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Original Article

Effect of Core Stability Training Program on Tuck Jump Kinematics in Male Youth Soccer Players with Core Dysfunction

Parsa Saber[1], Ali Asghar Norasteh[2], Amir Ghiami Rad[3]

1. Corresponding author: M.Sc of Physical Education-Sport Injury & Corrective Exercise, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran (Corresponding Author)
2. Prof., Ph.D Physiotherapy, Department of Sport injury & Corrective Exercise, Faculty of Physical Education & Sport Sciences , University of Guilan, Rasht, Iran.
3. Assistant Prof., Department of Physical Education and Sport Science, Faculty of Motor Behavior, University of Tabriz, Tabriz, Iran.

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Abstract

The tuck jump assessment (TJA) has been proposed to identify neuromuscular deficits and plyometric technique flaws related to anterior cruciate ligament injury. The aim of this study was to investigate the effect of core stability training program on TJA in male youth soccer players with core dysfunction. Totally, the participants of the current study were 30 elite youth soccer players screened by TJA to determine core dysfunction. During TJA, the players whose thighs were not parallel (peak of jump) and who had a pause between jumps as well as did not land in the same footprint were considered as participants with core dysfunction. The participants were randomly divided into two groups including core-training (n=15) and control (n=15) groups participated in pre- and post-tests (age=16.08±0.81 years, weight=64.16±8.61 kg, height=1.74±0.06 m, body mass index=20.89±1.78 kg/m^2 and competitive history=4.28±1.10 years). Core stability training group completed 12-week training program (3 sessions each week, totally 36 sessions), while control group only did their traditional soccer training. The effectiveness of core stability training intervention was assessed by performing core stability tests with four positions. Data were analyzed using a mixed design (2×2) repeated measures ANOVA and Bonferroni test. The aim of this study was to evaluate core stability. Study results showed that core stability training significantly reduced the mean of tuck jump flaws. Consequently, 12-week core stability training provides noticeable improvement for kinematic of tuck jump in youth soccer players with core dysfunction.

Keywords: Anterior Cruciate Ligament Injury, Corrective Exercise, Functional Screening, Injury Prevention, Neuromuscular Deficits

