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Research article

Effects of Instability versus Traditional Resistance Training on Strength, Power and Velocity in Untrained Men

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Abstract
The purpose of this study was compare the effects of a traditional and an instability resistance circuit training program on upper and lower limb strength, power, movement velocity and jumping ability. Thirty-six healthy untrained men were assigned to two experimental groups and a control group. Subjects in the experimental groups performed a resistance circuit training program consisting of traditional exercises (TRT, n = 10) or exercises executed in conditions of instability (using BOSU® and TRX®) (IRT, n = 12). Both programs involved three days per week of training for a total of seven weeks. The following variables were determined before and after training: maximal strength (1RM), average (AV) and peak velocity (PV), average (AP) and peak power (PP), all during bench press (BP) and back squat (BS) exercises, along with squat jump (SJ) height and counter movement jump (CMJ) height. All variables were found to significantly improve ($p < 0.05$) in response to both training programs. Major improvements were observed in SJ height (IRT = 22.1%, TRT = 20.1%), CMJ height (IRT = 17.7%, TRT = 15.2%), 1RM in BS (IRT = 13.03%, TRT = 12.6%), 1RM in BP (IRT = 4.7%, TRT = 4.4%), AP in BS (IRT = 10.5%, TRT = 9.3%), AP in BP (IRT = 2.4%, TRT = 8.1%), PP in BS (IRT=19.42%, TRT = 22.3%), PP in BP (IRT = 7.6%, TRT = 11.5%), AV in BS (IRT = 10.5%, TRT = 9.4%), and PV in BS (IRT = 8.6%, TRT = 4.5%). Despite such improvements no significant differences were detected in the posttraining variables recorded for the two experimental groups. These data indicate that a circuit training program using two instability training devices is as effective in untrained men as a program executed under stable conditions for improving strength (1RM), power, movement velocity and jumping ability.

Key words: Unstable surfaces, strength training, back squat, bench press, jumping ability.

Introduction

Strength training programs performed under stable conditions are excellent for improving muscle force and power (ACSM, 2009; Kraemer and Ratamess, 2004), along with jumping ability (Adams et al., 1992). Among the different strength training modalities, circuit weight training is particularly effective at improving performance in untrained men (Harber et al., 2004).

Instability strength training programs have been the focus of few scientific studies (Anderson and Behm, 2005a). Moreover, most of this research has addressed the physiological mechanisms controlling stability (Anderson and Behm, 2005a) and only a small number of studies have examined the effects of balance on performance measurements (force, power, etc.). In effect, very few investigations have compared the effects of balance on performance measures in training programs performed under both unstable and stable conditions (Cowley et al., 2007; Sparkes and Behm, 2010). Some authors have also identified a need to further investigate short and long-term adaptations for instability training programs (Anderson and Behm, 2005a).

To date, the main conclusions drawn are that loads applied in unstable conditions may not be a sufficient stimulus to produce adaptations and gains in strength (Anderson and Behm, 2004), power (Drinkwater et al., 2007; Kornecki and Zschorlich, 1994), velocity and range of motion (Drinkwater et al., 2007). A likely explanation for this is that the muscles around the joints tend to prioritize stability over power production (Anderson and Behm, 2004).

In effect, in conditions of instability, stiffness of the joints performing the action may limit strength, power and movement velocity gains (Carpenter et al., 2001). According to Adkin et al. (2002), a postural threat in a subject (fear of falling) will lead to a reduced magnitude and rate of voluntary movements. Thus, muscle stabilization seems to compromise gains in strength, power and movement velocity (Kornecki and Zschorlich, 1994). It should also be considered that new movement patterns are generally learned at low velocity, while specific motor actions of a sport are executed at high velocity (Behm, 1995). This is a significant problem because an improvement in performance requires a high level of training specificity (Willardson, 2004).

A further factor to consider is that the main objectives of a training program (gains in muscular strength, power, and hypertrophy) are determined by exercise prescription, in which variables such as the intensity, volume and frequency of training are adequately controlled (Wernbom et al., 2007).

