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Relationship Between Elbow Proprioception, Upper Extremity Physical Performance, and Pass Accuracy in Adolescent Basketball Players: Cross-Sectional Study

Adölesan Basketbolcularda Dirsek Propriosepsiyonu, Üst Ekstremite Fiziksel Performansı ve Pas Doğruluğu Arasındaki İlişkinin İncelenmesi: Kesitsel Çalışma

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ABSTRACT Objective: The study aimed to investigate the relationship between elbow proprioception, upper extremity physical performance, and pass accuracy in adolescent basketball players. **Material and Methods:** A total of 45 adolescent basketball players, 22 girls and 23 boys aged 15-18 years, were included in the study. Angle repetition and force-matching skill tests were used to assess the elbow proprioception. Additionally, the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) and Seated Medicine Ball Throw Test (SMBTT) were conducted to evaluate the physical performance of the upper extremities. The American Alliance for Health, Physical Education, Recreation, and Dance passing skill test was also administered to measure the pass accuracy. **Results:** Elbow proprioception was not associated with upper extremity physical performance and pass accuracy ($p>0.05$). The CKCUEST normalized scores of the participants were found to have a weak, positive correlation with SMBTT distances ($r_s=0.336$, $p<0.05$), but there was no correlation with pass accuracy ($p>0.05$). However, the CKCUEST power scores showed a positive and weak correlation with SMBTT distances ($r_s=0.422$, $p<0.05$). Additionally, SMBTT distance was found to have a moderate, positive correlation with pass accuracy ($r_s=0.612$, $p<0.05$). **Conclusion:** It was concluded that elbow proprioception was not associated with upper extremity physical performance and pass accuracy in adolescent basketball players. However, adolescent basketball players who scored high in upper extremity physical performance tests exhibited greater passing accuracy.

Keywords: Adolescent; basketball; pass accuracy; physical performance; proprioception

ÖZET Amaç: Bu çalışmanın amacı, ergen basketbolcularda dirsek propriyosepsiyonu, üst ekstremite fiziksel performansı ve pas doğruluğu arasındaki ilişkiyi araştırmaktır. **Gereç ve Yöntemler:** Çalışmaya, 15-18 yaş arası 22 kız ve 23 erkek olmak üzere toplam 45 ergen basketbol oyuncusu dâhil edildi. Dirsek propriyosepsiyonunu değerlendirmek için açı tekrar ve kuvvet eşleme beceri testleri kullanılmıştır. Ayrıca üst ekstremitelerin fiziksel performansını değerlendirmek için Kapalı Kinetik Zincir Üst Ekstremite Stabilite Testi (KKZÜEST) ve Oturarak Sağlık Topu Atma Testi (OSTAT) uygulanmıştır. Amerikan Sağlık, Beden Eğitimi, Rekreasyon ve Dans Birliği pas becerisi testi de pas doğruluğunu ölçmek için uygulanmıştır. **Bulgular:** Dirsek propriyosepsiyonu, üst ekstremite fiziksel performansı ve pas doğruluğu ile ilişkili bulunmamıştır ($p>0,05$). Katılımcıların KKZÜEST normalize puanlarının OSTAT mesafeleri ile zayıf, pozitif bir korelasyona sahip olduğu ($r_s=0,336$, $p<0,05$), ancak pas doğruluğu ile korelasyon olmadığı bulunmuştur ($p>0,05$). Bununla birlikte KKZÜEST güç skorları, OSTAT mesafeleri ile pozitif ve zayıf bir korelasyon göstermiştir ($r_s=0,422$, $p<0,05$). Ayrıca OSTAT mesafesinin pas doğruluğu ile orta düzeyde pozitif bir korelasyona sahip olduğu bulunmuştur ($r_S=0,612$, $p<0,05$). **Sonuç:** Dirsek propriyosepsiyonunun, ergen basketbolcularda, üst ekstremite fiziksel performansı ve pas doğrululuğu ile ilişkili olmadığı sonucuna varılmıştır. Bununla birlikte üst ekstremite fiziksel performans testlerinde yüksek puan alan ergen basketbolcular daha yüksek pas isabeti sergilemiştir.