1. Email: parsaber7@gmail.com
2. Email: asgharnorasteh@yahoo.com
3. Email: amirghiami@yahoo.com

Introduction

Soccer is the most popular sport with nearly 300 million players worldwide.[1] Soccer as a complex and high intensity contact sport is associated with a great injury risk.[2] The rate of incidence is 0.40 injuries per player per season in elite male youth soccer, corresponding to 2.31 matches per injury as well as 21.9 days of average length of absence.[3] Despite a linear increase in number of injuries with age,[3] a period of heightened risk has been indicated during peak height velocity (PHV),[4] referring to the time of the maximal rate of growth during the adolescent growth spurt.[5] Moreover, the obtained data demonstrate that the injury rates are highest in players aged 15 years (80 injuries/ 1000 hours of practice).[6] Most anterior cruciate ligament (ACL) injuries occur during a non-contact episode, especially during deceleration, landing tasks or lateral pivoting, related to high loads on the knee joint.[7,8] Intrinsic risk factors for ACL injury are composed of neuromuscular, hormonal and anatomic abnormalities.[9] An aberrant neuromuscular control as one of these factors is modifiable; hence, it presents a direction for neuromuscular training with high-risk individuals.[10] Four common motor performance components, potentially contributing to non-contact ACL injury during landing have been found through video analyses:[10] 1) The knees collapse medially during landing, 2) The injured knee is near full extension at landing, 3) If the weight of most athletes not that of all of them is supported on a single limb, and 4) The trunk is bended laterally at landing. Moreover, there are four neuromuscular imbalances related to these components of ACL injury[10]as following: 1) An enhanced reliance on frontal plane control than sagittal plane control (ligament dominance or dynamic valgus),[11,12] 2) A quadriceps-dominant strategy to stabilize the knee joint with lower contributions from the hamstring muscles (quadriceps dominance),[13] 3) Greater coordination, balance and strength in the dominant limb (leg dominance),[12] and 4) Declined stability and proprioception of the trunk (trunk dominance).[14] Although there is little research, the relationship between knee injuries and neuromuscular risk factors has also been reported in young male athletes.[15] A number of studies have found the relationship between ACL non-contact injuries and poor core stability.[16,17] Specially, trunk neuromuscular control deficits enhance knee valgus and hip adduction torque during landing tasks finally causing ACL injuries.[17] Further, though existing research illustrates that the implementation of neuromuscular training intervention as an effective strategy prevents injuries in youth populations,[15,18] numerous Sports Associations have recognized the risk of injury for young soccer players and developed injury interventions or prevention programs for reducing them.[19,20] These standardized intervention programs are mainly proposed and aimed at improving neuromuscular control, strength, coordination and proprioception. When these interventions are properly implemented in youth soccer teams, the lower limb injuries are effectively reduced by 32–65%. [20, 23] so that these interventions have 50–66% and 77–90% risk decrease in ankle and knee injuries, respectively. [20, 22, 24] Conventionally, the kinematics has been evaluated by 3-dimensional (3-D) motion capture during various sport-specific movements. Assessment of kinematic variables via 3-D motion capture including knee valgus during jump-landing tasks represents both reliable and valid indicators of ACL injury risk. [12] Nevertheless, using 3-D motion capture needs extensive training and is expensive; hence, it is not practical to apply it in most clinical settings. [25] Whereas field-based work should take into account both practice-based and research evidence as much as possible, individuals working within elite sport settings preferentially should adopt strategies to align evidence-based interventions with the demands of professional environments. [26] The landing technique flaws are evaluated using TJA during a maximal repetitive plyometric activity [27] in which landing heights reflect jumping ability of each person and; hence, the forces are tantamount to those regularly experienced during sporting actions. Besides, the repeated nature of the TJA presents an indication for some inherent perturbation and reactive strength capabilities, more meticulously reflecting the demands of movement and high-risk mechanics which are involved in competition. [28] The TJA includes continuous maximal height tuck jumps during ten seconds and consists of the analysis of ten dichotomous and quantitative items. The mentioned ten items are applied to evaluate the four aforementioned neuromuscular imbalances associated with ACL injury (leg and trunk dominance, ligament and quadriceps). [10] The aim of this study was to evaluate the effect of neuromuscular core stability training intervention on reduction of injury risks in elite male youth soccer players with core dysfunction. In addition, considering the high prevalence of injury in young athletes and important role of talent management, the targeted screening and standardization of injury prevention programs seem necessary.

Methods

Participants

Totally, thirty young male soccer players with core muscle dysfunction and trunk dysfunction were screened by TJA and chosen from ninety players participated in the current study. During TJA, the players whose thighs were not parallel (peak of jump) and who had pause between jumps as well as did not land in the same footprint were considered as participants with core muscle dysfunction. [29] All players were members of young teams (15-17 years) from three clubs, which competed in the Iranian Soccer League, Division 1. The soccer players had at least 5-year soccer training and 3-year competitive experience in Iranian Youth Football League (age= 16.08 ± 0.81 years, weight=64.16 ± 8.61 kg, height=1.74 ± 0.06 m , body mass index=20.89 ± 1.78 kg/m2, competitive history=4.28 ± 1.10 years) (table 1). The participants were randomly divided into two groups including core stability training group (n = 15) and control group (n = 15). During the process of intervention, 5 participants were excluded from the rest of the tests due to the injury happened for them in their routine professional football exercises and because of that they could not continue to participate in the present study. Therefore, the current study was conducted on 12 participants as training group and 13 players as control group. For consideration of the ethics, before starting the study, the participants were informed about anonymity, experimental procedures and potential risks. All selected players were in health condition without any history of injuries.

