0 ± 17.3**	13.8
Quadriceps right 60°/s (Nm)	200.0 ± 40.0	207.9 ± 46.0	4.0	213.9 ± 30.4	222.1 ± 39.5	3.8	175.1 ± 29.5	178.6 ± 26.7	2.0
Quadriceps left 60°/s (Nm)	192. ± 35.4	204.3 ± 42.8	6.4	254.3 ± 34.7	255.9 ± 36.1	0.6	173.4 ± 30.2	174.6 ± 29.6	0.7
Hamstring right 180/s (Nm)	148.7 ± 29.9	159.6 ± 40.5**	7.3	144.8 ± 33.4	172.6 ± 29.6**	19.2	148.6 ± 19.9	157.8 ± 29.3**	6.2
Hamstring left 180/s (Nm)	146.2 ± 31.9	147.6 ± 32.4**	1.0	141.0 ± 32.1	162.4 ± 28.4**	15.2	132.6 ± 17.6	155.4 ± 27.5**	17.2
Quadriceps right 180°/s (Nm)	176.3 ± 37.3	193.4 ± 36.4*	9.7	174.7 ± 38.8	188.9 ± 32.2*	8.1	169.1 ± 24.86	177.8 ± 29.6*	5.1
Quadriceps left 180°/s (Nm)	177.6 ± 26.8	181.0 ± 33.7**	1.9	186.3 ± 34.7	197.4 ± 36.0**	6.0	170.4 ± 27.3	172.4 ± 223.7**	1.2
Squat jump	36.0 ± 2.8	38.9 ± 3.7**	8.1	31.0 ± 3.1	34.0 ± 2.7**	9.7	38.5 ± 5.7	40.4 ± 6.7**	4.9
Counter movement jump	41.0 ± 4.9	44.4 ± 4.7**	8.3	35 ± 2.00	37.7 ± 1.9**	7.7	44.6 ± 4.8	48.4 ± 3.5*	8.5

Data are presented as Means ± SD. The test was carried out using a isokinetic dynamometer. TC: Traditional combination training; CT: Contrast training; CP: Complex training. * Significant difference ($p < 0.05$) between pre- and post-test within group. ** Significant difference ($p < 0.01$) between pre- and post-test within group.

formances. If a significant interaction effect was observed, then a Tukey's post hoc analysis was applied to make a pairwise comparison between groups. The level of statistical significance was set at $p < 0.05$.

3. Results

Tables 4 and 5 outline the changes in isokinetic strength and jump performance between pre- and post-test for both female and male in all the training groups. Isokinetic leg strength, squat and countermovement jump performances increased between pre- and post-test independently of the specific training regime and gender, but the changes in Quadriceps Right 60°/s (Nm) and Quadriceps Left 60°/s (Nm) were non-significant. Table 6 shows the effects of different resistance training methods on isokinetic leg strength. The strength increased between pre- and post-test in all the training groups, but the changes in Quadriceps Right 60°/s (Nm) and Quadriceps Left 60°/s (Nm) were non-

