EFFECTS OF CONCURRENT EXERCISE PROTOCOLS ON STRENGTH, AEROBIC POWER, FLEXIBILITY AND BODY COMPOSITION

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Abstract:

In this study we evaluated the effect of concurrent resistance and endurance training on body composition, aerobic power and muscular endurance in college students and compared the two concurrent exercise protocols. Forty-two male students (22.02±1.91 years of age) were divided into three groups: Concurrent Distinct Endurance-Resistance (CDER), Concurrent Parallel Endurance-Resistance (CPER) and No Training controls (C). The subjects performed two training protocols per week for 12 weeks. In CDER group, resistance training and endurance training were performed on different days each week (two and two days per week). CPER group performed endurance and resistance training on the same days each week (two days per week). After a 12-week training period, fat-free mass, muscular strength [weight lifted in squat and bench press (kg)], muscular endurance [pull-ups and sit-ups (numbers)], aerobic power, flexibility and Sargent jump height increased similarly in both experimental groups (CDER and CPER). Also, decreases in body fat percentage, mean time in 60 m running and agility occurred in CDER and CPER. A significant difference in body fat percentage was seen in CPER when compared to CDER and C. Body mass increased significantly in CPER when compared to CDER and C. Although body mass increased only after the CPER protocol application, it can be concluded that both CDER and CPER protocols were similarly effective in positive transformation of body composition, aerobic power and muscular endurance.

Key words: *resistance training, endurance training, concurrent training, body mass,* VO_{2max}

Introduction

Some sports and sport events such as throwing events in track-and-field, are characterized by the demonstration of strength and high power outputs. In addition, many of the strength/power sports involve maximal efforts which must be repeated after relatively short rest periods (Tanaka & Swensen, 1998). Thus, some strength and conditioning professionals believe that the inclusion of aerobic endurance training may offer some benefits to strength/power athletes (Baechle, 1994). Additionally, it is well documented that strength/power athletes may perform endurance exercises in order to maintain an optimal body weight or to reduce body fat levels (Dudley & Fleck, 1987).

In the past two decades, concurrent resistance and endurance training programs have received much attention as a form of training. Several studies have shown that concurrent training (resistance and endurance training in the same session or program) interferes with the development of muscle strength or power (Chtara, et al., 2008; Nelson, Arnall, Loy, Silvester, & Conlee, 1990; Hennessy & Watson, 1994). On the other hand, some studies reported a compatibility of resistance and endurance training, and did not show any reduction in strength adaptations after concurrent strength and aerobic endurance training (Izquierdo, et al., 2004; Izquierdo, Hakkinen, Ibanez, Kraemer, & Gorostiaga, 2005; Glowacki, et al., 2004; Balabinis, Psarakis, Moukas, Vassiliou, & Behrakis, 2003). Furthermore, some studies demonstrate a positive effect of concurrent training on muscle strength (Gorostiaga, Izquierdo, Iturralde, Ruesta, & Ibanez, 1999; Davis, Wood, Andrews, ElkIind, & Davis, 2008a,b; Baker, 2001), muscular endurance (Hickson, Dvorak, Gorostiaga, Kurowski, & Forster, 1988; Kraemer, et al., 1995), maximal aerobic capacity (McCarthy, Agre, Graf, Pozniak, & Vailas, 1995; Kraemer, et al., 2001) and body composition (Garcia-Lopez, Galini, & Hamedinia, 2007; Rahnama, et al. 2007). While the mentioned studies have noted positive consequences of concurrent training, Glowacki et al. (2004) reported a small increase in aerobic power (maximal aerobic capacity) in untrained subjects after 12 weeks of concurrent resistance and endurance training with respect to endurance training exclusively. The authors also showed a significant increase in lean body mass in the resistance-trained groups and a significant decrease in body fat percentage in the endurance and concurrent training groups. However, VO_{2peak} increased only in the endurance group (Glowacki, et al., 2004). In addition, Gravelle and Blessing (2000) demonstrated that concurrent training is an effective method of improving aerobic power, maximal strength, and body composition and it does not interfere with maximal strength and aerobic power gains. Moreover, some studies investigated the effects of a concurrent training type with regard to whether it is performed on the same day (Dolezal & Potteiger, 1998; Craig, Lucas, Pohlman, & Stelling, 1991) or on the alternate days each week (Bell, Syrotuik, Martin, Burnham, & Quinney 2000; Glowacki, et al., 2004), but the results were controversial and less conclusive. However, the difference in training methods as the difference in concurrent training order may explain, in part, these discrepancies in previous studies' results. Therefore, the aim of the current study was to investigate the effect of two different methods of concurrent training (one training session including both types of exercise vs. each type of training implemented in separate sessions) on strength, body composition, aerobic power and flexibility in untrained individuals.

