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Examining the Effects of Corrective Exercise on Balance and Performance in Female Volleyball Players with Dynamic Knee Valgus Deformity

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ABSTRACT

Background: This study aimed to assess the impact of a corrective exercise program on the balance and performance of female volleyball players with knee dynamic valgus defects.
Methods: This study employed a semi-experimental design in the field of sports. The study's target population comprised female volleyball players in East Azarbaijan with knee dynamic valgus defects. From this population, 30 subjects were selected and randomly divided into control and experiment groups, following the completion of personal profiles and screening for knee dynamic valgus defects using a squat test. The study measured static and dynamic balance through the Balance Error Score System (BESS) and Y balance tests for lower limb assessment and upper extremity function through the Y functional test for upper extremities in both groups. The experimental group underwent a 10-session program of corrective exercises, while the control group continued with their regular volleyball exercises. After the training period, both groups underwent a post-test. The data's normality was assessed using the Shapiro–Wilk test. The effect of the corrective exercise program on the research's dependent variables was analyzed through covariance analysis and dependent t-tests, with a confidence level set at $P \leq 0.05$.
Results: The results showed a positive impact of corrective exercises on static and dynamic balance ($P=0.001$) and upper extremity function ($P=0.001$) in volleyball players with dynamic knee valgus defects.
Conclusion: The study results demonstrate that the corrective exercise program, following the National Academy of Sports Medicine approach, significantly reduces knee dynamic valgus, improves balance, and enhances upper extremity function in young female volleyball players.

Introduction

Positioning the knee joint at the midpoint of the kinetic chain in the lower limb subjects it to significant stress, particularly during weight-bearing physical activities [1]. The mechanical characteristics of this central knee joint's proximal and distal joints determine the correct or incorrect distribution of forces on the musculoskeletal system of the knee [1]. Therefore, an athlete's ability to maintain appropriate dynamic alignment of the lower limb segments is vital in preventing knee injuries during exercise [2].

Among knee injuries, damage to the anterior cruciate ligament (ACL) is particularly common, especially among young athletes aged 15 to 25. Approximately 70% of ACL injuries result from non-collision incidents, with the remaining 30% occurring during collision [3]. In the United States alone, around 200,000 ACL injuries

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are reported annually [4]. Notably, volleyball, a sport with approximately 240 million registered and active players worldwide, experiences an injury rate of about 10-35 injuries per 1000 hours of play in adult men, with a higher occurrence among younger and less skilled players [5]. In Iran, it has been reported that 46% of all knee injuries in football and volleyball are attributed to ACL injuries [4].

The primary strategy for preventing sports injuries involves identifying and addressing risk factors and mechanisms. The most common mechanism for ACL injury is non-collision, accounting for 72% of all ACL injuries and typically occurring during activities such as deceleration, jump landings, and shearing movements [6]. Researchers have identified various risk factors, both modifiable and nonmodifiable, for knee injuries [7-9].

In studies examining body mechanics and injury patterns in individuals during or immediately after ACL injuries, video analysis has revealed various components contributing to these injuries. These include a decrease in knee flexion angle, an increase in hip flexion angle, knee valgus collapse, a decrease in ankle plantarflexion angle, an increase in hip internal rotation, and changes in tibia rotation (internal or external) during non-collision ACL injuries [10, 11]. The current study focuses on knee dynamic valgus defects, which strongly correlate with ACL injuries ($r2=0.88$) due to their prevalence as a common mechanism of non-collision ACL injuries [2]. Research has shown that an increase in knee valgus leads to changes in lower limb function in the frontal plane [12]. These changes could be attributed to alterations in the contraction patterns of trunk muscles, hip adductors, and abductors, as well as knee flexor muscles (hamstrings and gastrocnemius muscle) [13]. Evidence suggests that corrective exercises positively affect knee valgus angle among individuals with dynamic valgus. Studies by Saki et al. and Shahheidari et al. have demonstrated the positive effects of corrective programs on knee valgus angle in active women [14, 15]. Similar results were achieved by Mohammadi et al. in male basketball players [16]. Babagol Tabar et al. also demonstrated the positive effect of a warm-up program on valgus angle in adolescent futsal players [17].