Anahtar Kelimeler: Adölesan; basketbol; pas doğruluğu; fiziksel performans; propriosepsiyon

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Passing is the most critical action for a team after shooting and is frequently utilized during the basketball game.[1] Pass accuracy has a significant impact on team performance, offensive efficiency, and the generation of scoring opportunities. As such, it is a skill that can greatly influence the game's outcome.[2] In youth basketball, where players are still developing both physically and tactically, passing performance - such as accuracy and decision-making under pressure- has been linked to offensive efficiency and overall team effectiveness.[3] As a result, enhancing passing accuracy is crucial for coaches and trainers who work with adolescent athletes.

Basketball skills involving the upper extremities, such as passing and shooting, require coordinated movement between the shoulder, elbow, and wrist. Some studies indicate that joint position sense (JPS) in the distal joints, particularly the wrist and elbow, is associated with success in basketball free-throw.[4] Similarly, elbow proprioceptive feedback may also contribute to passing accuracy.

Proprioception, which is the ability to sense the position and movement of one's body, is especially important for controlling and coordinating complex movements that involve multiple joints.[5] Proprioceptive control is crucial for enhancing sports performance, managing medical conditions, improving activities of daily living, and overall physical abilities.[6] A recent systematic review has shown that proprioceptive training enhances balance, neuromuscular control, and sport-specific skills across various sports.[7] In basketball, proprioceptive programs that utilize unstable surfaces have been found to improve both the accuracy of passes and quick shooting skills in young basketball players.[8]

Despite promising findings from interventions focused on proprioception and balance, direct evidence linking elbow proprioception to basketball performance remains inconsistent. Studies that have directly tested elbow JPS in adolescent basketball players found no significant correlation between errors in elbow JPS and the accuracy of shooting or chest passes.[9,10] However, biomechanical research indicates that coordinated timing of the shoulder, elbow, and wrist segments is critical for accurate shooting performance.[11] These mixed results suggest that the role of elbow proprioception in basketball performance remains unclear.

The adolescent period is crucial for motor learning, neuromuscular development, and skill acquisition.[12] Understanding how elbow proprioceptive acuity affects passing accuracy and upper extremity performance during this time is essential for improving effective training strategies and injury prevention. However, to date, no studies have specifically investigated these relationships in adolescent basketball players. Therefore, the aim of this study was to explore the relationship between elbow proprioception, upper extremity physical performance, and passing accuracy in adolescent basketball players. We hypothesized that players with better proprioceptive acuity would demonstrate higher levels of upper extremity physical performance and improved passing accuracy.

MATERIAL AND METHODS

DESIGN

This was a cross-sectional study in which measurements were performed during a single visit, and the results were recorded. The evaluations were conducted at the Dumlupınar Indoor Sports Hall located in the city center of Kütahya. This study was conducted in accordance with the principles of the Declaration of Helsinki, and all participants provided written informed consent prior to enrollment. The Non-Interventional Clinical Research Ethics Committee of Kütahya Health Sciences University approved this study (date: December 22, 2021; no: 2021/17-08). The study was registered at ClinicalTrials.gov before the enrollment of participants (NCT05307302).

Participants

The study included 45 licensed adolescent basketball players aged 15-18 years, consisting of 22 girls and 23 boys. To be eligible for participation in the study, the individuals needed to meet the following criteria: they should be licensed basketball players playing in a club and between the ages of 15-18, have Turkish speaking and writing communication skills, volunteer to participate in the study, and provide written consent for participation by the participant or their legal representative. Exclusion criteria were having undergone surgery involving the upper extremities

and upper limb within the last 6 months, having acute shoulder pain, taking a break from sports for at least 3 months, and not actively participating in training. We obtained written informed consent from all participants and their families for those under 18 before the participation.