To determine the real effects of a strength training program regardless of conditions of stability and instability, it is essential to fix the workload. The overload principle is essential in that the exercises must continue to challenge the individual for training adaptations to occur. These adaptations may appear from 40% of the one-repetition maximum (1RM) (Behm, 1995; Tan, 1999) in resistance training. However, resistances in most unstable

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surface training exercises are autoloads (i.e., bodyweight) and exercise magnitude of effort will depend on the degree of instability caused by the devices and body positions. This makes it difficult to objectively prescribe a given intensity or volume of exercise. One way of controlling the magnitude of effort in conditions of instability could be the use of the rating of perceived effort (RPE) (Borg, 1970) measured by assigning a numerical score at the end of each exercise and each training session (Day et al., 2004). This procedure has proved effective at controlling the intensity of resistance training in conditions of stability (Lagally et al., 2004). To date, no objective measure to quantify the instability produced by the different devices or postural changes has been developed to determine the real magnitude of effort of the load.

To the best of our knowledge, no study has examined the adaptations to unstable training produced at high exercise velocities under training control through RPE. The present study was designed to compare the effects of a traditional versus an instability whole-body strength circuit training program in terms of the adaptations produced in strength (1RM), power, movement velocity and jumping capacity in young untrained adults.

Methods

Experimental approach to the problem

The effects were compared of two strength training programs (7 weeks, 3 d·w^{-1}) in physically active subjects who were not accustomed to or had little experience with resistance training. In one of the training programs, subjects completed a resistance training circuit including the use of weight training machines and free weights. The other program was based on a similar resistance training circuit but devices designed to produce instability were used (BOSU® and TRX®). To examine the response to each program, all subjects underwent tests on their upper and lower limbs before and after each training program. The variables determined in these tests were jumping capacity measured as squat jump (SJ) height and counter movement jump (CMJ) height, and strength (1RM), average power (AP), peak power (PP), average velocity (AV) and peak velocity (PV) during the bench press (BP) and back squat (BS) exercises.

Subjects

Thirty-six students from the faculty of Physical Activity and Sport Sciences were randomly assigned to two experimental groups and one control group (CG). The CG was made up of 12 men (age = 22.3 ± 2.4 years, weight = 75.4 ± 9.9 kg, height = 1.76 ± 0.07 m). Experimental group 1 (12 men: 21.5 ± 3.03 years, 75.7 ± 9.2 kg, 1.78 ± 0.05 m) underwent an instability resistance training program (IRT) as a circuit using unstable and suspension platforms. Experimental group 2 (12 men: 21.8 ± 1.1 years, 71.8 ± 6.5 kg, 178.4 ± 5.4 cm) performed a traditional resistance training program (TRT), also as a circuit, with dumbbells, barbells and weight training machines. All participants were healthy active men that engaged in physical activity at least 2-3 times per week. Some had a little experience in training with free weights or bodybuilding machines and none had trained on unstable platforms. Participants were informed of the experimental procedures and signed an informed consent document before each test. They were all requested to refrain from additional strength and/or resistance training or physical activity during the course of the program. The study protocol was approved by the Review Board of our university's (Alfonso X el Sabio University, Madrid, Spain) Department of Physical Activity and Sport Sciences according to the principles and policies of the Declaration of Helsinki.

Testing

In a preliminary session, we obtained personal data and medical history data through questionnaires and conducted medical examinations on the participants. Subjects arrived at the laboratory well-rested after an overnight fast. After data collection, subjects were allowed to practise the jumping exercises. The following morning, they received instruction in some of the weight lifting exercises using light and moderate loads (BS and BP). Forty-eight hours after the second evaluation session, participants performed the jumping capacity test, followed by the BS test and then the BP test.

Both the pretraining and posttraining tests were identical and administered by the same investigators. Participants were asked to refrain from any intense physical effort 48 hours before the test dates. In addition, they did not eat or smoke in the two hours prior to the tests (they were allowed water).

Jumping ability

The protocol for this test is shown in Table 1. The test began with a standard warm-up for all participants, which consisted of 5 min of gentle running followed by 5 min of stretching and joint movements of the arms and legs. For the SJ, the subject started from an initial position with knees and hips flexed (~90º) avoiding countermovement and maintaining this position for about 4 s to avoid the build up of elastic energy during flexion to be used in the concentric phase of exercise. From this position, the participant executed knee and hip extension as rapidly and explosively as possible. The starting position for the CMJ test was a normal standing position with knees and hips extended. To perform the jump, the subject underwent a

Table 1. Test session protocol.