ACL injuries in athletes are associated with disorders in balance and posture control, with poor balance being considered a risk factor for knee and ankle injuries [18]. Balance training alone has significantly reduced the incidence of ACL injuries in athletes [19]. Ghassab et al. discovered that athletes with dynamic knee valgus have lower balance than those without this defect, suggesting that athletes with dynamic knee valgus may be more prone to knee injuries [20]. However, the rehabilitation programs in the aforementioned studies either lacked balance exercises or did not include balance assessment.

The performance of athletes is a critical consideration, and corrective exercises have merged as a significant area of interest for researchers due to their potential to enhance athletic performance. It is common for coaches and players to allocate time for corrective exercises to improve performance [19].

Volleyball is a sport characterized by a high frequency of jumps and landings. For instance, during a volleyball game, athletes may perform an average of 100 paired jumps, 50 single-leg spike jumps, 150 paired jumps, and 80 single-leg defense jumps [21]. Given the importance of addressing dynamic knee valgus, a common risk factor for ACL injuries in a sport that requires frequent jumps and landings, and the need to enhance the balance and performance of these athletes, this study aims to investigate the impact of a corrective exercise program on the balance and performance of female volleyball players exhibiting dynamic knee valgus defects.

Methods

This study employed a semi-experimental design in the field of sports. Ethical considerations were taken into account, and the study was assigned the ethics code: IR.IAU.URMIA.REC.1398.014. also consent form was obtained from each subject.

The target population of this study consisted of all female volleyball players from East Azerbaijan with knee dynamic valgus defects. These players had between 3 and 8 years of sports experience, engaged in at least three weekly training sessions, and participated in the provincial league. The sample size was determined using G Power software, considering the ANCOVA statistical test with a covariate, a significance level of 0.05, a power of 0.2, and an effect size requiring a statistical power of 0.8, which is suitable for experimental studies. This calculation resulted in a sample size of 15 participants per group. Before the research began, all subjects signed informed consent forms to participate in the research tests. A meeting was held to explain the testing procedures to the subjects. All participants were in good health and had no history of back pain. Those with dynamic valgus defects were included in the study. The samples were then randomly divided into two groups: the experimental group, which performed corrective exercises, and the control group, which continued with their regular exercise sessions after the pre-test. The dynamic balance test measured the actual length of each subject's leg, extending from the anterior superior iliac spine (ASIS) to the inner ankle, to normalize the data and compare the subjects. This measurement was taken twice for each subject, and the average of the two measurements was used to establish their leg length. The superior (dominant) leg was determined based on this information, indicating which lower limb the subject had a greater tendency to use for shooting the ball [22].

The overhead squat test was used to assess the presence or absence of dynamic knee valgus. Each subject performed five squat tests in a standing position, with both legs in a standard position (feet shoulder-width apart, toes pointing straight forward, hands extended overhead with elbows fully extended, and knees flexed to 90 degrees). An examiner observed the subjects from the front as they performed these squat tests. Subjects were allowed to practice this test before the official assessment. If, during the execution of 3 out of the five squat tests, the examiner visually noticed that the midpoint of the patella on the superior leg passed through the inner part of the big toe when viewed from the front, the individual was determined to have dynamic knee valgus [23]. The validity and reliability of this test were reported as 78% and 73%, respectively [24].

The landing-jumping test was employed to evaluate knee valgus quantitatively. In this test, the subjects were positioned on top of a box with a height of 50 cm, and the distance between the inner ankles was set at 35 cm. The subjects were instructed to land and perform a maximal vertical jump while raising their hands. To restrict horizontal body movements, the subjects were asked to keep the heel of the tested foot in contact with the front edge of the box. Each subject made three correct attempts with a 2-minute interval between each attempt. The landing-jump test was chosen for this study because, according to Nagano et al.'s (2009) research, this test is considered the most suitable for screening athletes at risk of anterior cruciate ligament injury [16, 25]. Information from the superior leg was used in the final analysis. To conduct the landing-jump test, cameras with external memory were set on tripods placed 365 cm from the landing-jump platform, which was determined based on the subjects' height [26]. During the test, the athletes performed the correct landing-jumping sequence three times. After completing all three attempts, the final analysis was done using Kinova software.