Procedures

After obtaining the informed consent, the demographic characteristics of the participants were recorded. In the first stage, elbow joint proprioception measurements were performed. The participant's elbow JPS and force-matching ability were evaluated for the proprioception measurement. We used a smartphone app (Caliper Clinometer, PlaincodeTM v 2.4, plaincode™, Germany) to measure elbow JPS. The force-matching ability was evaluated using a hand dynamometer (MicroFET2-Hoggan Health Industries Inc., Salt Lake City, Utah, USA). During the 2nd stage of the evaluation, the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) and Seated Medicine Ball Throwing Test (SMBTT) were conducted to assess the participant's upper extremity physical performance. In the last stage, a specific test called the American Alliance for Health, Physical Education, Recreation and Dance test (AAHPERD) was used to evaluate the participant's ball control and passing ability while in motion. Participants were given a 2-minute break between assessments, which lasted about 45 minutes for each participant.

Assessment of Joint Position Sense

Elbow JPS was assessed with an active joint repositioning task, a smartphone goniometer app called Caliper Clinometer, PlaincodeTM v 2.4, which is highly valid and reliable [intraclass correlation coefficient (ICC)=0.98].[13] During the assessment, the athlete was seated in a chair with their hip flexed at approximately 90° and their back straight. The physiotherapist taught the target ranges of motion of 45°, 60°, and 75° elbow flexion once at the beginning. The smartphone (Xiaomi Redmi Note 8 Pro, Xiaomi Communications Co., Ltd., China) was then secured to the midpoint of the dominant limb forearm of the participant with a band, with the elbow in full extension for the starting position. The test was performed 3 times with eyes open and 3 times with eyes closed, and the actual test began. The participant was asked to confirm "OK" when they believed they had reached the target angle, and their angle was recorded. During the test, the participant was expected to reach the target angles with their eyes closed 3 times. We recorded the error angle, the absolute difference value between the angle the participant realized and the target angle. The mean error angles from the 3 tests were calculated and used for statistical analysis. The ICC values of JPS assessment [ICC (3,k)] were 0.92 for 45° [95% confidence internal (CI)=0.87-0.95], 0.91 for 60° (95% CI=0.85-0.95), and 0.87 for 75° (95% CI=0.79-0.92) in our study.

Assessment of Force-Matching Ability

We selected elbow flexor muscles of the dominant extremity to assess force-matching ability.[14] To measure this, we used a digital handheld dynamometer. During the evaluation, the athlete's forearm was placed in supination, while the elbow and shoulder were flexed at approximately 90° and rested on a table. The athlete was instructed to flex their elbow and bring their palm towards their shoulder. The movement was demonstrated prior to evaluation. We instructed the participant to perform 3 MVC and recorded the dynamometer readings. We calculated the average of the 3 readings and then determined 30% of this average as the target force value for the individual. Next, the individual was asked to apply force to the dynamometer using elbow flexion for 3-4 seconds while holding the same position, attempting to meet the target force. To familiarize the participant with the procedure, we tested them 3 times with their eyes open and 3 times with their eyes closed. Afterward, the physiotherapist conducted the actual test 3 times with the participant's eyes closed, following the same procedure. After each measurement, the participant's deviation from the target value was recorded, and the average of the 3 trials was calculated. Next, the mean value obtained was divided by the MVC, and the result was multiplied by one hundred. This calculation gave the relative error rate of the participant deviating from the target force (%MVC). Finally, we used this value in the data analysis. The ICC values of the force matching test [ICC (3,k)] were 0.97 for %30 MVC (95% CI=0.94-0.98) and for MVC 0.91 (95% CI=0.84-0.95) in our study.

Closed Kinetic Chain Upper Extremity Stability Test

A 91.4 cm strip was marked on the floor of the basketball court. The participant was instructed to assume a push-up position on their hands with extended elbows. Within 15 seconds, they were asked to touch the opposite side of the strip as fast as possible, alternating between sides. Only one attempt was allowed during this test to prevent fatigue and help the participant get familiar with the procedure. Participants repeated the test 3 times with a rest interval of 45 seconds between repetitions to obtain the actual result. The arithmetic mean of the recorded evaluations was calculated for analysis.[15] A normalized score was obtained by dividing the total number of touches by the participant's height. The average number of touches was multiplied by 68% of the participant's body weight in kilograms to calculate the strength score. This score corresponds to the weight of the participant's arms, head, and trunk divided by 15.[16] The normalized score and power score were used for statistical analysis. The ICC value of CKCUEST [ICC (3,k)] was 0.95 (95% CI=0.91-0.97) in our study.