1º SWUP		2º SJ PR		3º CMJ PR		4º SWUP		5º BS PR		6º BP PR	
Jump/R	**R**	**Jump**	**R**	**Jump**	**R**	**Rep. X L**	**R**	**Rep. X L**	**R**	**Rep. X L**	**R**
3 SJ/30''	3	1 SJ	1	1 CMJ	1	8 x bar	1	4 x 40 kg	3	4 x 30 kg	3
3 CMJ/30''	3	1 SJ	1	1 CMJ	1	6 x 20 kg	1	3 x 50 kg	3	3 x 40 kg	3
		1 SJ	3	1 CMJ	5	4 x 30 kg	3	2 x 60 kg	3	2 x 50 kg	3
								1 x 85% 1RM	5	1 x 85% 1RM	

BP = Bench Press; BS = Back Squat; CMJ = Counter movement jump; L = Load; bar = Barbell; PR = Protocol; R = Recovery Time (minutes); Rep. = Repetitions; RM = Repetition maximum; SJ = Squat jump; SWUP = Specific warm up.

rapid flexion-extension of the knees and hips with minimum accommodation between the eccentric and concentric phases. For both jumps, knee flexion was around 90º with hands on hips to avoid any help with the arms. During the flight stage, the knees were extended, making contact with the ground with the toes first. To soften the fall, the knees may be bent at an angle close to 90º. In all jumps, vertical height was recorded by a contact infrared platform (Optojump System, Microgate SARL, Bolzano, Italy), and the average of the three jumps used for subsequent analysis. The Optojump system measures the flight time of vertical jumps with a precision of 1/1000 seconds (1 kHz). Jump height is then estimated as 9.81 X flight time^2/8 (Bosco, Luhtanen, and Komi, 1983).

Back squat and bench press

Five minutes after the last CMJ, the strength, velocity and muscular power assessment was initiated in the upper and lower body (Table 1). For this purpose, two popular exercises for weight training were selected; BS and BP. A Smith machine (Multipower, Reebok) was used for these tests. The protocol followed similar guidelines to those prescribed by Sánchez-Medina et al. (2010). 1RM was calculated according to the velocity of movement recorded using an isoinertial dynamometer T-Force Dynamic Measurement System (TFDMS) (Ergotech, Murcia, Spain). The reliability and validity of this method was established in a pilot study (Sánchez-Medina et al., 2010. One of the advantages of this measurement system is that 1RM can be measured in real time for each repetition executed according to the movement velocity of the barbell. Given the inexperience of the subjects with this type of protocol, an objective of the test was that subjects should complete more than 4 exercise sets to determine their 1RM and that loads should be under 85% of their 1RM. This is because in individuals unaccustomed to lifting such heavy weights, measurements may be affected by fatigue. After a warm up period, the BS protocol for 1RM determination was performed as 4 sets of increasing loads (Table 1): 4 repetitions with a load of 40 kg; 3 repetitions with one of 50 kg; and 2 repetitions with one of 60 kg. Using this 60 kg weight, 85% 1RM was estimated according to the barbell displacement velocity. The fourth set was performed using the weight corresponding to 85% 1RM, and the final 1RM calculated for the barbell displacement velocity produced in real time. Participants were asked to perform each repetition at the maximum velocity possible. In addition, to confirm the measures estimated according to displacement velocity, in the last set, the subject was instructed to perform as many repetitions possible until failure using the load equivalent to 85% of 1RM. If 5 to 6 repetitions were conducted, the 1RM calculation was taken as valid given the direct relationship between the number of repetitions that can be executed at 85% and 1RM (Baechle and Earle, 2008). The recovery time between sets was 3 min.

The different kinetic and kinematic variables were calculated as follows:

Velocity ($m \cdot s^{-1}$) = vertical displacement of the barbell (m) x time (s^{-1})
Acceleration ($m \cdot s^{-2}$) = vertical barbell velocity ($m.s^{-1}$) x time (s^{-1})

Force (N) = system mass (kg) × vertical acceleration of the barbell ($m \cdot s^{-2}$) + acceleration due to gravity ($m \cdot s^{-2}$)

Power output (W) = vertical force (N) × vertical barbell velocity ($m \cdot s^{-1}$)

Once the subjects had completed the BS protocol, they rested for 5 min and then started the BP test (Table 1) following the same instructions as for the BS procedure. Measurements of AV, PV, AP, PP and 1RM in the concentric phase (propulsive) were obtained by the TFDMS equipment. All technical details of how the BS and BP should be performed were based on the recommendations of the National Strength and Conditioning Association (NSCA) (Baechle and Earle, 2008). For analysis, we considered the means of the best repetitions executed using each load (40 kg, 50 kg and 60 kg for BS and 30 kg, 40 kg and 50 kg for BP). These were selected because in the practice sessions, it was observed that these weights corresponded to the loads at which the subjects developed maximum AP and PP, approximately at a relative intensity of 40% to 60% 1RM.