The analysis involved selecting two images by advancing frame by frame in the video. The first image, captured before landing, shows the moment the toe touched the ground immediately after landing from the box. The second image, taken at the landing moment, represents the lowest point in the jump (maximum knee flexion). The valgus angle in the image from the frame before landing and the flexion angle in the image from the landing frame were calculated using Kinova software. Synchronization of the cameras was achieved using the software, specifically in the image related to the initial contact (frame before landing) [16].

The current study assessed static balance using the balance errors test. This test involved six different positions, including three standing positions (standing on both legs, standing with one leg in front and the other behind, and standing on one leg), performed on both soft and hard surfaces. In each position, the subjects closed their eyes and placed their hands on their waists. Each position was held for 20 seconds, and the number of errors made during these six positions was calculated to determine their score. Errors included any instance where the subjects separated their hands from their waists, opened their eyes, or experienced any form of balance disturbance. Before the formal testing, subjects were allowed to practice the test three times to become familiar with the assessment procedure [27].

This study used the Y balance test (YBT) to assess dynamic balance. During the YBT, the subjects positioned themselves at the center of the directions, stood on one leg, and performed a reaching action with the other leg before returning to the normal position on both legs. In each specified direction, the subject aimed to touch the farthest possible point with her toe. The distance from the point of contact to the center, measured in centimeters, and considered the reach distance (Figure 1).

To minimize learning effects, each subject practiced this test six times in three different directions [22]. The dynamic balance score in each separate direction was calculated using the following formula:

$$\text{Score} = \frac{\text{reach distance}}{\text{limb length}} * 100$$

The Y Balance Upper Quarter (YBU-UQ) performance assessment, developed by Pliski, was used to evaluate the performance of the upper extremity. The developer reported the validity of this assessment to be between 0.85 and 0.91%. The YBU-UQ device consists of a fixed plate with three rods connected to it in three directions: internal, lower external, and upper external arm, each set at 120 degrees to each other. Each rod is marked in centimeters, and each scaled rod has a movable indicator. The subject's free hand is used to push the indicator to the maximum reach distance (Figure 2).

Here is how the YBU-UQ performance assessment is conducted:

1. Adopting the Swedish swimming position, the subject initiates the assessment with her non-dominant hand resting on the fixed plate for support.
2. The dominant hand is subsequently utilized to reach in three directions: internal, lower, and upper external, each targeting the maximum possible reach distance.
3. The subject maneuvers her hand in each specified direction before returning to the initial test position.
4. The maximum reach distance is measured and documented from the scaled rod located on the edge of the indicator.

The maximum permissible distance between the two feet during the assessment is 30 cm. The test was administered

Figure 1: Y (Y balance) Test Evaluation Method

Figure 2: Evaluating Methods of Upper extremity function

three times for each designated hand. The average of the three trials in each direction was utilized for analysis. To mitigate fatigue, a rest period of two minutes was allocated between each attempt. Additionally, before initiating the test, the subjects' dominant hand was ascertained based on their preferred hand to throw the ball. The length of the upper extremity influences their reach distance; consequently, the raw balance scores were normalized relative to the upper limb length. The distance between the spinous appendage of the seventh vertebra and the tip of the middle finger was measured to document the length of the upper limb. This measurement was taken while the shoulders were abducted at 90 degrees, and the elbows, wrists, and fingers were fully extended [28].

During each session, the subject was progressively challenged by increasing the number of sets, repetitions, or resistance or introducing new exercises. A comprehensive approach was adopted, focusing on proximal and distal knee joints. This was achieved by assigning five exercises each to the hip and ankle muscular structures. These exercises were designed to correct alignment during the performance of functional activities.

This study implemented a modified exercise intervention protocol, drawing on the approach of Bell et al. [29]. The intervention program was designed in accordance with the strategies for corrective exercises delineated in the book published by the National Academy of Sports Medicine [30]. Each exercise session incorporated a 5-minute warm-up at the outset and a 5-minute cool-down at the conclusion. Participants in the training group undertook ten training sessions over three weeks, each conducted under the vigilant supervision of the principal researcher.

During these training sessions, each participant was progressively challenged with increasing the number of sets, repetitions, and resistance levels or introducing new exercises. The training program adopted a comprehensive approach that targeted both the proximal and distal knee joints. This approach included a set of 5 exercises focused on the hip musculature and another set of 5 exercises targeting the ankle musculature. The exercises were designed to correct alignment issues while simulating functional activities.

