A Comparison of two Plyometric Training Programmes on Vertical and Horizontal Power Enhancement

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Abstract

For many years, plyometric exercises that involve stretching an active muscle prior to its shortening (SSC) have been used by coaches for improving jumping ability and anerobic power. One of the most popular plyometric exercises is drop jumping, or depth jumping (DJ, Wilt, 1975). The present study compared the effects of the conventional bounce drop jump (BDJ) training with the no-bounce drop jump training which proclaimed by Dursenev and Raevsky (1978) to be more effective. Forty-eight female nursing students from Meiho Institute of technology served as the subjects and the whole training course took 12 weeks to complete. The training effects compared 4 sets of pre- and posttest results of 50-meter dash, 9 x 4 meters shuttle run (tests of horizontal power), standing broad jump and jump-and-reach tests (tests of vertical power) using one-way ANOVA and t-test. Both training groups showed significant improvement on the 50-meter dash performance ($p<0.004$) when compared to the control group. The two training groups also showed pre- to post-test significant training effects on vertical power (the standing broad jump at $p<.01$ and jump-and-reach tests at $p<.001$). It was concluded that both of these training programmes were effective in improving horizontal and vertical power; however, the results did not support the speculation of Dursenev and Raevsky (1978) that no-bounce drop jump was more effective than the conventional drop jump. Based on these results, the author recommended that the conventional bounce drop jump be used in the future jump training. The conventional BDJ can provide the training result the athletes need in both eccentric and concentric contraction regimens.

Keywords: Plyometrics; Stretch shortening cycle; Stretch shortening cycle; Conventional bounce drop jump; No-bounce drop jump; Power; Eccentric contraction

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Introduction

For many years, plyometric exercises that involve stretching an active muscle prior to its shortening have been used by coaches for improving jumping ability and anaerobic power. One of the most popular plyometric exercises is drop jumping, or depth jumping (DJ; Wilt, l975). Performing the drop jump involves an athlete dropping from a raised platform and upon landing, immediately performing a vertical jump. At the instant of landing, the knees of the athletes are forced to flex downward due to gravity, which causes athlete's extensors muscles to stretch eccentrically. It has been demonstrated in experiments with isolated frog muscles (Asmussen, et at 1974; Thys, 1972) that if the stretched muscles respond fast enough without too much delay, the elastic energy generated by the stretch reflex, or myotatic reflex could be reutilized to generate much stronger contractions. In this process, the reutilization of elastic energy combines with the myotatic reflex and, together with the shortening of the amortization phase, creates a much more forceful contraction in the muscles than a simple concentric contraction alone. This process is termed the stretch shortening cycle (SSC; Steben and Steben 1981) which is central to plyometric training (Radcliffe and Farentinos 1985; Chu, 1998).

The enhancement of performance by using the SSC has been demonstrated in both isolated animal muscle as well as in human experiments. Komi and Bosco compared the vertical jump performance of men and women under three conditions: squat jump (SJ), countermovement jump (CMJ) and drop jump (DJ). All subjects attained the greatest jump heights in the DJ condition, followed by the CMJ and SJ conditions. Men jumped higher than women, but women were better able to utilize stored elastic energy (Komi et al l978). Early Soviet research concluded that DJ is an effective means of increasing athletes' speed and strength capabilities. Verkhoshanski (1969) proclaimed 0.8 m as the ideal height for achieving maximum speed in switching from the eccentric to the concentric phase of the stretch-shortening cycle and l.l meters for developing maximal dynamic strength. He also recommended no more than 40 jumps in a single workout, performed no more than twice a week (Chu, 1998).

A later study by Verkhoshanski and Tatyan (1973) comparing three groups of athletes showed that depth jumps were more effective than weight training, the jump-and-reach, or horizontal hops for developing speed and strength capabilities. Several researchers have found that jumping height can really be improved through plyometrics. Keohane (1977) found that female figure skaters who participated in a drop jump programme increased not only their score on a jump-and-reach test, but also gained 5.8 cm in height during an actual skating jump. Blattner and Noble (1979) compared a DJ group, an isokinetic group, and a control group. They found both the DJ and isokinetic groups jumped significantly higher than the controls. Polhemus and Burkhardt (l980) examined the effects of various plyometric programmes on strength gains using college football players. They compared three training methods: conventional weight training, weight training plus DJ, and DJ with additional weight vest. The results indicated that the DJ group with additional weight vest was significantly superior to the other groups in all tests except the military press. Research conducted in the United States since the late 1970s has shown that drop jumps generally increase athletes' abilities to jump higher in test situations. Only in the study done by Scoles (1978) was the gain not significantly different from zero, but this could be attributed to the fact that he did not select a very sensitive statistical test (Bobbert, 1990).

