FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 4, N^{o} 1, 2006, pp. 1 - 8

Scientific Paper

EVALUATION OF PLYOMETRICS, WEIGHT TRAINING AND THEIR COMBINATION ON ANGULAR VELOCITY

UDC 796.015.52

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Abstract. *The purpose of this study was to examine the effectiveness of six weeks of plyometric training, weight training and their combination on angular velocity during a 60-second test cycle ergometer. Based on their training, forty-eight male college students were divided into four groups: a plyometric training group (n=13), a weight training group (n=11), a plyometric plus weight training group (n=14), and a control group (n=10). The angular velocity was measured by a 15 and 60-second cycle ergometer test before and after a six-week training period. Subjects in each of the training groups trained two days per week, whereas the control subjects did not participate in any training activity. The data was analyzed by a one-way analysis of variance (repeated-measures design). The results showed that all the training treatments elicited significant (P<0.05) improvement in angular velocity. However, the combination training group showed signs of improvement in the angular velocity that was significantly greater than the improvement of the other two training groups (plyometric training and weight training). It was concluded that a combination of traditional weight training and plyometric drills "complex training" enhance angular velocity production in cycling. Therefore, complex training may help improve performance in sprint cycling that requires angular velocity, angular acceleration and power.*

Key words: *plyometrics, angular velocity, weight training*

Received March 3, 2006

1. INTRODUCTION

Cycling is a popular form of exercise used for aerobic conditioning, as a competitive sport, and as rehabilitation modality in physical therapy. In competition, the major focus is on maximal performance, in which the rider assumes an aerodynamic position designed to minimize wind drag a maximizing energy input to the crank. Sprint events call on the use of the high-energy compounds adenosine tri-phosphate (ATP) and phosphocreatin (PC). Match sprints, which last approximately 10-seconds, rely heavily on the combined ATP-PC energy sources. The cyclist needs a high anaerobic capacity for starts, acceleration, hill climbing, break away, sprints, and finishes. Therefore, some portion of the training schedule must address the short-term high-intensity effort (explosive performance) (Garrett and Kirkendall, 2000). Power is an essential component for successful performance in many sports. Power represents the amount of work a muscle can produce per unit of time. An increase in power gives the athlete the possibility of improved performance in sports in which the improvement of the speed-strength relationship is sought (Luebbers et al., 2003). Angular velocity is an essential component for successful performance in cycling. Angular velocity (ω) represents the amount of angle changes per unit of time. It bears a direct relation to the velocity of movement ($V = \omega r$), angular acceleration ($\alpha = (\omega_2 - \omega_1) / (t_2 - t_1)$) and power. Therefore, an increase in angular velocity gives the cyclist the possibility of improved velocity of movement and explosive performance.

Plyometrics consists of exercises commonly used to enhance explosive power via the stretch-shortening cycle (SSC), (Michael et al., 2001; Rahimi, 2005). The stretch component of the SSC refers to the eccentric muscle action, whereas the shortening refers to the concentric muscle action (Michael et al., 2001). Elastic energy is stored in the tendomuscular system during the eccentric action (Michael et al., 2001). This is accomplished by optimizing the stretch-shortening cycle, which occurs when the active muscle switches from rapid eccentric muscle action to rapid concentric muscle action (Luebbers et al., 2003; Lachance et al., 1995; Wagner et al., 1997). The muscle elasticity feature and the miotatic reflex play an important role in the plyometric method. A number of studies have demonstrated the effectiveness of plyometrics compared to non-exercising control groups (Blakey et al., 1987; Diallo et al., 2001; Ebben, 2002). Wagner and Kocak (1997) have examined the effect of a plyometric training program on anaerobic power in three groups: basketball players, non-sportsmen that took part in six-week plyometric training program and the third group was the control group with no recorded training. The vertical jump test showed little change for the three groups; for the 50-yard dash, there was a change between –0.2% for the control group, and –2.1% for the training groups.