The exercise program was structured with a specific sequence, following a corrective exercise strategy that encompassed the following steps: (1) inhibiting overactive muscles, (2) increasing the length of stiffened muscles, (3) strengthening weak muscles, and (4) performing integration exercises with a proper form and technique, including keeping the knees in line with toes during these exercises.

Participants received detailed instructions at the beginning of the integration exercises. Each subject's exercise progression was determined individually based on feedback and the principal researcher's assessment. If an exercise became easier for a participant, gradual progression was introduced in the subsequent session. Throughout each training session, the principal researcher communicated with each participant to ensure they were appropriately challenged with the resistance level or the number of repetitions. All participants completed a total of 10 training sessions. The post-test assessments were conducted one to two days after the final training session for the experimental group. The control group participants returned for their post-test assessments three weeks later. Both groups were instructed not to engage in any other training program during this period.

The study's data were analyzed using descriptive and inferential statistical methods. The Shapiro-Wilk test was used to check the normality of data distribution. An analysis of covariance statistical test was applied to examine the difference in balance between the two groups of athletes. To examine intra-group changes, a dependent t-test was used at a significance level of 0.05. All statistical operations were carried out using SPSS version 23.

Results

Table 1 presents the mean and standard deviation of the subjects' characteristics, including age, height, weight, and body mass index (BMI).

Table 1 reports demographic information.

Table 1: Anthropometric indices of the two groups

Measurement index	Group	SD±M	T	P
Age (year)	Control	18.93±1.43	-1.45	0.15
	Training	19.73±1.57		
Height (meter)	Control	1.68±0.08	1.51	0.14
	Training	1.64±0.03		
Weight (Kg)	Control	58.20±6.72	0.24	0.80
	Training	57.66±4.99		
Body Mass Index (Kg/M^{2})	Control	20.46±1.43	-1.21	0.23
	Training	21.24±2.03		

Given that the data followed a normal distribution, as verified by the Shapiro-Wilk test, the authors utilized analysis of covariance and dependent t-tests to evaluate the effects of the exercises and conduct between-group comparisons.

An analysis of covariance was used to compare the knee valgus angle, balance, and upper limb performance between the two groups in the pre-test, taking into account the results of Mauchly's Test of Sphericity. The outcomes are summarized in Table 2.

The covariance analysis results revealed a significant difference between the two groups in the knee valgus tests, as well as static and dynamic balance and upper extremity function tests ($P<0.05$). A review of the mean scores showed that the training group participants outperformed those in the control group. Dependent t-tests were used to compare balance and upper extremity function within the research groups and between the pre-test and post-test. The results are displayed in Table 3 (Figure 3).

The results outlined in Table 3 demonstrate that the exercise program significantly impacted knee valgus, as well as static and dynamic balance and upper extremity function ($P\leq0.05$).

Discussion

The research findings highlighted the significant influence of the corrective program in reducing knee valgus, enhancing balance, and improving upper extremity function. Dynamic knee valgus is defined as an abnormal inward knee movement during weight-bearing activities [31]. Prospective studies have pinpointed an increased knee valgus angle and abduction torque during landing as predictive elements for non-contact ACL injuries among female athletes [32]. Consequently, various exercise programs have been explored by researchers to mitigate dynamic knee valgus. For example, Herman et al. examined the effect of a 9-week strength training program on the knee valgus angle among women aged 18-30 who participated in recreational basketball, soccer, and volleyball activities 1-3 times a week. They employed a 3D evaluation method and a stop-jump test for their assessment.