Such relative intensities were used to determine maximum power levels since recent studies examining multi-joint dynamic muscle actions in isoinertial conditions have shown great variation in intensities (20%-80% of 1RM) (Cormie et al., 2007). Several studies have shown that the highest levels of power for BP exercise are between 45% (Izquierdo et al., 2002; Newton et al., 1997) and 55% (Sánchez-Medina et al., 2010) of 1RM. Equivalent figures for BS are 48%-63% (Baker et al., 2001) or 45% of 1RM (Izquierdo et al., 2002).

Circuit training program

The circuit training program started one week after the pretests. After completing the program and resting for 5 days, the posttests were conducted. Overall, 21 sessions of approximately 45-65 min each were completed over the 7 weeks (three sessions per week). Subjects who failed to complete more than 2 training sessions were not entered in the subsequent analysis leaving only 10 subjects in the TRT group.

Since few participants were accustomed to the use of free weights and weight training machines and no subject had used an instability device, participants undertook a one-week practice period of 3 sessions, each separated by one day, to avoid the influence of a learning effect on the results.

Two different routines were alternated in both training programs every week. Each circuit training session was comprised of 8 alternating exercises selected from among a variety of upper and lower body exercises. These exercises were chosen so that they worked the same muscle groups and elicited similar movements in both programs (Table 2). For each exercise, participants carried out 3 sets of 15 repetitions during the 7 weeks training. All participants indicated their self-perceived exertion by providing Borg Scale (CR-10) scores after each exercise set and training session (Borg, 1970). One of the investigators provided guidelines for gradual load increases during the entire training program depending on the perceived exertion of the previous weeks. In the first two weeks, the workload was chosen by each subject.

Table 2. Training programs.

Nº	Workout Exercise traditional	Exercise unstable
	Routine 1	
1	Back. Pulldown Cable.	Back. Pulldown TRX®
2	LE. Lunge Dumbbell	LE. Lunge BOSU®
3	Chest. Incline Bench Press Dumbbell	Chest. Incline Push up TRX®
4	LE. Step down. Dumbbell	LE. Step down. BOSU®
5	Shoulder Press Dumbbell	Shoulder. Front Raise Incline TRX®
6	Power Snatch	Similar movement TRX®/ BOSU®
7	Biceps Curl. Dumbell	Biceps. TRX®
8	Triceps Pushdown. Cable	Triceps-swinging body. TRX®
	Routine 2	
1	Back. Seated row Cable	Back. Row. TRX®
2	LE. Side Lunge. Dumbbell	LE. Side Lunge. BOSU®/TRX®
3	Chest. Decline Push up	Chest. Decline Push up. BOSU®
4	LE. Step ups. Barbell	LE. Step ups. TRX®
5	Shoulder. Upright row	Shoulder. Similar movement. TRX®
6	LE. Back Squat	LE. Back Squat Medicine Ball. BOSU®
7	Triceps extension overhead. Cable	Triceps extension overhead. TRX®
8	Biceps curl overhead. Cable	Biceps overhead. TRX®

LE = Lower extremity

Subjects were instructed to adequately perform the xercises at the fastest speed possible. An observer specialized in resistance training and the use of instability devices controlled exercise performance during each training session.

For the IRT protocol, when the RPE score indicated by participants was 5 to 7, body position was varied and/or an unstable platform was added. For scores of 8 and 9, the body position adjustment was less marked while for scores higher than 10, no position change was made. Thus, load increases were provided by greater body instability caused by the body position, the instability devices and the higher number of body segments involved.

For the TRT procedure, load was increased by 10% when RPE was 5 to 7, by 5% when RPE was 8 or 9, and by 0% when scores were 10 or higher.