Methods

Participants

Forty-two healthy untrained male students volunteered to participate in the study. The subjects were randomly divided into Concurrent Distinct Endurance-Resistance (endurance training and resistance training performed on different days each week; CDER) (n=14, age: 21.24±1.50 years, height: 174±4.67 cm, body mass: 69.84±11.07 kg); Concurrent Parallel Endurance-Resistance (endurance training and resistance training performed on the same days each week; CPER) (n=14, age: 22.85±2.41 years, height: 177.7±7.43 cm, body mass: 70.31± 7.17 kg), and control C group (n=14, age: 21.7±1.5 years, height: 175.7±4.9 cm, body mass: 66.8±5.8 kg). Both CDER and CPER groups then participated in a 12-week experimental training program. Inclusion criteria for all the participants in this study were the following: they should have been physically active, but should have not done any resistance training for at least five months prior to the start of the study; they should not have performed any type of regular physical activity during the study other than the prescribed training and regular military physical activity program; they should not have had any functional limitations for the resistance training or 1RM tests; they should not have had any medical condition that could jeopardize the training program; and they should not have been using any nutritional supplementation. The experimental procedures were approved by the Ethics Committee of the Guilan University.

Measurements

One week prior to the experiment, the participants underwent a 1RM test for the six dynamic continuous exercises with external resistance (bench press, lat-machine pull-down, cable biceps curl, leg press, leg curl and leg extension). The 1RM testing protocol has been previously described elsewhere (Simão, Farinatti, Polito, Viveiros & Fleck, 2007). To minimize errors during 1RM testing, standardized instructions concerning the testing procedure were given to the participants before the test and they received standardized instructions on exercise technique performance. Also, verbal encouragement was provided during the testing procedure. The 1RM was determined in fewer than five attempts with a rest interval of five minutes between each 1RM attempt, whereas a 10-minute rest was allowed before the next exercise 1 RM test. To determine new 1RMs in different exercises, as training indicators, the 1RM testing was performed every two weeks.

Pre-training assessments included:

(1) *Body composition* (fat-free mass, body fat percentage and body mass). It was assessed using a body composition analyzer (3.0, Korea). Measurements were performed without accessories that contain metal (earrings, belts, coins). To ensure normal hydration status for body composition testing, participants were asked to adhere to the following pre-test requirements: (a) no vigorous exercise within 24 hours prior to the test and (b) no caffeine or alcohol consumption for 12 hours prior to the test.

(2) *Muscle endurance*. Shoulder muscular endurance was assessed by the pull-up test, and the sit-up test was used to assess abdominal muscular endurance.

(3) *Maximal aerobic capacity (VO_{2max})*. It was estimated using Fox protocol [heart rate response to five minutes of cycle ergometry at 150 W ($6300-19/26\ (HR_{5min}) = VO_{2max}$)] (Fox, 1973).

(4) *Lower-body flexibility (hamstrings and lower back)*. It was assessed using the sit-and-reach test (American College of Sports Medicine, 2000).

(5) *60-m sprint*. It was measured using a stopwatch (Citizen, RYP Sports, Inc.) by three timers. The subjects were instructed to run as fast as possi-

ble from the start-line to the finish-line on the track.

(6) *The Sargent jump height*. It was tested using jump-and-touch testing method. The Sargent jump height was determined by the difference between the subject's highest jump touch and the subject's standing reach.

(7) *Agility*. It was assessed as the shuttle-run test (25 yards) for each subject. Two lines 25 yards apart were traced and two blocks of wood behind one of the lines were placed. The participants were instructed to run from the start-line to the other line, pick up a block and return to place it behind the starting line, then return to pick up the second wood, and run with it back across the line.

Heart rate was controlled by a heart rate monitor and maximal heart rate (HR_{max}) was calculated from 220 – age equation (American College of Sports Medicine, 2000). All subjects were encouraged to adhere to their normal and similar dietary patterns throughout the study. Each subject trained at the same time of the day (late afternoon) to minimize variance associated with different starting times. Ambient temperature was between 21 and 25°C. All participants completed the study protocol. Generally, each item (except 1RM testing) was tested twice.