Luebbers et al. (2003) examined the effect of a plyometric training program on vertical jump performance and anaerobic power. The Margaria Staircase power test and vertical jump test were used, and the results showed that vertical jump height decreased in both groups while the results for anaerobic power increased in both groups from Pre to Post.

The comparison of plyometric exercises and weight-training protocols has produced controversial results. Plyometric protocols have been shown to be more effective (Verchoshanski & Tatyan, 1983), equally effective (Adams et al., 1992; Anderst et al., 1994; Ioannis et al., 2000), or less effective (Stone & O'Bryant, 1986; Verkhoshanski & Tatyan, 1983) than weight training in improving the vertical jumping ability.

The combination of plyometric exercise and weight training increased (Adams et al., 1992; Baur et al., 1990; Behm & Sole, 1993; Ioannis et al., 2000) or maintained as unaffected the vertical jumping performance (Stone & O'Bryant, 1986). Adams et al. (1992) suggested that this combination may provide a more powerful training stimulus to the vertical jumping performance than either weight training or plyometric training alone. However, Clutch et al. (1983) did not reach similar conclusions.

It seems that researchers have not come to an agreement about the relative effectiveness of plyometric training compared with weight training or the combination of both in the development of explosive power performance.

A variety of test modes have been utilized to measure anaerobic capacity that changes due to plyometric training, including running (Scott et al., 1991; Adams et al., 1992; Olsen et al., 1994; Medbo & Sejerstad, 1997; Wagner et al., 1997; Rahimi & Behpur, 2005), vertical jump test (Blattner et al., 1997; Clutch, 1983; Luebbers et al., 2003; Rahimi & Behpur, 2005), and stair climbing (Luebbers et al., 2003). However, the test most frequently cited as the standard in the assessment of anaerobic capacity, the cycle ergometer test (Vandewlle et al., 1985). It seems likely that different durations of training periods, different training procedures and different subject levels of fitness or different test modes have caused the discrepancy in the results from the previous studies.

To our knowledge, no studies have addressed the effects of plyometric training, weight training and their combination on angular velocity completed during the 15 and 60-second maximal exertion test cycle ergometer. Therefore, the purpose of the present study was to determine how the angular velocity in a 60-second maximal test and anaerobic power are affected by a typical six-week plyometric training, weight training and their combination "complex training".

2. METHODS

Subjects

Forty-eight male college students (19.27 ± 1.36 years of age) volunteered to participate in this study (the subjects' characteristics are given in Table 1). All of the subjects played on different teams in college and none were being trained by means of a plyometric training program. All of the subjects had successfully passed a physical exam and completed a medical history questionnaire in which they were screened for any possible injury or illness. The subjects received all the necessary information about the study's procedures in oral and written form. Each subject completed a medical history form (special care was given to hypertension and orthopedic status screening), a training background questionnaire, and a written informed consent form.

Table 1. Descriptive data of the subjects' characteristics

Group*	*n*	Height (cm)	Weight (kg)	Age (y)
Control	10	174.80 ± 6.94	70.13 ± 6.60	19.30 ± 1.1
P.T.	13	174.79 ± 6.36	68.36 ± 7.74	19.70 ± 1.5
W.T.	11	178.90 ± 9.80	71.59 ± 4.40	19.09 ± 1.2
P.W.T.	14	173.64 ± 5.51	66.99 ± 9.90	18.92 ± 0.9

Test Procedures

The test was performed on an electrically-braked cycle ergometer. Subjects brought their own pedals and cycling shoes and adjusted the seat and handlebars to their specifications. They warmed-up at a comfortable speed with zero resistance for approximately two-three minutes. During testing, the subject was asked to pedal against a pre-selected opposing resistance at the maximum pedal rate possible for 60 seconds.