Table 1 - Mean (±standard deviation) of Anthropometric and characteristics of participants

Variable	Experimental(n=12)	Control(n=13)	T-test (P-value)
Age(years)	16±0.85	16.15±0.80	0.644
Height(m)	1.74±0.06	1.75±0.07	0.603
Weight(kg)	63.75±9.42	64.53±8.16	0.825
Body Mass Index($\frac{kg}{m2}$)	20.92±2.07	20.85±1.56	0.923
Competitive Experience(years)	4.33±1.07	4.23±1.16	0.755

Procedures

One week before data collection, participants were familiarized with testing procedures, and then anthropometric measurements were conducted. Study participants were shown a video presentation and a demonstration of correct tuck jump technique. The video was composed of repeated images from sagittal and frontal views of a tuck jump. The TJA comprised continuous maximal height tuck jumps during ten seconds. Participants were asked to put their feet in the middle of the rectangle which was marked on the floor. The core stability training protocol was completed by training group at the same time of their scheduled team soccer training, but control group performed routine program without any intervention. The duration of the core-training session was approximately 30 minutes, 3 times a week for 12 weeks (totally, 36 sessions), performed at the end of every training session. The participants were instructed via testing procedure, and the tests were carried out before and after 12 weeks. The tests were done in the same order and scheduled at 02:00 p.m. o'clock. Every test phase was performed on 2 separate days. On the first test day, the tuck jump was assessed. On the second day, the trunk endurance tests were performed followed by the core stability tests. The players performed 15-min warming-up such as mobility and stretching exercises before each testing day. The participants were instructed on how to do each test and were allowed to carry out a familiarization period, and after three minutes of this period, they underwent the tests in order. The rest period between the core stability tests was at least 5 minutes, and all players were told to do their maximum effort throughout each test.

Measurements

Tuck jump assessment

The TJA is a clinical functional screening tool designed to identify neuromuscular deficits related to the ACL injury. [29] Repeated tuck jumps were performed in place (35×41cm) for 10 seconds, and the subjects were assessed using a ten-point rating scale with a greater number of deficits representing increased injury risk. [29] Like original TJA, a lower score indicated a better performance. To increase accuracy, 2D video cameras were used to capture the test and grade each player's technique retrospectively.

Videos were imported into Kenova analysis program to make slow down and compare both sagittal and frontal plane movements. This software allowed videos to be played at various speeds and frame-by-frame. Two raters participated in the present study. Both of them were certified strength and conditioning coaches with over five years of clinical experience. Each participant’s recorded performance was independently scored by two raters based on ten criteria. Raters were blinded to training status and training type, subsequently, the participants were evaluated in terms of their biomechanical deficits shown in videos provided in a random order. To determine athletes’ scores, their individual score was averaged between the announced scores of two raters. Another investigator, who was blind to the identity of the raters, performed the statistical analysis of the data (scores of 10 items).

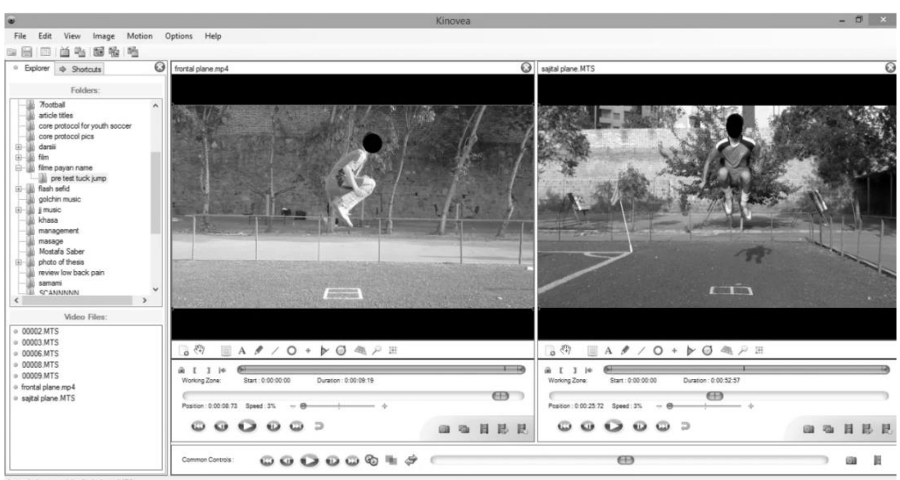

Figure1-Tuck jump video analysis in kinovea

Core Stability Tests

The trunk muscle endurance tests of McGill used to assess core stability [30] were as following: 1) The extensor endurance test (Figure 2-A), 2) The flexor endurance test (Figure 2-B), and 3) The side bridge test (Figure 2-C).