Seated Medicine Ball Throw Test

A 10-meter strip was placed on the field floor. The participant sat with their back and hips against a wall, centered the strip between their legs, and threw a ball as far as possible on the strip without breaking contact with the wall. The throw was made from the chest with shoulders in 90° abduction, and elbows flexed. Participants were required to repeat the throw if they broke contact with the wall or threw the ball with one hand outside the lane, rendering the test invalid. The participant performed 3 practice throws and then 4 test throws for the actual test. A 30-second rest break was given between the 4 throws. The participants were instructed to hold the medicine ball with their elbow extended and shoulder in 90° flexion, then release the ball without breaking contact with the wall to account for varying arm lengths. The physiotherapist measured the distance between the ball and the wall in cm and subtracted the arm length from the throwing distance.[17] The average throwing distance was recorded for analysis. The ICC value of the SMBTT test [ICC (4,k)] was 0.98 (95% CI=0.98-0.99) in our study.

Passing Accuracy Test

The AAHPERD test, designed by the American Alliance for Health, Physical Education, Recreation and Dance, was performed to assess basketball passing skills.[18] The test involved 6 squares formed by tape on a wall, with 3 at a height of 152 cm (1st, 3rd, and 5th squares) and 3 at 91 cm (2nd, 4th, and 6th squares), with a 61 cm gap between each. A straight line was drawn on the floor parallel to the wall at a distance of 244 cm. Athletes had to throw a ball at each of the 6 squares in a specific order within 30 seconds without stepping on the line. Athletes must accurately throw a ball at 6 targets, starting from the 1st target. If they reach the 6th target within 30 seconds, they return to the beginning by throwing the ball to each target in a reverse sequence. Participants scored 2 points for each shot inside the target square or on the boundary lines and one point for each shot in the space between the squares. A trial measurement was taken to determine the participant's score, followed by 2 actual measurements. The total score was the sum of the scores from these 2 measurements. The ICC value of the pass accuracy test [ICC (2,k)] was 0.85 (95% CI=0.73-0.91) in our study.

STATISTICAL ANALYSIS

IBM SPSS Statistics (version 15, Armonk, New York City, USA) was used to analyze the data. The sample size for the study was determined using G*Power version 3.1.9.2 (Heinrich-Heine-University in Düsseldorf, Germany). Based on an expected effect size of r=0.50, a significance level of α=0.05, and a desired statistical power of 0.80, the minimum required sample size was calculated to be 29 participants. To account for potential data loss, we aimed to include approximately 20% more participants, targeting a total of at least 35 participants for the study. Descriptive statistics were applied to all data, expressed as mean, standard deviation, number, and percentage. The data were tested for normal distribution using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Nonparametric tests were used where data showed nonnormal distribution. Spearman correlation analysis was performed to investigate the relationship between elbow joint proprioception, upper extremity physical performance, and passing accuracy variables. To de-

termine the statistical significance of the data, we set a significance level of $p<0.05$.

RESULTS

The study involved 45 adolescent basketball players aged 15-18 who met the inclusion criteria. Of these participants, 22 (48.9%) were girls and 23 (51.1%) were boys. They had an average of 2.2 years of basketball experience. The demographic details of the participants are presented in Table 1.

During the active angle repetition test performed at 45°, 60°, and 75°, the median absolute errors were recorded as 5.67, 4.67, and 5.67, respectively. In addition, the force-matching skill test conducted at 30% of MVC recorded a median relative error value of 16.47. The CKCUEST recorded a median number of touches of 18, with a median normalized score of 13.11. The median power score for CKCUEST was 61.83, with a median SMBTT of 3.38 meters and a median pass accuracy of 33 points. These results are shown in Table 2.

The correlations between elbow proprioception and the upper extremity physical performance test and passing accuracy are shown in Table 3. Non-parametric correlation analysis revealed that neither force matching nor JPS showed significant correlation with physical performance measures and pass accuracy scores ($p>0.05$).