Training Protocols

After the initial measurements, the subjects were divided into four groups: the control group (n = 10), the plyometric training group (n = 13), the conventional weight training group (n = 11), and the combination of plyometric plus weight training group (n = 14). The control group did not train. The other three training groups trained for six weeks, two days per week. Before the initiation of the training periods, the subjects of all the groups were instructed about the proper execution of all of the exercises to be used during the training period for all training regimens. The training protocols included only leg exercises. None of the subjects had used plyometric exercises before. The training programs were designed to overload the leg muscles involved in the cycling and explosive performance. The subjects in the plyometric group performed four plyometric drills: the Depth jump, the Split squat jump, the Rim jump, the Box to box depth jump. The depth jump height started at 40 centimeters and progressed to 75 centimeters in the fourth three-session. The subjects in the weight training group started with four sets of ten repetitions at 40 percent of 1RM during the First three-Session, and progressed to four sets of six at 100 percent of 1RM during the Fourth three-Session. The plyometric-weight training group performed a combination of the two training programs (plyometric and weight training program) but the volume and intensity of the work was reduced by 25 percent (Adams et al., 1992). All of the training sessions were supervised. The training programs are shown in Tables 2, 3 and 4.

Table 2. Plyometric training (PT) Program

Plyometric training	First 3-Session	Second 3-Session	Third 3-Session	Fourth 3-Session
Depth jump	† 3*6(40) 30	3*8(50) 30	4*7(60) 30	4*8(75) 30
Split squat jump	3*6(–) 30	3*8(–) 30	4*7(–) 30	4*8(–) 30
Rim jump	3*6(–) 30	3*8(–) 30	4*7(–) 30	4*8(–) 30
Box to box depth jump	★2*6/4(40)30	3*5/5(50)30	4*5/5(60)30	4*6/6(75)30

†Sets*reps at (box height (cm)) times rest between sets
★ Sets*reps/ at (box height (cm)) times rest between sets

Table 3. Weight training (WT) Program

Weight training	First 3-Session	Second 3-Session	Third 3-Session	Fourth 3-Session
Squat	‡ 4*10 (40%) 60	4*10 (60%) 60	4*8 (80%) 50	4*6 (100%) 40
Leg press	4*10 (40%) 60	4*10 (60%) 60	4*8 (80%) 50	4*6 (100%) 40
Leg extension	4*10 (40%) 60	4*10 (60%) 60	4*8 (80%) 50	4*6 (100%) 40
Leg extension	4*10 (40%) 60	4*10 (60%) 60	4*8 (80%) 50	4*6 (100%) 40

‡ Sets*reps at (percentage of 1RM) times rest between sets

Table 4. Plyometric + Weight training (PWT) Program

Complex training	First 3-Session	Second 3-Session	Third 3-Session	Fourth 3-Session
Depth jump	†3*4(30) 30	3*6(40) 30	3*7(45) 30	4*6(55) 30
Split squat jump	3*4(–) 30	3*6(–) 30	3*7(–) 30	4*6(–) 30
Rim jump	3*4(–) 30	3*6(–) 30	3*7(–) 30	4*6(–) 30
Box to box depth jump	★3*4/3(30)30	3*4/4(40)30	3*5/5(45)30	3*6/6(55)30
Squat	‡4*8(30%) 60	4*8(45%) 60	4*6(60%) 50	3*6(75%) 40
Leg press	4*8(30%) 60	4*8(45%) 60	4*6(60%) 50	3*6(75%) 40
Leg extension	4*8(30%) 60	4*8(45%) 60	4*6(60%) 50	3*6(75%) 40
Leg extension	4*8(30%) 60	4*8(45%) 60	4*6(60%) 50	3*6(75%) 40

† Sets*reps at (box height (cm)) times rest between sets
★ Sets*reps/ at (box height (cm)) times rest between sets
‡ Sets*reps at (percentage of 1RM) times rest between sets

Statistical Analyses

Paired t-tests were used to identify any significant differences between the groups at the PRE and POS-tests for the dependent variables. An analysis of variance with repeated measures was used to determine significant differences for angular velocity in the 15 and 60-second cycle ergometer test within the four training groups. When a significant difference among the training programs was detected, a pair-wise comparison of the programs was done using a Bonferroni post hoc test to identify significant differences between the training programs. The alpha level was set at 0.05 in order for the difference to be considered significant. All values are reported as mean ± standard deviation (Table 2).