Figure 2- Mc Gill core stability tests, A) trunk extensor endurance test (Sorensen test); B) Flexor endurance test (60 degree sitting test) ; C) side bridge test (Lateral musculature endurance test)

Intervention

The current study was conducted in pre-season phase. The intervention group completed a 12-week core-training program as well as their normal training, while the control group performed their routine professional football exercises under the supervision of their coach. The core-training program included 7 exercises according to the existing literature, which were as follows: prone bridge (Figure 3-a), side bridge (Figure 3-b), bird dog (Figure 3-c), straight-leg raise (Figure 3-d), overhead squat (Figure 3-e), medicine-ball sit twist (Figure 3-f), and shoulder press (Figure 3-g). [31] A model for exercise progression was incorporated gradually by increasing the number of sets, repetitions and, where appropriate, the level of resistance (Table 2) or period in a hold position. Over the 12-week training period, the core exercises were performed 3 times a week. Each core-training session lasted approximately 30 minutes.

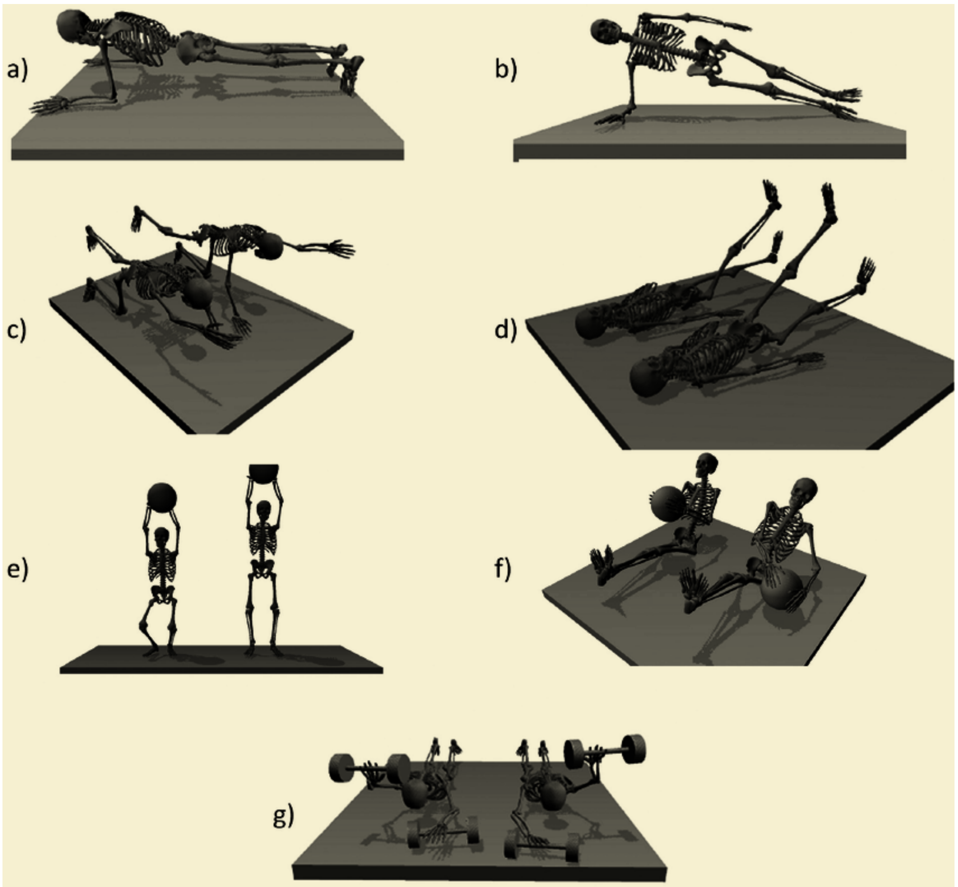

Figure 3- Core-training exercise details. (a) Prone-bridge. Hold a straight body position supported on elbows and toes. Brace the abdominal muscles and hold the back in a neutral position. (b) Side bridge. Lie on one side, ensuring top hip is positioned above the bottom hip. Push up until there is a straight body line through feet, hips, and head. (c) Bird dog. Position hands below shoulders and knees below hips. Place back in neutral, slowly extend one leg backward, and raise forward the opposite arm until level with back. Ensure that back does not extend and shoulders and pelvis do not tilt sideways. Bring leg and arm back to start position and swap sides. (d) Leg raise. Lie on back with knees extended on floor. Place back in neutral position and lift one leg straight up, keeping knee extended and other leg held out horizontally off floor. Raise leg till hip at 75°, then return to start position and repeat with opposite leg. (e) Overhead squat. Using weighted medicine ball, place hands on either side of ball and raise above head with straight arms. Feet shoulder width apart, squat down as low as possible while maintaining balance, keeping ball, head, and back vertical. Straighten legs and repeat. (f) Sit twist. Sit up with knees bent and lean back at 45°. Feet off floor, keeping back in neutral, using a 4-kg medicine ball, twist waist and shoulders to one side with ball held out in front of you. Return to forward and repeat on other side. (g) Shoulder press. Lie prone on the floor with both arms fully extended.