Table 6
Changes in isokinetic strength performance between pre- and post-test

	TC			CT			CP		
	Pre-test	Post-test	%	Pre-test	Post-test	%	Pre-test	Post-test	%
Hamstring right 60°/s (Nm)	141.0 ± 24.1	155.6 ± 23.1**	10.4	138.0 ± 33.5	144.1 ± 32.6**	4.4	137.2 ± 25.5	146.0 ± 25.1**	6.4
Hamstring left 60°/s (Nm)	125.7 ± 31.6	139.6 ± 26.3**	11.1	130.8 ± 35.4	133.3 ± 27.1**	1.9	129.1 ± 31.0	143.3 ± 25.3**	11.0
Quadriceps right 60°/s (Nm)	161.0 ± 40.9	165.3 ± 46.0	2.7	170.6 ± 33.4	179.7 ± 72.5	5.3	163.7 ± 38.5	167.8 ± 40.7	2.5
Quadriceps left 60°/s (Nm)	154.1 ± 35.4	165.0 ± 50.8	7.1	191.6 ± 52.1	193.8 ± 34.1	1.1	164.3 ± 43.6	167.7 ± 39.2	2.1
Hamstring right 180/s (Nm)	117.2 ± 32.2	124.8 ± 41.0**	6.5	121.2 ± 37.4	134.1 ± 39.6**	10.6	119.1 ± 22.8	129.7 ± 35.1**	8.9
Hamstring left 180/s (Nm)	112.1 ± 37.7	114.0 ± 39.4**	1.7	114.8 ± 34.1	127.2 ± 36.4**	10.8	108.3 ± 24.2	125.2 ± 38.5**	15.6
Quadriceps right 180°/s (Nm)	134.0 ± 42.3	143.7 ± 49.4*	7.2	143.5 ± 43.6	153.6 ± 41.9*	7.0	140.2 ± 33.86	150.7 ± 48.6*	7.5
Quadriceps left 180°/s (Nm)	135.0 ± 44.4	139.5 ± 48.7**	3.3	143.8 ± 40.3	155.5 ± 43.19**	8.1	142.5 ± 34.7	148.0 ± 39.5**	3.9
Squat jump	141.0 ± 24.1	155.6 ± 23.1**	10.4	138.0 ± 33.5	144.1 ± 32.6**	4.4	137.2 ± 25.5	146.0 ± 25.1**	6.4
Counter movement jump	125.7 ± 31.6	139.6 ± 26.3**	11.1	130.8 ± 35.4	133.3 ± 27.1**	1.9	129.1 ± 31.0	143.3 ± 25.3**	11.0

Data are presented as Means ± SD. The test was carried out using a isokinetic dynamometer. TC: Traditional combination training; CT: Contrast training; CP: Complex training. * Significant difference ($p < 0.05$) between pre- and post-test within group. ** Significant difference ($p < 0.01$) between pre- and post-test within group.

significant. Similarly, between- group differences were non-significant.

Figures 1 and 2 show the effects of the different resistance training methods on counter movement jump and squat jump performance, respectively. Counter movement jump and squat jump performance did not significantly diffe between groups and all the training groups significantly improved their performance in both of these areas ($p < 0.01$).

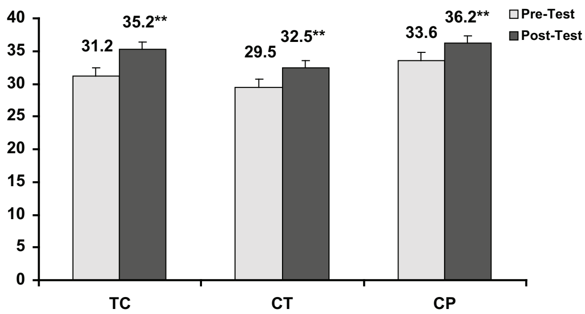

Fig. 1. Change in counter movement jump performance (cm) between pre- and post-test for each of the groups. TC: Traditional combination training; CT: Contrast training; CP: Complex training. Error bars: SD Significant difference between pre- and post-test: ** $p < 0.01$.

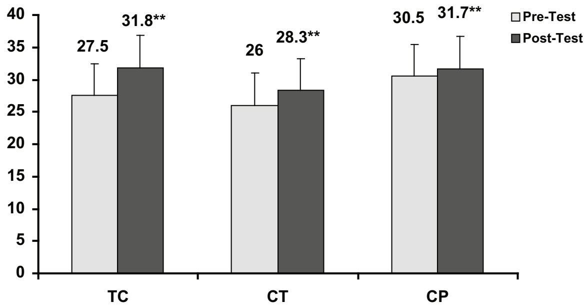

Fig. 2. Change in squat jump performance (cm) between pre- and post-test for each of the groups. TC: Traditional combination training; CT: Contrast training; CP: Complex training. Error bars: SD Significant difference between pre- and post-test: ** $p < 0.01$.

4. Discussion

The current study indicates that 6 weeks of traditional combination training, contrast training and complex training elicited enhancements in counter movement jump and squat jump performance as well as in for selected isokinetic strengths of the hamstring and quadriceps in both legs and in both genders. This points out to the training efficacy of all three training modes irrespective of group or gender. In spite of gender differences in fiber types make-up the uniform improvement is likely to result from neural changes [22] suggesting that these three programs can be used interchangeably in order to improve power and strength performance for both genders.