3. RESULTS

Means and SEs for angular velocity in the 15 and 60-second tests are listed in Table 5. ANOVA procedures demonstrated a significant value ($P < 0.05$) for both tests and the results of the experimental groups were better than those of the control group. The Bonferroni post hoc test was used for a pair-wise comparison of the programs (Table 5).

Table 5. Means ± SEs between pre-training and post-training for both dependent variables for the four groups

15-second cycle ergometer test (rad.S^{-1})			60-second cycle ergometer test (rad.S^{-1})		
Pre	Post	Change percent.	Pre	Post	Change percent.
6.30 ± 0.85	8.67 ± 0.25	37.61%	6.07 ± 0.58	7.50 ± 0.63	23.55%
6.40 ± 0.35	7.44 ± 0.65	16.25%	5.84 ± 0.65	7.30 ± 0.84	25.00%
6.18 ± 0.41	10.23 ± 0.84	65.53%	5.68 ± 0.36	8.74 ± 0.32	49.11%
5.91 ± 0.36	5.75 ± 0.69	–2.70%	5.58 ± .069	5.75 ± 0.34	3.04%

The PWT (complex training) training was significantly better ($P = 0.001$) than either the PT or WT, but there were no differences between the PT and WT ($P = 0.762$) in increasing angular velocity production and speed as measured by the 15-second test cycle ergometer.

The PWT (complex training) training was significantly better (P = 0.05) than either the PT or WT, but there were no differences between the PT and WT (P = 0.08) in increasing angular velocity production and speed as measured by the 60-second test cycle ergometer.

Paired t-tests showed that the experimental groups showed a significant increase in: angular velocity in the 15-second cycle ergometer test (PT = 37.61%, P = 0.002; WT = 16.25%, P = 0.004 and PWT = 65.53%, P = 0.001), and in the 60-second cycle ergometer test (PT = 23.55%, P = 0.05; WT = 25.00%, P = 0.04and PWT = 49.11%, P = 0.001) in post-training in relation to pre-training.

4. DISCUSSION

Plyometrics are a popular form of training for improving vertical jump performance (Adams et al., 1992; Luebbers et al., 2003; Rahimi & Behpur, 2005) and anaerobic power (Luebbers et al., 2003; Ioannis et al., 2000). However, to our knowledge no studies have addressed the effects of these training programs on the angular velocity completed during the 15 and 60-second maximal exertion test cycle ergometer. In the present study, the especially complex training of the training program resulted in significant increases in angular velocity (65.53% [15-second test] and 49.11% [60-second test]). As previously mentioned, during plyometric training, the muscles were involved in a very rapid switch from the eccentric phase to the concentric phase (Stretch-shortening cycle). This SSC decreases the time of the amortization phase that in turn allows for greater than normal power production (Holcomba, 1996; Luebbers et al., 2003). In the SSC the muscles undergo transition energy (from eccentric to concentric muscle action), so that to train and enhance this transition phase requires a complex training, such as the programs used in this study. Thereby, weight training increases muscular strength and plyometric training exploits the SSC; therefore, the strength acquired by the weight training protocols will be used in this cycle (SSC) to produce a more forceful concentric muscle action and increase anaerobic power. The results of this study showed that complex training has a more significant effect than plyometric and weight training programs when it comes to increasing angular velocity, so these results are in accordance with previous studies (Baur et al., 1990; Adams et al., 1992; Ioannis et al., 2000). This improvement could be due to neuromuscular adaptations, such as increased inhibition of antagonist muscles as well as a better activation and contraction of synergistic muscles or increase in muscle fiber size (Gollnick, 1981; Potteiger, 1999; Thorstensson et al., 1976). When it comes to the comparison of plyometric and weight training in this study, significant differences have not been shown; therefore, these results are in accordance with previous studies that have been shown as being equally effective (Adams et al., 1992; Anderst et al., 1994; Ioannis et al., 2000). Verkhoshanski and colleagues (1983) have shown plyometric training to be more effective then weight training in improving the vertical jumping ability. This result is not in accordance with the results of this study. This could be due to the different test modes that were used. In contrast to the previous studies, the results of the present study indicate that angular velocity (rad.s^{-1}) increased as it was measured by the 15 and 60-second test cycle ergometre. However, the combination training treatment evoked the most significant changes (65.47% & 48.99% in the 15 and 60-second test respectively). The discrepancy between these results and the results of previous studies might be attributed to several reasons. First, the training experience level of the subjects. Second, the training programs and the intensity used might offer one explanation and third, the duration of the used training programs.