Despite the large number of plyometric studies, none have looked into the training of plantor flexor muscles in the eccentric regimen (ER). Dursenev and Raevsky (1978) contended that the training emphasis for jumping events should be on the knee extensors in the eccentric regimen, not the concentric regimen. It was argued that the strength needed most by a jumper is used to prevent excessive flexion during amortization and not for push-off leg extension. If excessive flexion of the support leg in this phase is prevented, then the final phase of the take-off is executed successfully. In order to develop the "super-maximum" strength in yielding phase, Dursenev and Raevsky conducted studies with the elevation of DJ heights to over 2 meters. They concluded that drop jumps from 2 meters or higher without rebound jumps (NBDJ) were superior for improving muscle strength to conventional DJ with lower dropping height. However, the statistical data, along with the methods for training and testing, were omitted in the translation paper. The training theory and effects of Dursenev and Raivsky (1978) has posted doubts and challenge to the effects of the conventional bounce drop jump method which must be tested and clarified as soon as possible.

Therefore, the primary purposes of this study were:

1. To investigate the training effects of the conventional drop jump training programme on vertical and horizontal power enhancement.
2. Using a modified height of l.1 meters, for untrained college age girls, incorporated with no-rebound drop jumps to verify the theory and training effects reported by Dursenev and Raevsky (1978).
3. To compare the effects of vertical and horizontal power enhancement of the two training programmes to see if one is superior to the other, and if so, determine where the differences exist.

Subjects and Protocol

Forty-eight female college students were recruited as subjects for the study from Meiho College of Technology in Taiwan. Descriptive characteristics of the subjects were as following:

Table 4.1 Subjects description

Groups	Subjects	Height (cm)	Mass (kg)	Age (yr)
NBDJ 110cm	N = 15	163 ± 5.2	50.8 ± 8.9	19 ± 1
DJ 70cm	N= 18	164 ± 5.8	52.2 ± 9.5	19 ± 1
Control	N= 15	163 ± 6.4	51.2 ± 9.2	19 ± 2

A total of 50 subjects started this experiment, 48 subjects finished the study.

After a regular physical check-up in the beginning of the semester, subjects were randomly assigned into one of three groups: NBDJ 110cm group, DJ 70cm group, or control group. At the time of the experiment, none of the subjects had potential medical problems or history of ankle, knee, or back injury. None of the subjects were participating in any inter- or intra-scholastic competitions, or any recreational activity that involved jumping. However, as physical education classes are mandatory to all students in Taiwan, the subjects participated in two such 50-minute sessions per week. Class activities varied from teacher to teacher, but all test subjects were enrolled in the same class; thus it is assumed that all subjects participated in the same amount and type of exercises. Subjects from NBDJ and DJ groups received two DJ training sessions per week during the beginning of PE class. Training groups had two familiarization sessions before 8 weeks of training, while control group students simply continued to engage in their regular PE activities.

<u>Tests</u>

Pretests were conducted two weeks before eight weeks of plyometric training. Two weeks of 4 sessions were used to give subjects an introduction, take random sampling, and familiarize them with the drop jump training. Post-tests were conducted right after training sessions. Four tests were selected to measure the enhancement of vertical and horizontal power: the 4 X 9 meter shuttle-run, 50 meter dash, standing broad jump, and countermovement jump-and-reach tests. All tests were executed, supervised, and conducted by the researcher. The procedures of these four tests are described below:

4 x 9 m shuttle run test:

On a volleyball court, the subject was asked to stand in front of a sideline facing the other sideline. Two relay batons were placed on the other sideline. The subject was instructed to run and pick up one baton from the other sideline, place it on the original sideline, run back to pick up the second baton, then rush pass the original sideline as fast as possible. The time (in seconds to two places of decimal) was recorded using a stopwatch by the author.

