

ORIGINAL RESEARCH

COMPARISON OF THE EFFECTS OF AN EIGHT-WEEK PUSH-UP PROGRAM USING STABLE VERSUS UNSTABLE SURFACES

Iván Chulvi-Medrano, PhD, NSCA-CPT¹
Esteban Martínez-Ballester, NSCA-CPT¹
Laura Masiá-Tortosa¹

ABSTRACT

Background and Purpose: Recently, the trend among physical training and rehabilitation professionals is the use of resistance exercise on unstable equipment in order to increase the effort of the agonist and stabilizing muscles. It is unknown if performing exercises on unstable surfaces provides a greater training stimulus as compared to training on a stable training surface. Therefore, the purpose of this research was to compare the effect that push-up training on stable and unstable surfaces had on strength performance in healthy young men.

Methods: Thirty subjects with experience in resistance training participated in push-up training two days per week for eight weeks on one of three different surfaces: the floor (Tp), the T-Bow® (TBp) or the BOSU® (Bp).

Results: Strength, as measured by one repetition maximum (1-RM) and muscle endurance, as measured by number of pushups performed did not improve significantly ($p > 0.05$) for any of the intervention groups.

Conclusions: The addition of unstable surfaces in push-up training does not provide greater improvement in muscular strength and endurance than push up training performed on a stable surface in young men.

Levels of Evidence: 3b

Keywords: BOSU®, push-up, T-Bow®, unstable surfaces

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Institutional Review Board

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CORRESPONDING AUTHOR

Iván Chulvi-Medrano
C/Conde Salvatierra nº 8 46.004 Valencia
(Spain)
Ivan.chulvi@now-you.es
chulvi77@hotmail.com
+ 34- 677-222-952

INTRODUCTION

Push-ups are a very common exercise that can be incorporated into conditioning programs in order to strengthen the upper body. As such, the basic exercise is a closed kinetic chain movement that targets the pectoralis major and triceps brachii, as well as the scapular stabilizing muscles.¹ Moreover, there are other muscle groups (e.g. anterior shoulder and core) that are involved and are important for prehabilitation purposes (e.g. preparation for the act of pitching).^{2,3}

Push-up exercises are commonly used in shoulder rehabilitation, for facilitation of proprioceptive feedback mechanisms, muscle co-contraction, and dynamic joint stability training.⁴ Recently, adding an unstable surface while performing the push-up has been suggested in order to increase muscular activity.⁵

One reason for the common utilization of the push-up exercise is due to the relative ease of learning the movement. Additionally, no equipment is necessary for the movement and the exercise can be modified for greater or lesser difficulty depending on the level of physical fitness of the patient. This adaptability is represented by variations that can be used to modify the basic exercise in order to alter the difficulty of the conventional exercise that requires that the hands be placed in a natural position under the shoulder, the back straight, head up, and lower limb straight using the toes as the pivotal point. Authors have used electromyography (EMG) to analyze the different variants of the push-up in order to report the most intensely involved muscles. For example, several push-up variants exist, including the rotational position of the hand-wrist during upper extremity weight bearing,⁶ and different spacing of the base hand position.⁷⁻⁸ With regard to these variations, Gouvali and Boudolos reported that in the posterior variant of the push-up (+30% of arm-forearm length posterior hand position) the pectoralis major was activated at a higher level than in the standard push-up.⁸ Recently, a new variant or modification of the push-up has been examined, namely performing push-ups on an unstable surface.⁸ Although it was difficult to monitor the intensity during the push-up with conventional assessment tools, it has been suggested that the perceived exertion scale may be used as a valid intensity assessment.⁹ The use of the stability ball as a platform for upper-body resistance training has gained

attention in recent years.¹⁰ Current information on the effectiveness of stability balls for athletic performance enhancement¹¹ and in rehabilitation¹² is contradictory and has been questioned because some unstable resistance training has been shown to induce deficits in measures of muscular performance that could impair the final functional performance.¹³ Some researchers have implied that stabilization training may have limited efficacy in altering strength and power due to the relatively low resistance loads utilized during this type of training.¹⁴⁻¹⁵ However, it must be emphasized that the vast majority of studies have studied intervention programs using resistance training exercise on unstable surfaces for the lower limbs.¹⁶

A study by Drinkwater et al¹⁷ examined squats on three different surfaces (stable floor, a foam pad, or the BOSU®). Researchers concluded that balance training should be separated from strength and power training.¹⁷ Cressey et al¹⁶ concluded that training on unstable surfaces for lower limbs attenuated functional performance improvements (e.g. sprint and power outcomes) in healthy, trained athletes. In the Cressey et al study, individuals who had completed 10 weeks of training on unstable surfaces had an average reduction in their performance on the T-Test (-2.9%), no change in countermovement jump predicted power (0.0%), only a slight increase in bounce drop jump (0.8%), and some improvements in the 40-yard sprint as compared with those who trained on a stable surface.