Training protocol

The CDER subjects trained four days per week – endurance exercises (two training sessions), and resistance exercises (other two training sessions). In contrast, CPER group trained two days per week (both the endurance and resistance exercises were performed in one training session consecutively).

Resistance training. Resistance exercises were performed in the following sequence during testing and training: bench press, lat-machine pull-down, cable biceps curl, leg press, leg curl and leg extension. During the experimental training period, intensity of training sessions was increased gradually by decrements in the number of repetitions and increments of loads (see Table1). In each session, the rest interval between sets and exercises was one minute and two to three minutes, respectively. The total volume of each session was calculated as *sets × repetitions × load* (Table 1).

Endurance training. Endurance training started with a 20-minute interval running using long and short distances at 70% of HR_{max}. During the training period, the physiological demands of training sessions were increased by prolonging work time and increasing HR_{max} (see Table 2). In other words, higher intensity interval running (e.g. 90-95% of HR_{max}) was associated with longer rest intervals and shorter distances. The endurance training was performed outdoors. The interval running was done over distances of 100 and 200 meters (passive recovery, 1:3), 400 and 600 meters (active recovery, 1:2), 2000 and 2400 meters (passive recovery, 1:1.3). Active recovery consisted of running at 40% of HR_{max} on the track.

Statistical analysis

Statistical evaluation of the data was accomplished by using a 3x2 analysis of variance (group x time). When a significant F value was achieved, a Tukey's *post hoc* test was used to locate the pairwise differences between the means. The level of significance for this investigation was set at $p<.05$. All data were reported as mean±SD. All statistical analyses were conducted using the statistical package for Social Sciences (SPSS, Version 14.0).

Results

The mean pre-training and post-training values of all the variables evaluated in CDER, CPER and C groups are shown in Table 3. There were no significant differences ($p>.05$) between the groups in height, body mass, or body fat percentage prior to

Table 1. Resistance training program

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Intensity (1RM)	65%	70%	65%	75%	80%	85%	85%	80%	90%	90%	85%	90%
Set	2	3	3	3	3	3	3	3	3	2	3	3
Repetition	10	10	10	10	10	8	6	6	4	4	6	4
Frequency	2	2	2	2	2	2	2	2	2	2	2	2
Rest time (min)	2-3	2-3	2-3	2-3	2-3	2-3	2-3	2-3	2-3	2-3	2-3	2-3

Table 2. Endurance training program

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Intensity (HR_{max})	70%	70%	75%	75%	80%	80%	85%	85%	90%	90%	95%	95%
Time (min)	20	22	24	26	28	30	32	34	36	38	40	45

Table 3. Physical characteristics of the subjects

Variables		CDER	CPER	C
Body mass (kg)	Pre	69.84±11.07	70.31±7.17	66.88±5.85
	Post	70.22±11.49	71.54±7.09*	67.80±6.39
Fat-free mass (kg)	Pre	55.86±8.32	58.77±7.17	54.75±6.01
	Post	56.85±8.07*	60.39±6.83*	54.62±6.05
Body fat percentage (%)	Pre	15.58±2.85	12.17±3.52	13.40±2.83
	Post	13.05±2.78*	10.44±2.86†§*	14.24±2.49*
Pull-ups (repetitions)	Pre	9.07±4.04	10.42±6.72	8.42±2.59
	Post	10.78±3.82*	14.71±7.25†*	8.78±2.93
Sit-ups (repetitions)	Pre	50.85±11.04	51.85±12.35	46.92±8.12
	Post	67.71±9.21†*	68.85±12.05†*	47.71±7.75
Aerobic power (ml·kg^{-1}·min^{-1})	Pre	48.98±10.15	48.35±5.33	50.92±5.46
	Post	59.86±9.35†*	57.42±4.85*	50.81±6.77
Bench press (kg)	Pre	78±20.21	77.10±12.74	75.71±13.27
	Post	82.57±18.47*	86.60±15.92*	76.85±13.58
Squat (kg)	Pre	107.60±28.61	118.35±21.9†	96.28±15.07
	Post	143.32±35.07†*	149.22±40.89†*	96.64±15.94
Flexibility (cm)	Pre	39.21±4.59	41.28±6.99	38.74±4.87
	Post	41.85±4.31*	44.28±6.08†*	38.92±5.22
Speed 60 m (sec)	Pre	8.76±0.48	9±0.40	8.97±0.36
	Post	8.35±0.5†*	8.54±0.69*	9.01±0.32
Agility (sec)	Pre	13.82±0.68	14.20±0.87	13.91±0.56
	Post	12.99±0.41*	12.98±0.52†*	13.83±0.59
Sargent jump (cm)	Pre	42.64±6.19	45.42±12.11	41.35±4.65
	Post	48±6.32*	53.85±10.91†*	41.35±4.95