50-meter dash test:

This test was also recorded using a stopwatch by the author. During the test, a student leader was asked to give the verbal order of "On your mark, ready? Go!", while the researcher stood by the 50 meter line keeping time. Subjects used standing posture to start the dash test.

Standing broad jump test:

Subjects stood before the test line with two feet about shoulder width apart. They were instructed to flex their knees once, using their hands to help the propulsion of the jump, and jump as far as possible. Steel meter tape was used to measure the distance using metrical system. Only the best score out of three trials was used for the test, with two digits after the decimal recorded.

Countermovement jump-and-reach test:

A Sergeant-jump test board was nailed to the wall of the gym for this test. Subjects were instructed to use countermovement jump from standing position to take the tests. Subject first used her dominant hand to reach up and make a high mark on the board, then jumped, making a second mark on the board. The test score was the distance between the first and second mark. Three trials were given, but only the best score was used for the test. Scores were recorded in meters, to 2 decimal places.

Training

The full programme took 12 weeks to complete. The first two weeks were used for grouping, pre-tests, training instruction, and familiarization. The last two weeks were for the post-testing. For the remaining eight weeks, both training groups completed four sets of ten repetitions in each session. Both training groups rested at least 20 seconds between each repetition, and a two-minute break was allowed in every set of training. The no-rebound jump group (NBDJ 110cm) trained with a 1.1 m box, performing drop jumps without rebounds in order to train the plantar flexor muscles of the eccentric (ER) phase. The conventional drop jump group (DJ 70cm) trained with a 70 cm box, using their hands to help their propulsion upon landing in order to train muscles of concentric (CR) phase. They were instructed to rebound off the ground as quickly as possible to prevent the delay (damping effect), which would increase the coupling time and decrease training effect on the joints.

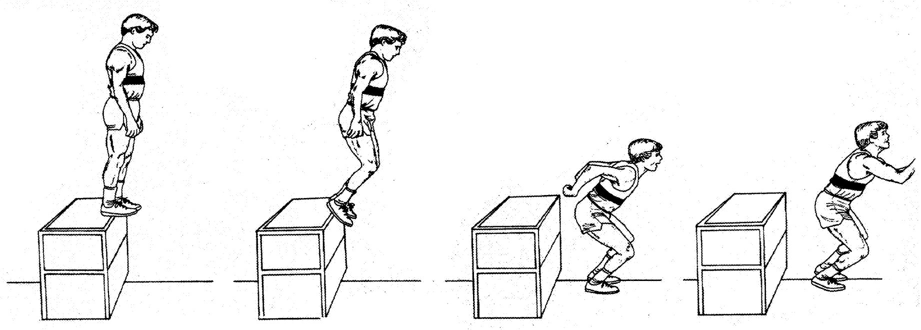

Figure 1: The sequence of a typical drop jump training (box jump)
(Excerpted from Radcliffe and Farentinos, 1985)

Statistical Analysis

Group data for each experimental group were inspected for distribution normality. Only the 50-meter dash group did not satisfy this requirement, with two outliers in the data set. A Kruskal-Wallis one-way ANOVA was used to correct and calculate the differences on this test, then, the Mann-Whitney U – Wilcoxon rank sum W test was employed to compare the differences within and between paired groups. As for the shuttle run, standing broad jump, and countermovement jump-and-reach tests, a one-way ANOVA was performed to analyze the difference of training effects. To compare the training effects of the other three tests groups for the pre- and posttests, a paired t-test was used. Alpha level was set at $p<0.05$ for all comparisons. The results of all statistical tests and group data are listed in the next chapters for discussion.

Results

The results of the present study indicated that an eight-week training programme of conventional DJ and NBDJ significantly improved 50 m dash speed, standing broad jump distance, and countermovement jump height. The only exception regarding improved performance was the shuttle run speed. There was also a significant difference in the 50m dash tests between DJ and control groups, as well as the NBDJ and control groups. However, no significant differences were found between DJ and NBDJ groups in any of the four tests. The control group showed no improvement in 4 x 9 shuttle run test, 50m dash test and standing broad jump test, the only improvement for this group is in the countermovement jump-and-reach test.