For both training programs, the scheduled recovery time between each exercise was initially 30 s and reduced thereafter by 5 seconds every week. In the final week, recovery time corresponded to the time needed to move from one circuit station to the next (ACSM, 2009). The initial recovery period between sets was 2 minutes and this was reduced by 10 s each week until an interval of 1 min between sets.

For the IRT program, several weight lifting protocols were executed using two instability devices: a hemispherical ball placed on the floor attached to a rigid plastic platform (BOSU® Balance Trainer^{TM}) and a non-elastic, adjustable harness suspended 2.5 meters from the floor. The harness made of industrial-strength nylon webbing forms a one-piece system that splits into two handles to hold on to or support any body part (TRX® Suspension Training).

Statistical analysis

The Levene test was used to check the homogeneity of variance among the pretraining variables and the normal distribution of data was confirmed by the Kolmogorov-Smirnov test. The effects of the two training programs on the variables recorded were compared by two-way ANOVA for repeated measures. To identify possible interaction effects we considered an inter-subjects factor, or group effect (3 levels IRT, TRT, CG) and an intra-subjects factor, or time effect (2 levels PRE, POST). In cases in which significant differences in the interaction Group x Time were detected ($p < 0.05$), a Tukey Post-Hoc one-way ANOVA test was used to compare differences between treatments (IRT, TRT, CG).

To determine the magnitude of the response to both training programs we analyzed the effect size (ES) (Cohen, 1988) using Cohen's qualitative descriptors to indicate the changes (small <0.41, moderate 0.41 to 0.7, or large >0.7). We also calculated the probability of demonstrating the effectiveness of each program through statistical power. The relative reliability of measures obtained in each exercise was determined by calculating intraclass coefficients (ICC).

Data are provided as the mean and standard deviation (*S*). All statistical tests were performed using the program SPSS version 17.0 (SPSS, Chicago, III). Significance was set at $p < 0.05$.

Results

Jumping ability

Improvements were observed in all the jumping ability variables for the factor Time and interaction Group x Time (Table 3). For SJ, large (ES = 0.8) and significant differences were detected for the Time factor ($F = 101.12$; $p < 0.001$), which increased by 22.1% in the IRT group and by 20.1% in the TRT group, and for the interaction Group x Time ($F = 24.7$; $p < 0.001$; ES = 0.6). Given that significant differences were observed in the interaction term, one-way ANOVA tests were conducted to assess group differences in POST training SJ. However, no significant differences emerged between groups ($F = 3.104$; $p = 0.059$).

CMJ performance also significantly improved ($F = 69.0$; $p < 0.001$; ES = 0.7) in response to training: by

17.7% in the IRT group and by 15.2% in the TRT group. There was also a significant effect of the interaction Group x Time (F = 17.4; p < 0.001; ES = 0.5). However, no significant difference between the three groups was noted in POST CMJ (F = 2.755; p = 0.079). The ICC for jumping ability was 0.881.

Back squat

Leg strength, velocity and power results of the BS tests performed on a Smith machine are provided in Table 3.

A moderate (ES = 0.5) significant improvement in 1RM was detected for the factor Time (F = 26.81; p < 0.001) and a small improvement (ES = 0.3) for the Group x Time interaction (F = 7.96; p = 0.002). Leg strengths increased by 13% in the IRT group and by 12.6% in TRT. One-way ANOVA performed on POST 1RM revealed a significant difference between CG and TRT (F = 3.797; p = 0.047).

AV increased by 10.5% in the IRT and 9.4% in the TRT groups. These increases were moderate (ES = 0.42) and significant for the Time factor (F = 46.06, p < 0.001, ES = 0.42) and slight (ES = 0.3) for the Group x Time interaction (F = 11.39; p < 0.001). PV significantly improved in small increments (IRT = 8.6% and TRT = 4.5%) for Time (F = 20.53; p < 0.001; ES = 0.2) and Group x Time (F = 5.74; p = 0.005; ES = 0.2).

AP increased by 10.5% in IRT and 9.3% in TRT. These increases can be classified as slight (ES = 0.2) and significant for the Time factor (F = 15.83; p <0.001), and for the Group x Time interaction (F = 11.15; p <0.001; ES = 0.3). One-way ANOVA detected significant differences between groups in POST AP (F = 3.73; p = 0.029), especially between the TRT and CG groups (p = 0.047).