There was a significant positive correlation between the CKCUEST normalized scores of the participants and the SMBTT scores, indicating a low level of correlation ($r_S=0.337$, $p=0.023$). However, there was no significant relationship between the CKCUEST normalized scores and pass accuracy ($r_S=0.247$, $p=0.102$). On the other hand, the CKCUEST power scores were significantly and positively correlated with both SMBTT ($r_S=0.770$, $p=0.000$) and pass accuracy scores ($r_S=0.422$, $p=0.004$). The correlation with SMBTT was moderate, while the correlation with pass accuracy was weak. It was also found that SMBTT distance had a moderate positive correlation with pass accuracy ($r_S=0.612$, $p=0.004$) (Table 4).

TABLE 1: The adolescent basketball players' characteristics

	Numbers (%)	$\bar{X}$ (SD)
Gender		
Female	22 (48.9)	
Male	23 (51.1)	
Dominant side		
Right	41 (91.1)	
Left	4 (8.9)	
Age (years)		15.62 (0.98)
Experience in basketball (years)		2.20 (1.73)
Height (m)		1.72 (0.11)
Body weight (kg)		63.22 (12.57)
Body mass index (kg/m^2)		21.08 (2.88)

SD: Standard deviation

TABLE 2: The measurement of elbow proprioception, upper extremity physical performance, and pass accuracy results

	Minimum	Maximum	$\bar{X}$ (SD)	Median (25th-75th percentiles)
Joint position sense				
45°	1.00	23.00	7.69 (6.02)	5.67 (3.16-11.16)
60°	0.67	26.67	6.53 (5.42)	4.67 (2.83-8.67)
75°	0.67	26.67	7.13 (5.69)	5.67 (3.50-9.33)
Force matching skill (%MVC)	3.85	95.94	23.93 (20.29)	16.47 (9.48-31.20)
Physical performance measurements				
Closed Kinetic Chain Upper Extremity Test (touches)	4.19	30.33	16.60 (8.04)	18.00 (8.51-23.16)
Closed Kinetic Chain Upper Extremity Test-normalized score	8.43	17.98	13.04 (2.22)	13.11 (10.97-14.60)
Closed Kinetic Chain Upper Extremity Test-power score	40.80	107.44	64.59 (17.59)	61.83 (48.90-76.79)
Seated Medicine Ball Throw (meters)	1.96	5.96	3.71 (1.14)	3.38 (2.80-4.76)
Passing accuracy (points)	20.00	39.00	31.74 (4.10)	33.00 (29.75-35.00)

SD: Standard deviation; %MVC: Percentage of maximal voluntary contraction

TABLE 3: The correlations between elbow proprioception, upper extremity physical performance tests, and passing accuracy in adolescent basketball players

	Elbow proprioception measurements							
			Joint position sense					
	Force matching		45°		60°		75°	
Variables	r_S	p value	r_S	p value	r_S	p value	r_S	p value
Closed Kinetic Chain Upper Extremity Test-normalized score	0.153	0.317	-0.248	0.100	-0.088	0.564	-0.222	0.161
Closed Kinetic Chain Upper Extremity Test-power score	0.141	0.355	-0.124	0.418	-0.077	0.617	-0.116	0.291
Seated Medicine Ball Throw Distance (meters)	0.141	0.354	0.031	0.841	0.003	0.982	-0.071	0.642

r_S: Spearman correlation coefficient; p: significance level

TABLE 4: The correlations in upper extremity physical performance tests and passing accuracy in adolescent basketball players

Variables		Seated Medicine Ball Throw distance (m)	Passing accuracy
Closed Kinetic Chain Upper Extremity Test-normalized score	r_S	**0.337**	0.247
	p value	**0.023***	0.102
Closed Kinetic Chain Upper Extremity Test-power score	r_S	**0.770**	**0.422**
	p value	**0.000***	**0.004***
Seated Medicine Ball Throw distance (m)	r_S		**0.612**
	p value		**0.000***

* = p<0.05; r_S: Spearman correlation coefficient; p: significance level

DISCUSSION

In this study, we found that elbow proprioception was not significantly associated with upper extremity physical performance or passing accuracy in adolescent basketball players aged 15 to 18. However, we did find a positive correlation between upper extremity physical performance, as measured by functional tests, and passing accuracy. Our findings indicate that physical capacities may be a more significant determinant of passing success than proprioceptive acuity in this population.