With a 3-kg dumbbell in each hand, raise one arm upward and then return the arm back to the floor. Repeat this movement, alternating arms.

Table 2- Core-Exercise Progression over the 12-Week Training Regimen(1)

		Weeks 1–2		**Weeks 3–4**		**Weeks 5–6**	
Exercise	**Progression**	**Repetitions**	**Sets**	**Repetitions**	**Sets**	**Repetitions**	**Sets**
Prone bridge	Volume	30-s hold	2	60-s hold	2	90-s hold	2
Side bridge	Volume	30-s hold	2	60-s hold	2	90-s hold	2
Bird dog	Volume	10	3	15	3	20	3
Leg raise	Volume	10	3	15	3	20	3
Overhead squat	Resistance	10 (3 kg)	3	10 (4 kg)	3	15 (5 kg)	3
Sit twist	Resistance	15 (3 kg)	3	15 (4 kg)	3	15 (5 kg)	3
Shoulder press	Volume	10	3	10	4	15	4
		Weeks 7–8		Weeks 9–10		Weeks 11–12	
Prone bridge	Volume	90-s hold	3	120-s hold	2	120-s hold	3
Side bridge	Volume	90-s hold	3	120-s hold	2	120-s hold	3
Bird dog	Volume	25	3	25	4	30	3
Leg raise	Volume	25	3	25	4	30	3
Overhead squat	Resistance	20 (6 kg)	3	20 (7 kg)	4	25 (7 kg)	3
Sit twist	Resistance	20 (6 kg)	3	20 (7 kg)	4	25 (7 kg)	3
Shoulder press	Volume	20	3	20	4	25	3

Statistical Analysis

The Shapiro-Wilk and Levene tests were utilized to verify normality and homogeneity of variances, respectively. A mixed-design (2 × 2: group × time) repeated-measures ANOVA was applied to test interaction and main effects of groups (core stability intervention group vs. control group) and time (pre-test versus post-test) on variables scores. Bonferroni test was employed to compare pre-test with post-test within groups. Statistical analyses were conducted in SPSS 21. Statistical significance was P≤ 0/05**.**

Table 3- Means, standard deviation and P-value comparison of core stability tests between experimental and control groups and within groups

position	Experimental (n=12)			Control (n=13)		
	Pre test	Post test	P-value	Pre test	Post test	P-value
60 degree sitting test(sec)	89.16±17.28	115.50±18.03	0.001	90.38±20.27	91±10.66	0.885
Sorenson(sec)	87.50±13.39	107.91±17.19	0.001	88.38±20.01	88.92±20.17	0.773
Side plank L(sec)	65.33±10.12	76.83±12.18	0.001	67.53±12.58	69.38±10.21	0.066
Side plank R(sec)	64.16±11.06	78.41±14.66	0.001	67.46±12.82	69.15±11.28	0.138

Results

The core-training intervention had a significant beneficial effect on core stability tests (Table 3). Comparison of mean values in all measurements between pre- and post-tests for training and control groups are presented in two below tables.

The results of core stability tests in four positions demonstrated a significant difference between pre- and post-tests for training group in all core test positions including 60-degree Sitting Test ($P = 0.001$), Sorensen ($P = 0.001$), Left Side Plank ($P = 0.001$) and Right Side Plank ($P = 0.001$); however, there was no significant difference for control group ($p > 0.05$) in all core test positions (Table. 3).