One of the most important findings of this study relates to the effects of plyometric and resistance training used within the same training session on both CMJ and SJ performance. Our findings suggest that the combination of plyometric and resistance training within the same training session can induce performance increases in SJ and CMJ independently of the order or gender of such exercises. This finding parallels that of Santos and Janeira [20], who reported that a 10-week in-season complex training program consisting of a set of resistance exercises followed by a series of plyometric exercises resulted in a significant improvement in counter movement jump and squat jump performance in young male athletes. Similarly, Alves et al. [1] analyzed the effects of complex training and contrast training on SJ and CMJ performance over six-weeks in male soccer players; they found an increase in SJ performance in both groups, but no significant differences in CMJ performance as well as no significant between- group differences for any of the tests. Juarez et al. [18] compared the effects of a complex training program and a conventional training program on CMJ and SJ performance in male sports science students. They reported that significant improvements were seen in both groups in terms of SJ performance, and also that a significant difference in CMJ performance was exclusive for the complex training group. There is only one study examining and comparing the chronic effects of the resistance exercises and plyometrics according to gender. In this study Mihalik et al. [22] found significant improvements in vertical jump height in 11 male and 20 female volleyball players divided into two groups, with one group following a complex training program and the other group following a compound training program consisting of resistance training in one session and plyometric training in the next. At the end of the study, neither group had improved more than the other. Additionally, they reported that these training methods effected both gender similarly. It was suggested that a plausible explanation for enhanced jump performance could be that *"complex training stimulates the neuromuscular system [7], that is, it activates both the muscular fibers and the nervous system, so that slow-twitch fibers behave like fast-twitch fibers [6]" [24].* On the other hand, it should be emphasized that several different factors may have beneficial effects on vertical jump performance, such as better synchronization of body segments, increased coordination levels, and a greater muscular strength/force [24]. In conclusion, the combination of plyometric and resistance training within the same training session seems to have promoted increases in SJ and CMJ performance independently of the order of the exercises and gender. It therefore seems advisable for coaches and sports scientists to use combination training, involving power training exercises combining strength training in the same training session [1] for both female and male [22].

Isokinetic dynamometry facilitates a dynamic, objective, accurate, and reproducible evaluation because of which it has been widely used in order to determine function and balance of players [25]. To our knowledge, the current study is the first to report changes in isokinetic strength following the combination of plyometric and resistance training. Furthermore, no study has so far reported data relating to difference in either isokinetic, or dynamic strength gains between genders following this kind of training. although a few studies have examined and compared the effects of different combinations of plyometric and resistance training on dynamic strength in male. One of these studies, Juarez et al. [18] evaluated the effects of a complex training program and a conventional training program on strength development in male students, concluding that both programs produced gains in the weight lifted in a 1RM back squat, although significant differences were not found between the training modes. In another study on weight lifted in 1RM back squats, Burger et al. [5] reported significant differences between a group which followed a 7-week complex training regime and another group which performed the same training exercises but did the weight exercises first and then the plyometric exercises. Our results suggest that the combination of plyometric and resistance training may promote increases in isokinetic strength in both genders. In addition, the improvements of leg strengths range between 1.1%–11.1% for all training groups in the present study. A plausible explanation for these findings could be due to the fact that the participants had little experience in strength training [13,18]. Moreover, it is highly unlikely that short-term studies would result in significant difference in strength improvement between any weight-training programs because neural factors may override the contribution of other factors in largely untrained people [13,18].

5. Conclusions

Isokinetic strength and vertical jump performance can be improved by a combination of resistance and plyometric training independently of the specific training regime and gender. The findings of this study demonstrate that all three training strategies may be suited for improving the power and strength of untrained male and female subjects. Thus the use of plyometric and resistance training within the same training session is recommended since these exercise types can be used in different orders and with similar efficiency in both genders.

References

[1] Alves JM, Rebelo AN, Abrantes C, Sampaio J. Short term effects of complex and contrast training in soccer players' ver-

tical jump, sprint, and agility abilities. J Strength Cond Res 2010; 24(4): 936-941.

[2] Bompa T. Power training for sport: Plyometrics for maximum power development (2.ed.), Gloucester, ON: Coaching Association of Canada, 1994.