In contrast, their findings did not indicate a significant change in the assessed variables [33]. Using three-dimensional evaluation, Snyder et al. examined the effects of six weeks of strength training targeting hip abductor and external rotator muscles on knee abduction, hip

Table 2: Results of covariance analysis of the impact on independent and predictor variables on the post-test

Variable	Test stage	Group	Mean$^{\times}$	F	Df	P	Eta squared
Knee valgus (degree)	Post-test	Control	8.94	119.89	1	0.001**	0/81
	Post-test	Experimental	5.85				
BESS Test	Post-test	Control	3.98	76.33	1	0.001**	0.73
	Post-test	Experimental	1.94				
Anterior direction of Y test	Post-test	Control	73.35	849.58	1	0.001**	58.24
	Post-test	Experimental	84.03				
Posteriomedial direction of Y test	Post-test	Control	86.04	954.95	1	0.001**	46.61
	Post-test	Experimental	97.44				
Posteriolateral direction of Y test	Post-test	Control	76.61	3497.49	1	0.001**	82.67
	Post-test	Experimental	99.12				
Overall score of Y test	Post-test	Control	78.57	1639.92	1	0.001**	145.40
	Post-test	Experimental	93.63				
The medial direction of the YB-UQ test	Post-test	Control	85.79	910.64	1	0.001**	23.22
	Post-test	Experimental	97.10				
Inferiolateral the direction of the YB-UQ test	Post-test	Control	68.98	865.74	1	0.001**	19.47
	Post-test	Experimental	80.23				
Inferiomedial direction of the YB-UQ test	Post-test	Control	45.89	1308.95	1	0.001**	53.57
	Post-test	Experimental	59.84				
Overall score of YB-UQ test	Post-test	Control	66.65	1074.06	1	0.001**	68.86
	Post-test	Experimental	79.28				

$^{\times\times}$Significance at the level of 0/01; $^{\times}$adjusted based on pre-test values; Balance Error Score System (BESS); Y Balance Upper Quarter (YB-UQ)

Table 3: Average difference in subjects' factors before and after implementing the training protocol

Group	Control (No. 15)				Training (No. 15)			
	Pre-test	Post-test	T	P	Pre-test	Post-test	T	P
Knee valgus	8.73±0.96	8.93±0.79	0.45	-0.76	8.86±1.12	5.73±0.74	8.87	0.001**
BESS	4.20±1.8	3.86±0.99	2.09	0.05	4.60±0.91	2.70±0.70	11.76	0.001**
Anterior direction of Y test	87.66±12.26	79.42±8.61	0.68	0.50	84.48±10.75	96.31±7.11	-6.22	0.001**
Posteriomedial direction of Y test	79.42±8.61	78.52±9.65	1.47	0.16	74.79±7.67	97.20±8.92	-9.69	0.001**
Posteriolateral direction of Y test	80.30±9.48	79.87±8.93	1.13	0.27	77.17±7.08	92.32±6.35	-12.14	0.001**
Overall score of Y test	73.81±10.42	73.93±9.29	-0.19	0.84	72.25±8.42	83.44±6.67	-7.53	0.001**
The medial direction of the YB-UQ test	88.9±15.09	87.93±15.13	0.84	0.41	83.29±9.98	94.95±5.73	-5.30	0.001**
Inferiolateral the direction of the YB-UQ test	72.76±17.31	72.40±16.66	0.39	0.70	63.84±10.33	76.87±6.76	-5.17	0.001**
Inferiomedial direction of the YB-UQ test	50.84±12.34	49.57±12.42	1.42	0.17	43.20±10.87	56.15±12.02	-8.41	0.001**
Overall score of YB-UQ test	70.88±14.28	69.99±14.13	1.08	0.29	63.40±7.63	75.94±6.25	-10.14	0.001**

Balance Error Score System (BESS); Y Balance Upper Quarter (YB-UQ)