When comparing pre- to post-test data in the 4 x 9 m shuttle run test, two experimental groups had gains very similar to the control group (Table 4.2 and Figure 4.1). There was no significant difference between or within the groups.

Table 4.2

Pre- and posttest means(s) of 4 x 9 m shuttle run test by the Group

Group	Pretest		Posttest		Gain	F	t-test (Pre-/Post)
	M	± SD	M	± SD	(S)		
1.NBDJ	10.90	0.36	10.73	0.57	-0.17	0.432 **NS**	NS
2.DJ	11.02	0.56	10.91	0.58	-0.11	0.432 **NS**	NS
3.Control	10.90	0.43	10.89	0.49	-0.01	0.432 **NS**	NS

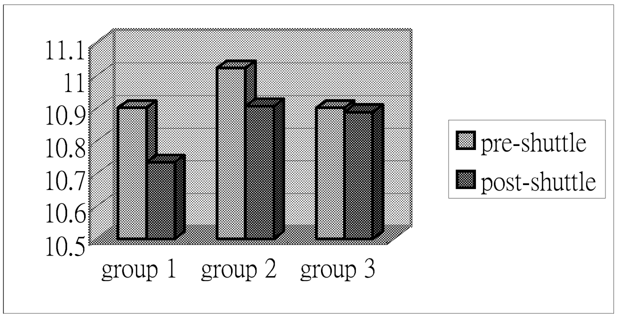

Figure 4.1 Mean (s) change (pre to post) of shuttle run test

Comparing pre- to posttest data in the 50 m dash test, the NBDJ and DJ training groups increased their speed by 0.22 and 0.30 seconds respectively, while the control group decreased their speed by 0.28 seconds. There was a significant difference between group 1 and group 3, also between group 2 and group3. The pre- posttest difference within group 1 and group 2 was significant at 0.05 and 0.001 level. (Table 4.3 and Figure 4.2).

Table 4.3

Pre- and posttest means (s) of 50 m dash test by the Group

Group	Pretest		Posttest		Gain	F	t-test (Pre-/post)
	M	±SD	M	± SD	(S)		
1.NBDJ	9.24	0.73	9.02	0.70	-0.22	**6.25 (p<0.04)**	* p<0.05
2.DJ	9.65	0.84	9.35	0.81	-0.30	$ NBDJ>control	** p<0.001
3.Control	9.57	0.87	9.85	0.61	+0.28	**Φ** DJ > control	NS

Φ: significance at 0.009 level $: **significance at 0.002 level**

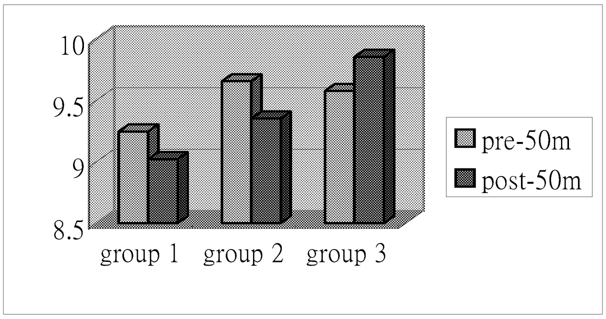

Figure 4.2 Mean (s) Change (post - pre) of 50 m dash test

Table 4.4 and Figure 4.3 show comparisons of pre- and posttest data for the standing broad jump test. The NBDJ, DJ and Control groups improved their jumping distance by 7 cm, 7 cm and 2 cm, respectively. The differences were significant within NBDJ group and DJ group at 0.01 and 0.001 levels, but not significant among the three groups.

Table 4.4

Pre- and posttest means (m) of standing broad jump test by the group.