[3] Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. Eur J Appl Physiol 1983; 50: 273-282.

[4] Bosco C, Belli A, Astrua M, Tihanyi J, Pozzo R, Kellis S et al. A dynamometer for evaluation of dynamic muscle work. Eur J Appl Physiol 1995; 70: 379-386.

[5] Burger T, Boyer-Kendrick T, Dolny D. Complex training compared to a combined weight training and plyometric training program. J Strength Cond Res 2000; 14: 360-361.

[6] Chu D. Explosive power and strength: Complex training for maximal results, Champaign, IL: Human Kinetics, 1996.

[7] Chu DA. Jumping into plyometrics (2nd ed.), Champaign, III: Human Kinetics, 1998.

[8] Docherty D, Robbins D, Hodgson M. Complex training revisited: a review of its current status as a viable training approach. Strength Cond 2004; 26(6): 52-57.

[9] Dodd DJ, Alvar BA. Analysis of acute explosive training modalities to improve lower-body power in baseball players, J Strength Cond Res 2007; 21(4): 1177-1182.

[10] Duthie GM, Young WB, Aitken DA. The acute effects of heavy loads on jump squat performance: An evaluation of the complex and contrast methods of power development. J Strength Cond Res 2002; 16(4): 530-538.

[11] Ebben WP, Watts PB. A review of combined weight training and plyometric training modes: complex training. Strength Cond 1998; 20: 18-27.

[12] Ebben WP. Complex training: A brief review. J Sports Sci Med 2002;1: 42-46.

[13] Fleck SJ. Periodized strength training: a critical review, J Strength Cond Res 1999; 13: 82-89.

[14] Fletcher IM, Hartwell M. Effect of an 8-week combined weights and plyometrics training program on golf drive performance. J Strength Cond Res 2004; 18(l): 59-62.

[15] Giannakopoulos K, Beneka A, Malliou P, Godolias G. Isolated versus complex exercise in strengthening the rotator cuff muscle group. J Strength Cond Res 2004; 18(2): 144-148.

[16] Güllich A, Schmidtbleicher D. MVC-induced short-term potentiation of explosive force. New Stud Athl 1996; 11(4): 67-81.

[17] Janz J, Dietz C. Malone M. Training explosiveness: Weightlifting and beyond. Strength Cond 2008; 30(6): 14-22.

[18] Juarez D, Gonzalez-Rave JM, Navarro F. Effects of complex vs non complex training programs on lower body maximum strength and power. Isokinet Exerc Sci 2009; 17: 233-241.

[19] Kotzamanidis C, Chatzopoulos D, Michailidis C, Papaiakovou G, Patikas D. The effect of combined high-intensity strength and speed training program on the running and jumping ability of soccer players. J Strength Cond Res 2005; 19: 369-375.

[20] Mathew JD, Chandrakumar M, Raju C, Rathinam S. Comparative study of complex training and conventional training in developing linear power among school children. J Exerc Sci Physiother 2006; 2: 71-78.

[21] Mayhew JL. Ware JS, Johns RA, Bemben MG. Changes in upper body power following heavy-resistance strength training in college men. Int J Sports Med 1997; 18(7): 516-520.

[22] Mihalik JP, Libby J, Battaglini CL, McMurray RG. Comparing short-term complex and compound training programs on vertical jump height and power output. J Strength Cond Res 2008; 22(1): 47-53.

[23] Robbins, DW, Docherty D. Effect of loading on enhancement of power performance over three consecutive trials. J Strength Cond Res 2005; 19(4): 898-902.

[24] Santos EJ, Janeira MA. Effects of complex training on explosive strength in adolescent male basketball players. J Strength Cond Res 2008; 22(3): 903-909.

[25] Siqueira CM, Pelegrini FR, Fontana MF, Greve JM. Isokinetic dynamometry of knee flexors and extensors: comparative study among non-athletes, jumper athletes and runner athletes. Rev Hosp Clin Fac Med S Paulo 2002; 57(1): 19-24.

[26] Smilios I, Pilianidis T, Sotiropoulos K, Antonakis M, Tokmakidis SP. Short term effects of selected exercise and load in contrast training on vertical jump performance. J Strength Cond Res 2005; 19: 135-139.