Legend: * significant difference from the pre-test (p<.05); † significant difference from C group; § significant difference between CDER and CPER.

training (Table 3). In the pre-training values, a significant difference occurred only in the squat trial between CPER and C (p=.01). No other significant differences between variables were observed prior to the experiment.

After the 12-week training program, significant increases in body mass occurred in CPER group (+1.7%) when compared with CDER (+0.5%) and C (+1.3%) groups. Fat-free mass increased in both experimental groups [CPER (+2.7%), CDER (+1.8%)], and not in C group (−0.2%). The subjects from CPER (−16.5%) and CDER (−19.3%) subsamples showed a significant decrease in their body fat percentage following the exercise training intervention while the controls did not (C, +0.6%). Also, body fat percentage for CPER was significantly lower than for CDER and C. Increases in the number of pull-ups and sit-ups occurred in CPER [pull-ups (+41.1%), sit-ups (+32.8%)] and CDER [pull-ups (+18.8%), sit-ups (+32.7%)], but not in C. Aerobic power (ml·kg^{-1}·min^{-1}) increased significantly in the subjects of CPER (+18.7%) and CDER (+22.2%) groups. Mean weight lifted in bench press (kg) [CPER (+12.3%), CDER (+5.8%), and C (+1.5%)] and squat (kg) [CPER (+26%), CDER (+33.1%), and C (+0.3%)] scores increased significantly in CDER and CPER. Mean sit-and--reach distance increased in both CDER (+6.8%) and CPER (+7.2%) groups. Improvements in mean time of running over 60 m occurred in all the groups [CPER (+5%), CDER (+4.7%), and C (+0.4%)]; however, this time decrease was not statistically significant in C group (p=.682). Agility times improved significantly in both CPER (+8.6%) and CDER (+6.6%). Increases in Sargent jump height were significant in CPER (+18.6%) and CDER (+12.6%) groups.

Discussion and conclusions

Although a concurrent training program can significantly enhance strength and muscle endurance, and improve body composition and flexibility (Davis, et al., 2008b), the effects of different models of concurrent training on some fitness factors such as aerobic power, strength, muscle endurance, body composition, and flexibility are not quite clear yet. Namely, it is well known that adaptations to training are very specific to the type of training, and that endurance training and resistance training cause different adaptations. Therefore, our purpose was to investigate the effects of two different methods of concurrent training application (one session including both types of exercise vs. two types of exercise in separate sessions) on changes in body composition, aerobic power and muscular endurance in untrained individuals. After the training period, fat-free mass, weight lifted in squat and bench press, number of pull-ups as well as the number of sit-ups, aerobic power, flexibility and Sargent jump height increased similarly in CDER and CPER. Also, body fat percentage, mean time of running over 60 m and agility time decreased similarly in both CDER and CPER. However, a significant difference was seen in body fat percentage changes in CPER when compared to CDER and C.

Results of the present study showed that body fat was significantly reduced in both groups [CPER (−16.5%), CDER (−19.3%)] after 12 weeks of experimental training. This reduction was evidently lower in CPER ($p<.05$) than in CDER and C group. A number of previous studies reported the highest reduction of body fat in the endurance training group and not in the concurrent group (e.g. Kraemer, et al., 1995; Glowacki, et al., 2004), whereas only Balabinis et al. (2003) have reported the highest decrease in body fat in the concurrent training group. The greater loss of body fat in CPER group may be related to the basal metabolic rate (Dolezal, & Potteiger, 1998). In the present study, body mass increased significantly in CPER group (+1.7%). It is possible that anabolic hormonal alternations in CPER vs. CDER group were different since increased body mass, caused by the concurrent training program, can increase muscle mass due to an increase in the anabolic responses (Kraemer, et al., 1995).