Additionally, descriptive studies on training protocols using unstable devices for the upper limbs have shown that such training conditions during the push-up exercise reduces the intensity of agonist muscle activation^{18,19} and does not result in greater recruitment of stabilizing muscles.^{18,20,21} It has been hypothesized that muscle activity can be influenced by the addition of an unstable surface; however, an increase in muscle activity does not influence muscles in all conditions or subjects equally.^{11,12,19} According to Behm et al¹⁰ the instability training may provide a minor stimulus for limb musculature during exercise but does provide a great deal of core muscle activation.

Finally, contradictory data exists about the effectiveness of resistance training programs implemented using unstable surfaces and few studies have been conducted to compare the effects of stable versus

unstable training on muscles of the upper extremities. Therefore the purpose of this research was to compare the effect that push-up training on stable and unstable surfaces had on strength performance in healthy young men.

METHODS

Subjects

Thirty recreationally active males were recruited (24.97 ± 3.09 years, 80.60 ± 6.94 kg, 175.43 ± 30.31 cm, 3.33 ± 1.62 years of experience), from a fitness center in Valencia, Spain. They reported a minimum of one year's experience in resistance training and affirmed no use of unstable training of the upper limbs in their resistance training programs. They were considered advanced in resistance training according to guidelines from the ACSM.²² None of the subjects had any upper extremity injury or prior shoulder pathology (e.g. stabilization surgery, impingement, pain) during the previous six months. Subjects with pain, neuromuscular disorders, joint or bone disease, or who were taking some form of performance enhancing medication were excluded ($n=12$). Prior to inclusion in the study, the subjects were informed about the investigation procedures and the experimental risks. To be included in the research, they were required to sign an informed consent form. The study was approved by the University of Valencia Institutional Review Board for use of human subjects in the spirit of the Helsinki Declaration, after a briefing by the study staff about the purposes, procedures, and risks of the study.

Design

This study utilized a quasi-experimental design with random group assignment. The purpose of this research was to compare the effects of 3 different push-up unstable training surfaces: floor, BOSU®, and T-Bow® during an eight week training period. Outcome measures included the one-repetition maximum (1 RM) in bench press (BP) and a push-up muscular endurance test performed using traditional floor push-ups. Subjects trained 2 days per week and the same procedures for training were conducted for the three different groups: traditional push-ups (Tp), BOSU® push-ups (Bp), T-Bow® push-ups (TBp). Each group performed three sets of 10 repetitions at a cadence during repetitions of a 2:2

ratio (2 seconds eccentric: 2 seconds concentric) during which a digital metronome set the timing. The authors choose the push-up because it is a multi-joint exercise for the upper limbs that elicits lumbar stability.²¹ Two unstable devices were employed because of their popularity and common utilization during functional training, and because their effects on muscular strength development in a healthy athletic population are unknown.^{10,13,23}

Procedures

Familiarization sessions were performed so participants could become accustomed to and learn the proper execution of the BOSU® and T-Bow® push-ups, as well as to determine maximal strength and muscular endurance. Data collection for both anthropometric and testing took place over a period of two weeks with one testing session each week. Testing sessions were carried out in summer, on the same day of the week, at the same time of day and under the same conditions for all tests. All subjects received verbal encouragement throughout all the physical tests. The main researcher and co-researchers collaborated in the procedures and data collection.