The significant differences were found between pre- and post-tests for tuck jump test in training group ($P = 0.001$) whereas no difference was observed in control group ($p > 0.05$) (Table. 4).

Table 4- Means, standard deviation and P-value comparison of tuck jump test between experimental and control groups and within groups.

Variable	Experimental(n=12)			Control(n=13)		
	Pre test	Post test	P-value	Pre test	Post test	P-value
Tuck jump flaws	6.5±1.16	4.66±1.15	0.001	5.92±1.25	5.76±1.09	0.584

Discussion

The main objective of the current study was to assess the effect of 12-week core stability training program on correction of tuck jump technique flaws as predictor for ACL injuries. In general, the results displayed that 12-week core stability training program could elicit significant improvements in kinematic of tuck jump and increase the core muscles endurance. Nevertheless, no significant increase was found in core muscle endurance and tuck jump errors for control group. Examining and comparing the tuck jump errors in pre- and post-tests displayed that the error related to landing in the same footprint dropped by 75% in the experimental group and just 16% in control group. In the error associated with item of parallel thighs (peak of jump), 50 and 8% reduction of error was observed in the experimental and control groups, respectively. In the pause between jumps, the errors were reduced by 42 and 8% in the experimental and control groups, respectively.

The average improvement of the mean tuck jump errors decreased by 18% after 12-week intervention in the experimental group while the error reduction was only 2% in the control group. According to the results, the highest error reduction was observed in landing in the same footprint item at the treatment. It is logical since when the core muscles are weak during landing and jumping tasks, the body movements on the frontal and sagittal plane enhance (especially lateral displacement). This will enable the person to control the upper body in tasks associated with unstable situations and perturbation. It makes the individuals not to land on the specified place as well as they land on their knees abducted, increasing knee valgus which is a risk factor for ACL injuries. In other words, the stronger core declines the lateral movements of the trunk in the state of perturbation and disturbance such as jumping and landing tasks. Improvement is found in items like pause between jumps, and thighs do not reach parallel, it makes sense that the strong core will make the spine and pelvis more stable; resulting in a better transfer of energy from trunk to other limbs and ultimately improving performance.

The core is considered as a box that helps the stability of the spine, pelvis and kinetic chain during functional movements. When this system is working properly, the optimal distribution and maximum power generation with minimum compressing, transitional, shearing forces in the kinetic chain of joints lead to optimal control of the movements and proper recruitment of the impact forces from the ground reaction forces.[32] It should be noted that various factors including time of interventions (pre-season or in-season), age and gender (young, adult, male, female), duration of interventions (weeks, sessions and time), competitive level (elite, amateur and professional), type and quality of the training program as well as the surface on which the training is done (static, dynamic, on stable or unstable surfaces) influence the effects of a program on a particular group. Some researchers have termed that the neuromuscular training is beneficial so that the mean of the tuck jump scores are reduced after the intervention.[33-35] Moreover, other studies have found that core stability exercises improve the balance, performance and ultimately reduction of lower-limb injury through muscular pre-planned feed forward activation patterns.[36-38] In contrast, some studies have suggested that there are no positive effects following core stability exercises,[29,40] and the tuck jump assessment fails to predict upper extremity injury risks.[41] Considering the mentioned literature, it can be inferred that the core stability intervention on the players exhibiting trunk dominance will purposefully target the deficits of the trunk control and improve them. The exercises used in this study possibly improve the strategies of core muscle activation, posture control and balance via improving the core strength. [42,43] These positive effects indicate that the strength of the core musculature may reduce the lateral displacement of the trunk during the jump, and all tasks with perturbation also improve the quality of tuck jump performance through improving posture control and balance.

Conclusions

The results of the present study demonstrated that 12-week core stability training in young soccer players with core muscle deficiency might improve kinematic of tuck jump. Practitioners, coaches and all soccer clubs may identify the young soccer players with core dysfunction who are at ACL injury risk using functional screening tests. Then, they can decline the ACL injury risks for young football players via core stability training. In addition, the core stability training can be used to decrease tuck jump errors (injury risks) through warming-up program in training schedules.

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Author Contributions

Parsa Saber written the paper was the M.Sc. student. Professor AliAsghar Norasteh served as a supervisor of thesis. Dr. Amir Ghiami Rad helped for data analysis.

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