Fat-free mass increased significantly in both experimental groups [CPER (+2.7%), CDER (+1.8%)] with no significant differences between them. This increased body mass in the training groups may be due to the increased fat-free mass, caused by an increasing anabolic trend resulting from resistance training.

Aerobic status is an index of pulmonary function, heart and vascular oxygen delivery and the mechanism of muscle oxidation (Brooks, 2000). Our results showed that aerobic power increased significantly after the executed training programs in both experimental groups and we also found aerobic power to be significantly higher in CDER than in C group. Many studies reported an increase of VO_{2max} in endurance (Radovanovic, et al., 2009) and concurrent groups (Balabinis, et al., 2003; Nader, 2006). Some of these studies announced a significant reduction in VO_{2max} after resistance training (Balabinis, et al., 2003). However, Glowacki et al. (2004) reported increased VO_{2max} only in the endurance training group. Moreover, Nelson et al. (1990) reported that concurrent training prevents aerobic preparedness. They suggested that the enzyme activity of citrate syntase increases only after endurance training and resistance training. Hypertrophy may dilute muscle enzymes of the Krebs cycle, thus reducing aerobic power. In the present study, due to a longer duration of endurance exercise in CDER group than in CPER group, it is thought that physiological adaptations in CDER subjects were stimulated more frequently on a weekly basis. Namely, in CDER group, endurance exercise program was performed separately from the resistance exercise program (not in the same training session like it was done in CPER group). Therefore, each training program in CDER group started at a lower rest heart rate value. It was clear that CDER subjects were able to perform exercises longer. As mentioned in previous studies, concurrent training resulted in cardiovascular and cardiorespiratory adaptations (Balabinis, et al., 2003). Therefore, the sequence and timing of concurrent training program may be effective in this adaptation (Kreamer, et al., 1995).

After a 12-week training period, lower-body muscle strength (squat), upper-body muscle strength (bench press), upper-body muscular endurance (pull-ups), lower-body muscular endurance (sit-ups) and lower-body power (Sargent jump) increased in both CDER and CPER. Also, agility was improved in CDER and CPER. However, the Sargent jump height and the number of pull-ups and sit-ups in CPER were superior to CDER and C. In addition, agility was significantly better in CPER group than in CDER and C groups. It seems that CPER training group, which performed both training programs in the same sessions, had more effective adaptations as regards muscular power, flexibility and endurance.

In general, either the CPER or CDER forms of concurrent training are equally effective in muscle strength, body composition, aerobic power and muscular endurance improvement. Moreover, it is thought that concurrent training performed on different days each week or on the same days each week evoked similar improvement in muscle strength, body composition, aerobic power and muscular endurance. However, CPER training was more effective in transforming body mass and body fat percentage than CDER training.

Although more work is warranted to describe accurately the effects of concurrent training protocols on the assessed factors in this study, our data suggest that endurance and resistance exercises applied either in CPER or CDER mode are effective in sport performance or body composition improvement. Since concurrent training executed either on different days each week, or on the same days each week has evoked similar effects on some factors related to muscle strength, aerobic power and muscular endurance, it appears that athletes can benefit from either CPER or CDER protocols to improve the mentioned fitness factors. However, for higher effects on body mass and body fat percentage reduction, it is proposed to utilize both the endurance training and resistance training on the same days each week as a concurrent training. Our findings suggest that either CDER or CPER protocols are similarly effective in body composition, aerobic power and muscular endurance development. Future studies should address effects of varying methods of concurrent training of different intensities and duration with other groups of people, such as trained populations, women and older people before in the current study obtained findings can be generalized for other populations.

References

American College of Sports Medicine. (2000). *ACSM's Guidelines for Exercise Testing and Prescription*. Philadelphia: Lippincott Williams & Wilkins.

Baechle, T.R. (1994). *Essentials of strength training and conditioning*. Champaign, IL: Human Kinetics.

Baker, D. (2001). The effects of an in-season concurrent training on the maintenance of maximal strength and power in professional and college-aged rugby league football players. *Journal of Strength and Conditioning Research*, *15*, 172–177.

Balabinis, C.P., Psarakis, C.H., Moukas, M., Vassiliou, M.P., & Behrakis, P.K. (2003). Early phase changes by concurrent endurance and strength training. *Journal of Strength and Conditioning Research*, *17*(2), 393–401.