Subjects included in the study were randomly assigned to the traditional group (Tp) ($n=10$), BOSU® group (Bp) ($n=10$) or T-Bow® group (TBp) ($n=10$). Before the intervention, subjects upper body muscular strength was evaluated using the maximum bench press strength test (1-RM)¹ and muscular endurance was evaluated using the push-up test.²⁴ The intervention lasted 8 weeks, and the subjects trained at a frequency of two days per week. The authors decided that intervention groups should train 2 days per week because: i) there is still a scarcity of studies that control the dose-response in unstable resistance training for strengthening; ii) although subjects were highly trained, it was the first time that they had performed periodized strength training on an unstable surface, and iii) two days is the minimum training frequency suggested for the improvement of strength.^{1,22}

In the intervention phase all groups performed 3 sets of 10 repetitions of push-ups in their respective training conditions. If a subject did not have enough intensity with their own body weight monitored by having at least a score of seven on the OMNI-Res (OMNI-R) scale, external load was added using weight plates that

were placed on the upper back of the subject in increments of 5-kg. The intensity of training was both assessed and maintained throughout the study by using the OMNI-R perception²⁵ of effort scale. OMNI-R (0-10) was defined as the sense of effort experienced while performing physical work, in this case subjects were told “we want you to rate your perception of exertion in relation to how heavy the exercise feels to you”. The traditional training group performed their push-ups on the stable surface (floor). The BOSU® group performed the push-ups on the BOSU®. The BOSU® was placed so the convex side was in contact with the ground. The T-Bow® group performed their push-ups on the T-Bow® with the convex side on the floor. Unstable resistance training decreases the force in the limbs during dynamic muscular effort because it is necessary for greater muscle stabilization to occur, therefore the external resistance must be decreased.^{14,15} In this sense, Behm and Anderson¹⁵ suggested that it is appropriate to adjust the number of repetitions and the resistance. Although the authors do not know the exact correlations in the intensities between exercises when performed in unstable and stable conditions, previous authors have concluded that using perceived exertion ratings during unstable exercise is a valid method for monitoring the intensity experienced during exercise⁹ similarly to monitoring during stable exercises.²⁷

Each test and intervention session was supervised by the same examiner (ICH-M), who monitored strict compliance with the protocol. Subjects were allowed to continue with their usual lower limb resistance training, cardiovascular training, and upper limb training other than chest press exercises and other exercises (e.g. shoulder press) that included elbow extension.

Testing

All testing was performed in a fitness center. Good intraclass correlation coefficient (ICC) reliability measures have been reported for the push-up test (0.8-0.9) and the bench press test (0.78-0.82).²⁸

1 RM Bench press

After an adequate warm-up of ten bench press repetitions that did not elicit muscular failure (inability to complete the full range of movement repetition for the exercise), a resistance was estimated that

would force the participant to fail to be able to complete more than 6 repetitions. The amount of weight that could be moved no more than 6 repetitions was recorded. Participants had a total of three attempts to adjust the weight, every attempt was separated by three minutes of rest participants' 1 RMs were calculated using tables provided by the National Strength and Conditioning Association.¹

Push-up muscular endurance test

The muscular endurance push-up test was performed using the criteria outlined in the ACSM's Health-Related Physical Fitness Assessment Manual.²⁴ In the standard push-up position, subjects raised the body by straightening the elbows and then lowered the body until the chin touched the mat, without allowing the stomach to touch the mat and then returned to the starting position. The maximum number of push-ups performed consecutively without rest was counted. The test was stopped when the subjects were unable to maintain the appropriate technique for two repetitions, with special emphasis on maintaining neutral positioning of the lumbar spine through the test.

Training Exercises

Push-up

Push-up training was carried out following the model previously established by Beachle & Earle.¹ The starting position was established as follows: back straight and stabilized, the hands shoulder-width apart and the elbows fully extended. From this



Figure 1. Traditional push-up position.



Figure 2. BOSU® push-up position.

position the body was lowered until the upper arms were parallel to the ground and then the subject returned to the original position and repeated the method for each condition (Figure 1).

BOSU® push-up

The subjects performed the BOSU® push-ups using the same technique as in traditional push-ups, but adding the BOSU® (flat side up) for instability.²⁹ The BOSU® was positioned with the convex part on the ground, so that the subject would begin in a starting position above the device (Figure 2).

T-Bow® push-up

The same push-up technique was utilized for the T-Bow® group. The T-Bow® is a curved, rectangular plastic device, in the design of an arch.²⁶ The T-Bow® was positioned so that the convex edge was in contact with the floor and the subject gripped the outside edges of the device (Figure 3). The grip on the device varied depending on the width of the subject's shoulders and by preference of the subjects; hands were placed in the position where the subject felt comfortable and safe to perform the exercise.