PP increased by 19.42% in IRT and 22.3% in TRT. Significant differences were found for the Time factor (F = 30.51; p < 0.001; ES = 0.3), and Group x Time interaction (F = 5.66; p < 0.001; ES = 0.2). One-way ANOVA indicated significant changes in POST PP between groups (F = 4.6; p = 0.014), especially between TRT and CG (p = 0.013). The ICC for BS was 0.821.

Bench press

Arm strength, velocity and power results of the BP tests performed on a Smith machine are provided in Table 4. Significant improvements in 1RM were only detected for the Time factor (F = 6.89; p = 0.013; ES = 0.2). Thus, in response to training, strength (1RM) increased by 4.7% in the IRT group and by 4.4% in the TRT group.

AP increased by 2.4% in IRT and by 8.1% in TRT. Statistically these improvements can be considered small (ES = 0.1) and significant for the Time factor (F = 9.24; p = 0.003) and Group x Time interaction (F = 3.46; p = 0.038).

PP showed the greatest improvement in response to training and increased by 7.6% in IRT and by 11.5% in TRT. These increases were slight (ES = 0.1) and significant for the Time factor (F = 6.88; p = 0.011) and Group x Time interaction (F = 4.68; p = 0.013). No significant differences in BP variables after training were detected between the three groups (p > 0.05).

The ICC for BP was 0.893.

Discussion

The main finding of this study was that both strength circuit training modalities (instability and conventional) induced similar effects in untrained young adults after 7 weeks of training. The 1RM variables recorded in our

Table 3. Effects of a 7-week training program on Strength, Velocity and Power variables in the Back Squat and Jumping Ability test. Data are means (±SD).

Variable	Group	Pre	Post	*p* for Group	*p* for GxTi ES/SP	*p* for Ti ES/SP
1RM BS (kg)	IRT	83.08 (13.84)	93.91 (17.37)	.034‡	.002‡ .3/.935	.000* .5/.999
	TRT	85.80 (26.16)	96.60 (21.32)			
	CG	78.91 (12.79)	78.41 (12.09)			
BS AV ($m\cdot s^{-1}$)	IRT	.95 (.15)	1.05 (.16)	.062	.000* .3/.991	.000* .4/1.0
	TRT	.96 (.19)	1.05 (.18)			
	CG	.95 (.14)	.95 (.14)			
BS PV ($m\cdot s^{-1}$)	IRT	1.52 (.23)	1.65 (.23)	.104	.005‡ .2/.850	.000* .2/.994
	TRT	1.57 (.30)	1.64 (.24)			
	CG	1. 51 (.24)	1.52 (.24)			
BS AP (W)	IRT	414.34 (68.71)	457.79 (69.86)	.029‡	.000* .3/.990	.000* .2/.975
	TRT	417.52 (81.29)	456.42 (80.48)			
	CG	422.10 (81.04)	407.88 (71.30)			
BS PP (W)	IRT	811.69 (170.1)	969.33 (188.20)	.014‡	.005‡ .2/.845	.000* .3/1.0
	TRT	832.56 (208.8)	1018.26 (289.50)			
	CG	815.70 (167.20)	835.37 (167.10)			
SJ (cm)	IRT	26.3 (4.7)	32.1 (5.4)	.059	<.001* .6/1.0	<.001* .8/1.0
	TRT	28.3 (6.2)	34.0 (5.2)			
	CG	28.6 (4.5)	28.8 (4.6)			
CMJ (cm)	IRT	31.7 (5.6)	37.3 (6.3)	.079	<.001* .5/.999	<.001* .7/1.0
	TRT	34.2 (7.0)	39.4 (6.3)			
	CG	33.8 (4.2)	33.9 (4.3)			

1RM = 1 repetition maximum; AP= Average power; AV = Average velocity; BS = back squat; CG = control group; cm = centimeter; CMJ = counter movement jump; ES = Effect size; GxTi = group x time; IRT= instability resistance training program; kg = kilogram; $m\cdot s^{-1}$= meter·second; Post = posttest; PP = Peak power; Pre = pretest; PV = Peak velocity; SJ = squat jump; SP = statistical power; TRT= traditional resistance training program; Ti = Time; W= watts. * = differences between groups; p < 0.001. ‡ = differences between groups; p < 0.05.

Table 4. Effects of a 7-week training program on Strength, Velocity and Power variables in the Bench Press test. Data are means (±SD).