Motor control and ecological dynamics perspectives suggest that beginners depend significantly on feedback to guide their movements. In contrast, skilled athletes perform more automatically, adjusting their actions based on task-related cues. Ecological dynamics particularly highlight that training in realistic, game-like environments facilitates the shift toward automatic control.[19,20] This insight may clarify why proprioceptive measurements in isolated tasks, such as assessing JPS, do not always correlate with performance in more complex skills like passing. Evidence from various sports indicates that proprioceptive function can enhance athletic performance. For instance, elite athletes often demonstrate more developed proprioception than their non-elite counterparts, which contributes to improved balance and movement control.[21] However, research findings in this area are inconsistent. For example, in a cross-sectional study, a limited relationship was found between active shoulder JPS and upper extremity function tests in university volleyball players.[22] Similarly, our results indicated that elbow JPS did not significantly associate with passing accuracy in adolescent basketball players.

There is limited literature on upper extremity proprioception in basketball, and their findings are consistent with ours. Kucuk and Karakaş examined elbow proprioception and shooting performance, reporting no significant relationship between JPS and shooting accuracy.[10] Similarly, Görgül and Altun found that shoulder and wrist JPS were not related to shooting accuracy in team sports.[9] Although proprioceptive ability contributes to general motor control, these findings suggest that its direct transfer to sport-specific skills such as pass accuracy may be limited.

Proprioceptive sensitivity and sensorimotor integration gradually develop from childhood through late adolescence.[23] In our study, most participants were 15 years old; however, the age distribution was uneven across the sample. As a result, proprioceptive mechanisms may not be fully mature in younger participants, potentially diminishing the likelihood of finding a relationship between proprioception and performance. Future research should consider using narrower age ranges or adopting longitudinal designs to account for developmental effects more effectively.

Our findings indicate that while there is no direct relationship between upper extremity physical performance and elbow proprioception, there is a positive correlation with passing accuracy. Passing is crucial for offensive efficiency and match outcomes, as it is one of the most essential skills in basketball.[2,3] Previous studies have demonstrated that acute upper extremity fatigue can lead to a decrease in grip strength and passing accuracy among young basketball players. This finding highlights the importance of muscle endurance and strength for successful technical performance.[24] Taking these findings together, we can conclude that while there is no direct link between elbow proprioceptive acuity and performance, the physical capacity of the upper extremity significantly influences passing accuracy in adolescent players.

Proprioceptive training plays an important role in athletic development. A recent systematic review showed that proprioceptive training can improve balance and neuromuscular control, as well as sport-specific skills such as dribbling and passing.[7] While our findings do not establish a direct link between elbow proprioception and passing accuracy -one of the key basketball skills- proprioceptive training may still offer indirect benefits for adolescent basketball players by improving their overall physical performance and movement efficiency.

CONCLUSION

In conclusion, this study found no relationship between elbow proprioception and passing accuracy or upper extremity physical performance in adolescent basketball players. However, a positive correlation was observed between upper extremity physical performance and passing accuracy, highlighting the importance of strength and power for successful passing. These findings suggest that while proprioception may support motor control, physical performance could be a more direct factor influencing passing accuracy in adolescent basketball players. Future studies should further explore the development of proprioception during adolescence and its interaction with the acquisition of sports-related skills.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Buse Nur Saltık Uygun;* ***Design:*** *Buse Nur Saltık Uygun, Hakan Akkan;* ***Control/Supervision:*** *Hakan Akkan;* ***Data Collection and/or Processing:*** *Buse Nur Saltık Uygun;* ***Analysis and/or Interpretation:*** *Buse Nur Saltık Uygun, Hakan Akkan;* ***Literature Review:*** *Buse Nur Saltık Uygun;* ***Writing the Article:*** *Buse Nur Saltık Uygun;* ***Critical Review:*** *Hakan Akkan;* ***References and Fundings:*** *Buse Nur Saltık Uygun;* ***Materials:*** *Buse Nur Saltık Uygun.*

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