STATISTICAL METHODS

All statistical analyses were carried out using Statgraphics Centurion XV version 15.2.06 (StatPoint Technologies Inc., Warrenton, VA). Data analysis was performed, including descriptive statistics to check the normality of distribution using Levene's test ($\alpha = 0.05$). The effect of the different push-up



Figure 3. T-Bow® push-up position.

conditions on 1 RM and push-up endurance tests was analyzed using a 2 x 3 repeated-measures ANOVA (dependent variable [1 RM, number of repetitions in push-up endurance test] type of training [Floor, BOSU®, T-Bow®] x time [pre- and post-treatment]). If the results met the assumptions of the model, one-way between-subjects ANOVA was then utilized to detect significant differences between push-up techniques. If significant differences were found, Fisher test (LSD) was used to distinguish if there was a significant difference between push-up techniques. p-values of ≤ 0.05 were used for all calculations to determine whether statistically significant differences existed.

RESULTS

Individual test means and standard deviations were analyzed (Table 1). No changes were between pre-training and post-training mean scores for endurance testing between conditions: TP (pre = 18.8 ± 5.78 repetitions; post 19.7 ± 6.07 repetitions) BP (pre = 17.4 ± 5.75 repetitions; post 19.9 ± 5.78 repetitions) and TBp (pre = 21.5 ± 6.05 repetitions; post: 24.4 ± 5.94 repetitions), and these results revealed no significant differences between groups. Mean 1 RM results demonstrated (Table 2) no significant improvement by any group: TP (pre = 81.9 ± 11.34 kg; post 82.3 ± 12.45 kg), BP, TBp (pre 76.4 ± 9.83 kg; post 80.2 ± 10.88 kg and pre 82.3 ± 9.16 kg; post 85.8 ± 9.22 kg, respectively), and there were no significant differences between groups. It should be noted that all groups show a trend for improvement

Table 1. Performance in the push-up endurance test in number of repetitions.

Push-up type	Mean repetitions pre-study	Mean repetitions inter-study	Mean repetitions post-study	F value ^a	ANOVA (p Value) ^b
Traditional (Tp) n= 10	18.8 ± 5.78 reps	18.8 ± 5.95 reps	19.7 ± 6.07 reps	0.08	0.92
Bosu (Bp) n = 10	17.4 ± 5.75 reps	19.1 ± 5.19 reps	19.9 ± 5.78 reps	0.01	0.99
T-Bow (TBp) n= 10	21.5 ± 6.05 reps	22.7 ± 6.44 reps	24.4 ± 5.94 reps	0.52	0.59

^aAnalysis of variance revealed no significant difference for three experimental conditions.
^bAnalysis of variance revealed no significant difference between groups.

in endurance and strength performance, even though changes were non-significant.

No statistically significant differences existed between the pre- vs post-treatment endurance test (F = 2.00; p = 0.154) or the 1 RM test (F = 0.67; p = 0.52) between training conditions.

Similarly, when comparing maximum strength, all groups increased their performance, but these improve-

ments were not statistically significant. There was no significant main effect for type of intervention in 1 RM (F = 1.74, p = 0.51).

DISCUSSION

Significant differences were not found between treatment groups and the current data appear to support the trend found in similar studies (with training of the lower limbs), where no statistically significant

Table 2. Performance on 1 RM bench press test in kilograms.

Condition	Mean kilograms pre-study	Mean kilograms inter-study	Mean kilograms post-study ^b	F.value ^a	ANOVA (p Value) ^b
Traditional (Tp) n= 10	81.9 ± 11.34	82.4 ± 11.32	82.3 ± 12.45	0.01	0.99
Bosu (Bp) n= 10	76.4 ± 9.83	78.1 ± 12.00	80.2 ± 10.88	0.86	0.43
T-Bow (TBp) n= 10	82.3 ± 9.16	84.6 ± 9.10	85.8 ± 9.22	0.38	0.68

^aAnalysis of variance revealed no significant difference for three experimental conditions.
^bAnalysis of variance revealed no significant difference between groups.