Variable	Group	Pre (mean ± *S)*	Post (mean ± *S)*	*p* for Group	*p* for GxTi ES/SP	*p* for Ti ES/SP
1RM BP (kg)	IRT	77.50 (8.22)	81.17 (9.65)	.932	.192 .1/.336	.013‡ .2/.719
	TRT	78.80 (16.20)	82.30 (16.93)			
	CG	81.72 (19.58)	81.00 (18.84)			
BP AV ($m \cdot s^{-1}$)	IRT	.77 (.11)	.78 (.15)	.943	.389 .03/.209	.018‡ .1/.671
	TRT	.74 (.19)	.78 (.17)			
	CG	.76 (.21)	.77 (.20)			
BP PV ($m \cdot s^{-1}$)	IRT	1.19 (.20)	1.23 (.23)	.899	.639 .01/.120	.012‡ .1/.717
	TRT	1.15 (.30)	1.20 (.27)			
	CG	1.20 (.39)	1.21 (.38)			
BP AP (W)	IRT	336.05 (35.10)	344.01 (56.06)	.940	.038‡ .1/.627	.003‡ .1/.849
	TRT	317.22 (70.74)	342.84 (69.81)			
	CG	335.89 (84.64)	337.09 (83.80)			
BP PP (W)	IRT	608.12 (116.70)	654.46 (163.20)	.946	.013‡ .2/.767	.011‡ .1/.737
	TRT	581.33 (192.95)	648.44 (193.39)			
	CG	689.32 (293.85)	669.88 (278.36)			

1RM = 1 repetition maximum; AP= Average power; AV = Average velocity; BP = bench press; CG = control group; ES = Effect size; GxTi = group x time; IRT= instability resistance training program; kg = kilogram; $m \cdot s^{-1}$= meter.second; Post = posttest; PP = Peak power; Pre = pretest; PV = Peak velocity; SP = statistical power; TRT= traditional resistance training program; Ti = Time; W= watts. ‡ = differences between groups; $p < 0.05$.

study are in line with those reported by others in similar studies (Sparks and Behm, 2010). Traditional resistance training is characterized by greater overload forces applied than in unstable conditions (Kibele and Behm, 2009). Results, especially the BS data, suggest that although no overloads are applied to the knee extensor muscles when using an instability device for training, strength gains could be related to increased activation of trunk muscles (Anderson and Behm, 2005b) and sympathetic transmission of motor neurons (Asanuma and Pavlides, 1997). This may promote intramuscular and intermuscular coordination in the muscle groups involved, as well as more economic activation of agonist muscles (Rutherford and Jones, 1986), increasing strength levels.

These arguments acquire greater relevance if we examine the exercises performed in the two training programs examined here. Thus, greatest strength gains were produced in the lower limbs, probably because the selected exercises were mainly unilateral and standing. Indeed, as the body moves in the vertical position as an inverted pendulum, there is a tendency for the center of gravity to swing (Roberson et al., 2004), increasing the degree of instability and possibly favoring the activation of the trunk muscles (Anderson and Behm, 2005b) and inter and intra muscular coordination (Rutherford and Jones, 1986). In contrast, the lower strength gains (1RM) produced in the arms could be attributed to the fact that the exercises were conducted in a sitting position such that there is minimum displacement of the center of gravity.

When we designed the protocols for the two training programs, we ensured that each exercise performed in stable conditions was matched with a similar exercise conducted in unstable conditions. The similar strength responses (1RM) produced by both modes of exercise could indicate that the body positions and degree of instability generated by the BOSU® and TRX® exercises, have a similar effect to that produced by the external load used in the conventional resistance training protocol.

A further finding of our study was a significant increase in power and movement velocity in the subjects assigned to the IRT protocol. Undoubtedly, the adaptations of strength, power and velocity are determined by the intensity of established resistance (Tan, 1999). One of the main theories regarding training in unstable conditions is that it provides similar strength adaptations to training under stable conditions with the use of lighter loads (Behm et al., 2002). The responses obtained here to both training programs suggest that exercises performed using the instability devices BOSU® and TRX® at high velocity could increase power and movement velocity in similar measure to traditional resistance training.