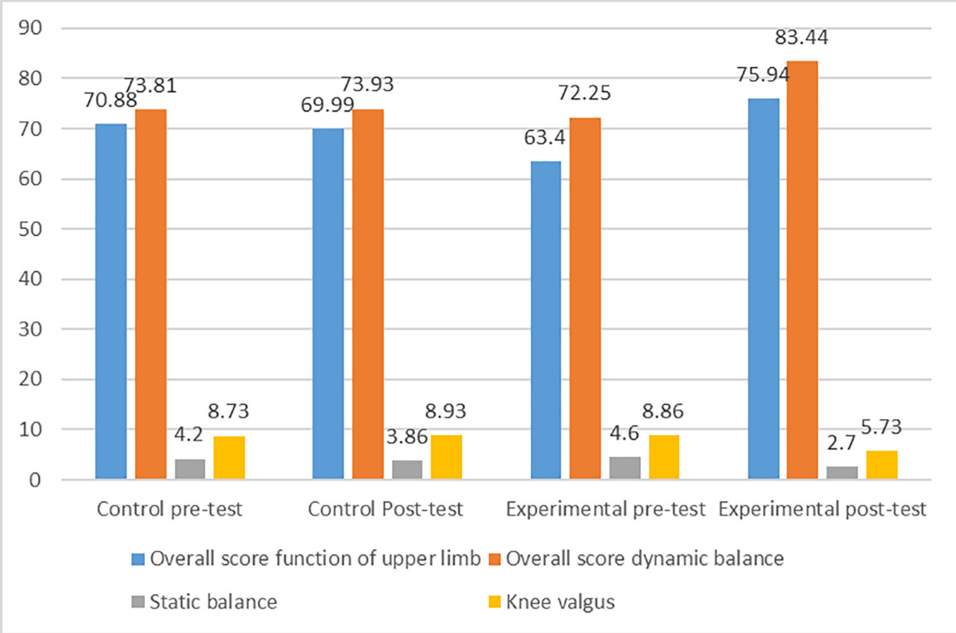

Figure 3: Schematic Overview of Results Derived from Averages.

adduction, and internal rotation in healthy women aged 21-23 while they were running. Their results indicated that this training protocol effectively increased the strength of the hip abductor and external rotator muscles, resulting in significant improvements. However, contrary to their initial hypothesis, the hip adduction range increased during running. Although there was a significant reduction in the range of eversion, hip internal rotation, rearfoot inversion, and knee abduction, this increase in hip addiction movement was not in line with their expectations [34]. Some prior exercise interventions have also failed to reduce dynamic knee valgus effectively [33-36].

Many of these programs have traditionally focused on either balance or strength training. However, research studies incorporating neuromuscular or plyometric training protocols have successfully reduced dynamic knee valgus [14, 16, 17, 29]. Neuromuscular exercises enhance the nervous system's ability to trigger rapid and optimal muscle activation patterns, thereby increasing joint dynamic stability, reducing joint forces, and retraining movement and skill patterns. The findings of the present study are in line with the results of Shahheidari et al. and Bell et al., who followed the same protocol that was implemented in the current study [15, 29].

The present study investigated changes in balance and functional activity following the application of corrective exercises. Therefore, it's plausible that part of the improvement in balance can be attributed to the correction of knee valgus and the improvement of muscle stiffness and weakness in the muscles around the proximal and distal knee joints. The improvement in balance among the volleyball players in the training group was expected in this study, considering that the final portion of each training session, i.e., the exercises related to the cohesion section, included balance and performance exercises.

Regarding upper extremity performance, it's important to emphasize that, among athletes, coaches, and health professionals, maintaining proper physical condition is crucial for achieving and sustaining optimal performance in athletes. Furthermore, proper flexibility is a widely accepted and standardized component of athlete fitness training, injury prevention, and rehabilitation protocols [37]. In various sports activities, minimizing injuries and promoting muscle recovery and relaxation [38] are essential. It appears that the impact of training on correcting this knee valgus defect also has positive effects on the performance of volleyball players.

The improvement in the Y test score of the upper extremity can be attributed to the exercises incorporated into the training protocol. Some exercises enhance flexibility, while others aim to increase muscle strength. Combining these exercises likely improved neuromuscular coordination, leading to better performance in the Y test. Therefore, by correcting abnormalities, individuals and athletes exhibit better patterns of physical activities and performance. Correcting abnormalities in alignment allows forces to pass through the body's kinetic chains and joints more effectively, enhancing skill performance. By addressing and rectifying irregularities dynamically, the muscles operate optimally in terms of their length-tension ratio, ultimately improving performance in dynamic assessments like the Y test for the upper extremity.

While the study's findings are promising, it's essential to acknowledge its limitations, including the quasi-experimental design instead of a randomized clinical trial. Nevertheless, these results suggest that coaches and therapists should consider periodically screening athletes for knee valgus defects, and correcting them, thereby reducing the risk of injury while enhancing performance.

Copyright of Picture

The person marked in the Figures 1 and 2 has expressed her consent to publish her images in the article.

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Conflict of Interest: None declared.

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