Bell, G.J., Syrotuik, D., Martin, T.P., Burnham, R., & Quinney, H.A. (2000). Effect of concurrent strength and endurance training on skeletal muscle properties and hormone concentrations in humans. *European Journal of Applied Physiology*, *81*, 418–427.

Brooks, G.A. (2000). *Exercise physiology: Human bioenergetics and its applications*. Mountain View, CA: Mayfield Publishing Company.

Chtara, M., Chaouachi, A., Levin, G.T., Chaouachi, M., Chamari, K., Amri, M., & Laursen, P.B. (2008). Effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. *Journal of Strength and Conditioning Research*, *22*(4), 1037–1045.

Craig, B.W., Lucas, J., Pohlman, R., & Stelling, H. (1991). The effects of running, weightlifting and a combination of both on growth hormone release. *Journal of Applied Sport Science Research*, *5*, 198–203.

Davis, W.J., Wood, D.T., Andrews, R.G., Elkind, L.M., & Davis, W.B. (2008a). Concurrent training enhances athletes' cardiovascular and cardiorespiratory measures. *Journal of Strength and Conditioning Research*, *22*(5), 1503–1514.

Davis, W.J., Wood, D.T., Andrews, R.G., Elkind, L.M., & Davis, W.B. (2008b). Concurrent training enhances athletes' strength, muscle endurance, and other measures. *Journal of Strength and Conditioning Research*, *22*(5), 1487–1502.

Dolezal, B.A., & Potteiger, J.A. (1998). Concurrent resistance and endurance training influence on basal metabolic rate in nondieting individuals. *Journal of Applied Physiology*, *85*, 695–700.

Dudley, G.A., & Fleck, S.J. (1987). Strength and endurance training: Are they mutually exclusive? Sports Medicine, 79-85. Fox, E.L. (1973). A simple, accurate technique for predicting maximal aerobic power. *Journal of Applied Physiology*, *35*, 914–916.

Garcia-Lopez, D., Hakkinen, K., Cuevas, M.J., Lima, E., Kauhanen, A., Mattila, M., Sillanpää, E., Ahtiainen, J.P., Karavirta, L., Almar, M., & González-Gallego, J. (2007). Effects of strength and endurance training on antioxidant enzyme gene expression and activity in middle-aged men. *Scandinavian Journal of Medicine and Science in Sports*, *17*, 595–604.

Glowacki, S.P., Martin, S.E., Maurer, A., Baek, W., Green, J.S., & Crouse, S.F. (2004). Effects of resistance, endurance, and concurrent exercise on training outcomes in men. *Medicine and Science in Sports and Exercise*, *36*, 2119–2127.

Gorostiaga, E.M., Izquierdo, M., Iturralde, P., Ruesta, M., & Ibanez, J. (1999). Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *European Journal of Applied Physiology and Occupational Physiology*, *80*, 485–493.

Gravelle, B.L., & Blessing, D.L. (2000). Physiological adaptation in women concurrently training for strength and endurance. *Journal of Strength and Conditioning Research*, *14*, 5–13.

Hennessy, L.C., & Watson, A.W.S. (1994). The interference effects of training for strength and endurance simultaneously. *Journal of Strength and Conditioning Research*, *8*, 12–19.

Hickson, R.C., Dvorak, B.A., Gorostiaga, E.M., Kurowski, T.T., & Forster, C. (1988). Potential for strength and endurance training to amplify endurance performance. *Journal of Applied Physiology*, *65*, 2285–2290.

Izquierdo, M., Häkkinen, K., Ibanez, J., Kraemer, W.J., & Gorostiaga, E.M. (2005). Effects of combined resistance and cardiovascular training on strength, power, muscle cross-sectional area, and endurance markers in middle-aged men. *European Journal of Applied Physiology*, *94*, 70–75.

Izquierdo, M., Ibanez, J., Häkkinen, K., Kraemer, W.J., Larrion, J.L., & Gorostiaga, E.M. (2004). Once weekly combined resistance and cardiovascular training in healthy older men. *Medicine and Science in Sports and Exercise*, *36*, 435–443.