Prior studies have shown that instability training does not improve power development or movement velocity (Drinkwater et al., 2007; Kornecki and Zschorlich, 1994; Koshida et al., 2008). One of the features of instability resistance training is that exercises trigger a process of learning new motor patterns, leading to a lower execution velocity (Behm, 1995). In addition, the muscles around joints tend to favor stability over power generation. Several resistance training studies have shown that an essential factor for improving power development and movement velocity regardless of the load used is that exercises should be executed at an explosive velocity (ACSM, 2009; Häkkinen, 1989). The similar power and velocity gains produced in our two experimental groups suggest that the instability provoked and the execution velocity of movements in unstable conditions give rise to similar neuromuscular adaptations to traditional resistance training, resulting in increased power and movement velocity.

As participants adapt to the degree of instability or load, it might be interesting to increase the execution velocity of muscle actions, simulating the specific motor patterns (Willardson, 2004) of other sports, provided the exercise is technically well-executed. We would argue that any improvement in power and movement velocity in conditions of instability will depend on two essential factors: that exercises are repeated and that loads are gradually increased in the mid and long term. This will likely determine a need to learn new motor patterns and adaptation towards the improved specificity of movements.

In our study, we also observed a marked improvement in jumping ability despite the fact that the study participants were accustomed to sports such as basketball, volleyball and handball, in which jumping is a major specific motor action. In effect, several studies have reported significant improvements in vertical jump following lower body resistance training (Adams et al., 1992; Baker et al., 1994). Improved strength and power of the lower limbs may be a main trigger for significant gains in jumping ability (Häkkinen and Komi, 1985). The latter is in turn related to sports performance.

An essential component of the design of any training program is the control of exercise intensity in the long term. Resistance training progression models in healthy adults indicate that a critical factor for power development is the gradual increase of loads (ACSM, 2009). In our study, training intensity was monitored using the indicator RPE. Several authors have shown the reliability (Day et al., 2004) of this method for strength training prescription (Lagally et al., 2004). In the subjects assigned to the TRT program, load increases were established according to self-perceived effort.

Nevertheless, resistances provoked by an unstable surface whether attached to the floor like BOSU® or suspended like TRX® are autoloads. The RPE enabled us to determine the effort perceived by the subjects assigned to the instability circuit training program and to accordingly modify the degree of instability and/or body position to optimize the intensity of exercise. To date, no objective method to quantify exercise intensity for unstable surfaces has been described. This could thus be a useful tool to control exercise intensity in unstable conditions.

We feel the circuit-type protocol also played an important role in controlling stimuli. By alternating upper and lower extremity exercises, muscle fatigue affecting the same muscle groups is avoided (Baechle and Early, 2008). The circuit's stations could be designed to consider adequate recovery periods between exercises working different muscle groups. If at a given station a particular group of muscles is exercised, these muscles would not be the focus of the adjacent stations or posts until an adequate rest period were completed.

The similarity of the results recorded in our tests suggests the similar perception of stimuli by the participants of both training programs. RPE was probably a key factor for the proper control of the intensity of instability training.

We could interpret the results of our study as suggesting that IRT produces similar adaptations to those of TRT. Thus, exercises executed on or using unstable devices like BOSU® or TRX® could improve strength (1RM), power, movement velocity and jumping ability in young untrained adults in the same measure as weight lifting exercises performed in stable conditions. Other studies that have compared resistance training conducted in instability or stable conditions have identified two critical factors: the speed at which exercises are executed and the control of training intensity through RPE.

We consider that our results cannot be extrapolated to high performance athletes or to subjects with experience in resistance training. This idea, however, prompts a new line of investigation in which the possibilities of the instability approach to training are further explored. Future studies need to establish the long term effects of instability strength training programs in other population groups.

Conclusion

Healthy, physically-active individuals with or with limited experience in resistance training may either use the instability approach using devices that induce instability or undertake a more traditional training program using free weights and weight training machines in stable conditions.

For the traditional approach, larger resistance loads are used, which could be more appropriate for developing muscular power and hypertrophy. In contrast, instability training may be a good complementary option to vary exercise stimuli within a periodized model.

For athletes training in sports such as basketball or volleyball at least two or three times per week, the instability approach could be an interesting option to improve sports performance in terms of gains in strength, power, movement velocity and jumping capacity.

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Key points

- Similar adaptations in terms of gains in strength, power, movement velocity and jumping ability were produced in response to both training programs.
- Both the stability and instability approaches seem suitable for healthy, physically-active individuals with or with limited experience in resistance training.
- RPE emerged as a useful tool to monitor exercise intensity during instability strength training.

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