Group	Pretest		Posttest		Gain	**F**	t-test (pre-/post)
	M ±	SD	M ±	SD	(m)		
1.NBDJ	1.68	0.19	1.75	0.21	+0.07	2.483 **NS**	* $p<0.01$
2.DJ	1.62	0.22	1.69	0.21	+0.07	2.483 **NS**	** $p<0.001$
3.Control	1.64	0.17	1.66	0.16	+0.02	2.483 **NS**	NS

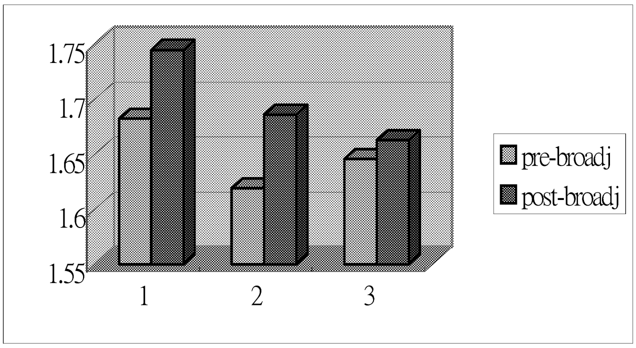

Figure 4. 3 Mean (cm) change (post - pre) of standing broad jump test

Table 4.5 and Figure 4.4 compare the pre- and posttest data of the countermovement jump-and-reach test. All three groups improved their jumping heights significantly after the training period by 3.86, 4.17 and 3.07 cm, respectively.

However, no significant difference existed among any of the three groups.

Table 4.5

Pre- and posttest means (cm) jump-and-reach test by the group

Group	Pretest		Posttest		Gain	F	t-test (Pre-/Post)
	M ± SD		M ± SD		(cm)		
1.NBDJ	32.67	4.58	36.53	4.56	+3.86	0.385 **NS**	* **p<0.001**
2.DJ	31.22	6.02	35.39	5.99	+4.17	0.385 **NS**	* * **p<0.001**
3.Control	36.80	7.45	39.87	5.60	+3.07	0.385 **NS**	**$ P<0.01**

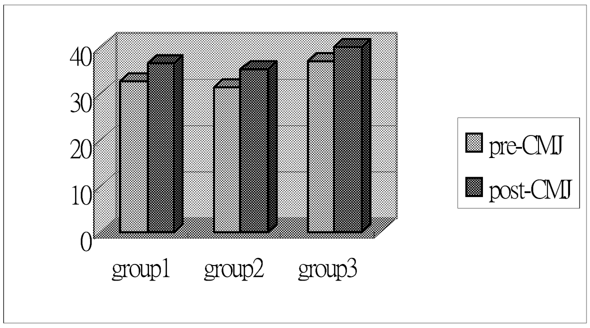

Figure 4.4 Mean (cm) change (post - pre) of jump-and-reach test

It appeared that both NBDJ group and DJ group had about the same improvement rate in all four tests over eight weeks of training. Both training groups showed training effects on the 50 m dash test, standing broad jump and jump-and-reach test, but not on the 4 x 9 m shuttle run test. There was no significant difference between the two experimental groups in any of the four tests, and since neither group scored higher over the other group in horizontal power tests (50 m and shuttle run) or vertical power tests (standing broad jump and jump-and-reach test), there was no interaction between two groups.

Discussion

The study by Dursenev and Raevsky (1978) purported that training with a combination of a very high dropping distance (2 meters or more), a no-rebound jump, and the targeting of plantar flexor muscles could bring about the best gains in super-maximum power. The purpose of the present study was to compare this special training method with the conventional bounce drop jump training aimed at improving power and speed.

The outcome of the present study showed one significant between-group results, with both training groups significantly improved the 50-meter dash performance (horizontal speed, $F = 6.250$, $p<0.004$) when compared to the control group. The two training groups also showed pre- to post training effects on vertical power (the standing broad jump and jump-and-reach tests). In the standing broad jump test, the NBDJ group increased their mean jumping ability by 0.07 cm ($p<0.01$) and the DJ group also increased 0.07 cm ($p<0.001$). At the same time, the NBDJ group increased their mean jump-and-reach ability by 3.86 cm (11.82%), with the DJ group increasing 4.17 cm (13.36%). The results were comparable to the study of Gehri et al (1998), which the DJ group showed improvements of 13.61%, 8.04% and 10.95% respectively in SJ, CMJ and DJ tests. But our results were lower than Tsai's study (1998), which documented improvements in its speed-control group of 6.96 cm (18.27%) and 7.8 cm (21.67 %) in its volume-control group. This may be explained by Tsai's use of the 'the best drop jump' to first measure subject's ability before starting the training programme, while neither our study nor the Gehri et al study employed 'the best drop jump' technique. This training variable deserves more serious attention.