Kraemer, W.J., Keuning, M., Ratamess, N.A., Volek, J.S., McCormick, M., Bush, J.A., Nindl, B.C., Gordon, S.E., Mazzetti, S.A., Newton, R.U., Gomez, A.L., Wickham, R.B., Rubin, M.R., & Häkkinen, K. (2001). Resistance training combined with bench-step aerobics enhances women's health profile. *Medicine and Science in Sports and Exercise*, *33*, 259–269.

Kraemer, W.J., Patton, S.E., Gordon, E., Harman, M.R., Deschenes, K., Reynolds, R.U., Newton, N., & Travis-Triplett, J.E. (1995). Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. *Journal of Applied Physiology*, *78*, 976–989.

McCarthy, J.P., Agre, J.C., Graf, B.K., Pozniak, M.A., & Vailas, A.C. (1995). Compatibility of adaptive responses with combining strength and endurance training. *Medicine and Science in Sports and Exercise*, *27*, 429–436.

Nader, G.A. (2006). Concurrent strength and endurance training: from molecules to man. *Medicine and Science in Sports and Exercise*, *38*(11), 1965–1970.

Nelson, A.G, Arnall, D.A, Loy, S.F, Silvester, L.J., & Conlee, R.K. (1990). Consequences of combining strength and endurance training regimens. *Physical Therapy*, *70*, 287–294.

Radovanovic D., Bratic, M., Nurkic, M., Cvetkovic, T., Ignjatovic, A., & Aleksandrovic, M. (2009). Oxidative stress biomarker response to concurrent strength and endurance training. *General Physiology and Biophysics*, *28*, 205–211.

Rahnama, N., Gaeini, A.A., & Hamedinia, M.R. (2007). Oxidative stress responses in physical education students during 8 weeks aerobic training. *Journal of Sports Medicine and Physical Fitness*, *47*, 119–123.

Simão, R., Farinatti, P.T.V., Polito, M.D., Viveiros, L., & Fleck, S.J. (2007). Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercise in women. *Journal of Strength and Conditioning Research*, *21*, 23–28.

Tanaka, H., & Swensen, T. (1998). Impact of resistance training on endurance performance: A new form of cross-training? *Sports Medicine*, *25*, 191–200.

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UČINCI KONKURENTNIH TRENAŽNIH PROTOKOLA NA SNAGU, AEROBNI KAPACITET, FLEKSIBILNOST I SASTAV TIJELA

U ovom su istraživanju vrednovani učinci konkurentnoga treninga s opterećenjem i treninga izdržljivosti na sastav tijela, aerobnu izdržljivost i mišićnu izdržljivost studenata i ta su dva konkurentna protokola vježbanja uspoređena. Uzorak ispitanika činila su 42 studenta (22,02±1,91 godina) koji su podijeljeni u tri grupe: CDER – konkurentni programi su se primjenjivali odvojeno, CPER – konkurentni program su se primjenjivali usporedo i kontrolna grupa (C). Eksperimentalni programi vježbanja su se provodili tijekom 12 tjedana. U CDER grupi je trening izdržljivosti i trening s opterećenjem organiziran u različitim danima u tjednu (4 dana u tjednu). CPER grupa je provodila trening izdržljivosti i trening s opterećenjem istoga dana u tjednu (2x tjedno). Nakon 12 tjedana treninga u obje eksperimentalne grupe (CDER i CPER) zabilježeno je jednako povećanje u bezmasnoj masi tijela, u maksimalnoj snazi (mjereno čučnjem i potiskom s ravne klupe), repetitivnoj snazi (mjereno zgibovima i pretklonima trupa iz ležanja), aerobnom kapacitetu, fleksibilnosti i visini skoka u Sargentovom testu. Također, u obje eksperimentalne grupe zabilježeno je i smanjenje postotka tjelesne masti, te poboljšanje rezultata u sprintu na 60 metara te u testu agilnosti. Značajna razlika u postotku tjelesne masti zabilježena je između CPER grupe te CDER i C grupe. Značajno povećanje mase tijela zabilježeno je u CPER grupi u odnosu na grupe CDER i C. Iako je zabilježeno povećanje tjelesne mase samo nakon primjene CPER protokola, može se zaključiti kako su oba protokola primjene konkurentnoga treninga podjednako učinkovita u smislu pozitivne transformacije sastava tijela, aerobnoga kapaciteta i mišićne izdržljivosti.

Ključne riječi: *trening s opterećenjem, trening izdržljivosti, konkurentni trening, tjelesna masa,* VO_{2max}