PRACTICAL APPLICATION

Based on the results of this study, angular velocity in the 15 and 60-second test increased in all of the training programs but the combination of plyometric and weight training showed a significantly greater increase in angular velocity than the plyometric or weight training alone. As we know, angular velocity is an essential component of successful performance in cycling. We must bear in mind that angular acceleration, velocity of movement and power, depend heavily upon angular velocity; thereby, increasing angular velocity due to complex training increased these essential factors, ultimately increasing anaerobic capacity. As indicated earlier, the cyclist needs a high anaerobic capacity for starts, acceleration, hill climbing, breakaways, sprints and finishes. Therefore, some portion of the training program of this athlete must involve plyometric training in combination with weight training or "complex training" in order for him to improve his performance.

Acknowledgement. *The authors extend their gratitude to Mr. Saeed Reza Noori, assistant department chair in the Department of Physical Education and Sports Science at the University of Kurdistan, for his excellent assistance and to all those who participated in this project.*

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EVALUACIJA UTICAJA PLIOMETRIJE, TRENINGA SNAGE I NJIHOVE KOMBINACIJE NA UGLOVNU BRZINU

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Cilj ovog istraživanja je bio da se ispita efekat šestonedeljnog pliometrijskog treninga, treninga snage i njihove kombinacije i uticaj na uglovnu brzinu tokom 60 sekundnog testa na bicikl-ergometru. Zavisno od treninga 48 muškaraca studenata koledža je podeljeno na četiri grupe: grupa koja ima pliometrijski trening (n=13), grupa na treningu snage (n=11), grupa koja je podvrgnuta kombinaciji ove dve vrste treninga (n=14) i kontrolna grupa (n=10). Uglovna brzina je merena u 15 šezdesetsekundnih bicikl-ergometar testova pre i nakon šestonedeljnog treninga. Ispitanici u svakoj od navedenih grupa trenirali su 2 dana u nedelji dok kontrolni ispitanici nisu učestvovali ni u jednoj aktivnosti. Podaci su analizirani jednosmernom analizom varijanse (ponovljena merenja). Rezultati su pokazali da su svi ispitanici koji su trenirali postigli znatno poboljšanje uglovne brzine (P<0,05). Međutim, ispitanici iz grupe koja je imala kombinovani trening su imali značajnije veće povećanje uglovne brzine u odnosu na ostale dve grupe (pliometrijski i trening snage). Zaključeno je da kombinacija tradicionalnog treninga i pliometrijskih dril "kompleksnijih treninga" omogućava postizanje veće uglovne brzine u vožnji bicikla. Stoga kompleksno treniranje može pomoći da se poboljša performansa u sprint biciklizmu koji zahteva uglovnu brzinu, uglovno ubrzanje i snagu.

Ključne reči: *pliometrija, uglovna brzina, trening snage*