While there were improvements in training from both DJ programmes, one of the horizontal power test items (shuttle run) did not produce the same result. The results also indicated that the control group did not make any improvement on this shuttle run test either. It was observed by the researcher that during the tests, subjects sometimes threw the batons before they actually reached the line. All These findings could indicate that this test was not a valid measurement of horizontal speed, due to the use of batons that decreased reliability. This speed test should be abandoned or revised in the future.

In summary, since the results did not show that either training methods was better than the other in improving test results, and there was no interaction between two methods on vertical power or horizontal speed improvement, our investigation did not support the super training effects purported by the training method described by Dursenev and Raevsky (1978). Why there was inconsistency between our present study and the study of Dursenev and Raevsky (1978) is unclear. In biomechanics, the best training for maximal jumping improvement should include the elements that can maximize both the potential and kinetic energies. This maximization should also include the finely tuned movement control, so the energy produced by the muscles of the lower extremities would not be wasted in the execution of joint rotations. The training method of Dursenev et al apparently is a dynamical resistance training also which targeted the eccentric regimen (ER). This method might be very useful for jumpers who needed the remedy specifically designed for their ER training problem. The common athletes either have no need to get this special training or the traditional bounce drop jump can train this as well since the traditional BDJ consists the training of both the ECC and CC phases. While further studies are needed in order to probe this issue further, the present study does provide some useful information. The strength and conditioning professional can use key findings for improving vertical and horizontal jumping ability by including phyometrics in the athlete's overall training programme.

Conclusion

Based on the results of the present investigation, the training effects of the conventional drop programme and the super training programme purported by Dursenev and Raevsky (1978) are concluded as following:

1. The super training programme purported by Dursenev and Raevsky (1978) is effective in enhancing 50 m dash, standing broad jump and jump-and-reach test performance, however,
2. The conventional bounce drop jump programme is equally good, if not better than the super training programme purported by Dursenev and Raevsky (1978).
3. Based on the results of the present study, the super training programme purported by Dursenev and Raevsky (1978) could not be supported. Athletes who are interested in enhancing power and speed for their sports should use the conventional bounce drop jump instead of the super training programme.

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兩種深跳式訓練法分別對縱向及水平向爆發力的提昇之比較研究

廖逢錦*

摘要

自 1970 年以來，深跳式訓練法(Plyometrics;Depth jump or Drop jump)普遍被田徑界及跳躍性運動項目選手視爲是加強爆發力(Power)的最佳訓練方式.這種訓練方法的理論在西方稱之爲伸展-收縮循環(Streth shortening cycle).本研究比較傳統的深跳式訓練法(Conventional bounce drop jump)與加大深跳距離而無回跳式(No-bounce drop jump)的兩種深跳式訓練法之實際訓練效果.實驗對象爲 48 名美和技術學院護理系女學生：其平均年齡(19±1；19±1；19±2 歲)、平均身高(163±5.2；164±5.8；163±6.4 公分)及平均體重(50.8±8.9；52.2±9.5；51.2±9.2 公斤)；分三組以隨機抽樣參加爲期 12 週的不同訓練。訓練的結果以 50 米短跑、9 米折返跑(水平向爆發力)、立定跳遠及薩氏縱跳(縱向爆發力)等四項測驗使用統計方法(One-way ANOVA 及 t-test)比較其訓練結果，實驗結果顯示兩實驗組在 50 米短跑的訓練成績均明顯優於對照組(P<0.004)；同時兩實驗組在立定跳遠以及薩氏縱跳兩項目上亦有訓練前後顯著之差異效果(立定跳遠 p<0.01；薩氏縱跳 p0.001).而兩實驗組就四項測驗的前後測的組間結果之分析而言，兩實驗組無統計上的顯著差異.根據這個結果本研究判定加大深跳距離而無回跳式的訓練法沒有比傳統式的深跳訓練法優異;加大跳跳距離而無回跳式的訓練法或許對某些需要特別加強離心收縮(Eccentric contraction)訓練的選手有其特殊意義，對一般選手而言傳統式的深跳訓練法已足以達到他們所需要的訓練目標。

關鍵字：深跳式訓練法；伸展-收縮循環；傳統的深跳式訓練法；
加大深跳距離而無回跳之深跳式；爆發力；離心收縮

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