improvements were reported between groups of highly trained subjects who trained on stable surfaces and groups who trained on unstable surfaces.¹⁶ Previous authors have reported that the use of moderately unstable surfaces did not provide sufficient challenges to affect muscular strength status in highly resistance-trained individuals.¹¹ This could be a cause of the current results because the subjects in the current study were advanced (individuals with years of resistance training experience) in resistance training. The primary reason for lack of change in muscular strength and endurance could be the insufficient stimulus for muscle strengthening when performing resistance training on unstable surfaces because it is necessary to utilize many muscles to maintain balance and stability. A second possible explanation for the results of the current study is that, as stated in previous reports,^{10,19,30} there was a reduction in muscle activation of the major muscles when training using an unstable environment. Additionally, many authors have suggested that levels of muscle activity are task-dependent, and using unstable surfaces limits task specificity.^{2,19,31} Other factors that have been suggested to influence muscle activation while on unstable surfaces include placement of the device,⁹ characteristics of the unstable device,¹¹ and the training status of the subjects.^{2,15}

In a previous study, Cowley et al³² reported that an unstable platform was effective in increasing strength and work capacity in the barbell chest-press exercise for untrained women. In their study only three weeks of training was performed using three sets of 3– 5 repetitions at loads greater or equal to 85% of 1 RM. The load used by Cowley and colleagues was quite different than that used in the current study. The primary difference between these two studies is the placement of the unstable devices. In the current study the unstable devices were placed so that the upper limbs became unstable, whereas Cowley's study utilized the unstable devices as a replacement for the flat bench, where the lower back rested on the device.

The data from the current study is very similar to that from previous research by Cressey et al.¹⁶ Trained subjects did not increase athletic performance after 10 weeks of training intervention utilizing an unstable surface. The main difference between the studies is that the current study used unstable devices for upper limb training, while Cressey con-

ducted lower limb training. Interestingly, results of both studies were not statistically significant with regard to measures of muscular strength and endurance performance in trained subjects. The results of the current study are similar to previous research that involves unstable resistance training of the lower limb¹⁶ and open kinetic chain upper limb exercise,^{18,30} and is consistent by recent conclusions reported by Behm et al¹⁰ in the Canadian Society for Exercise Physiology.¹³ Interestingly, in the current investigation, there was no attenuation in performance of the bench press 1 RM. This data could indicate that training performed on an unstable surface is a sufficient stimulus to maintain strength levels in highly resistance trained subjects if they exercise at the same OMNI-R intensity used during exercises performed on stable surfaces.

The following limitations may have effects on interpreting the results of the study. The lack of an electromyographic (EMG) analysis and the status of the highly trained subjects constitute a limitation at present, as it has been impossible to compare our results with previous studies such as Lehman et al¹⁸ who reported no increase in EMG with the use of elements of instability while performing push-ups. Another limitation was that the subjects were allowed continue with their resistance training for lower limbs and upper limbs (without similar press-type exercises) which could have interfered with the research results. Since this study was conducted with highly trained individuals no direct clinical comparisons can be made to other populations. The sample size of the current investigation was small, and perhaps a greater number of subjects have demonstrated more robust results.

Future research should be conducted to investigate interventions of longer duration and include the use of core stability tests such as the Biering-Sorensen test, curl-up test, and the side bridge test as suggested by McGill et al³³ in order to assess the effects on the trunk that may occur during upper extremity training using unstable surfaces. Lastly, future researchers could evaluate the effects of upper extremity training on unstable surfaces on the stabilizers of the scapulothoracic articulation and glenohumeral joint in order to determine their contribution to the shoulder complex muscular performance.

Practical applications

Results of the current study may be useful for coaches, rehabilitation professionals, and personal trainers when choosing upper extremity closed chain resistance-training exercises because the current data demonstrated that no significant improvements were obtained after performance of a push-up training program in unstable conditions. Therefore, push-up training using unstable surfaces may need to have schedules implemented in phases designed to maintain maximum strength and muscle endurance for push-ups as compared to a goal of increasing strength and endurance. This might be an alternative for a mesocycle as the muscles of the upper extremities would have to adapt to a new training stimulus or when high loads might be contraindicated.

Unstable devices used during push-up training could be implemented in phases orientated toward enhancement of core strengthening and therapeutic training (e.g proprioceptive or neuromuscular control objectives).^{10,13} However, if the decision is made to use unstable surfaces, caution must be taken with persons with shoulder pathology or unstable joints.

CONCLUSION

The results of the current study indicate that the use of unstable surfaces during the push-up exercise in trained subjects leads to comparable, non-significant improvements in the performance of maximum strength and muscular endurance measurements to those seen during push-ups performed on stable surfaces.

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