

Examination of Force and Joint Position Senses in Hip Joints of Aerobic Gymnasts of Different Age Groups, and Comparison Effect of External Load to Joint Position Sense

Farklı Yaş Gruplarındaki Aerobik Cimnastikçilerin Kalça Eklemelerinde Kuvvet ve Eklem Pozisyon Duyularının İncelenmesi ve Dış Yükün Eklem Pozisyon Duyusuna Etkisinin Karşılaştırılması

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ABSTRACT Objective: This study aimed to investigate the development of target joint position sense (JPS) and force sense (FS) in young gymnasts at different age groups and compare the effect of external load on position sense. **Material and Methods:** A total of 38 gymnasts were divided into three age groups: 12-14, 15-17, and 18 and over age groups. The maximum voluntary isometric contraction (MVIC) forces of the participants at a 90-degree hip angle were measured with an isokinetic dynamometer. For the isometric FS test, the target of 50% MVIC was used. Two active JPS tests were performed with and without a load. For the JPS test under load, 50% of MVIC was isotonically applied. The error scores were acquired from the absolute difference between the reproduced and targeted values in all conditions. **Results:** Results of repeated measures indicated the significant main effect of loads [$F_{(1,37)}=7.41$, $p=0.010$, $\eta^2=0.17$]. Significant differences were found between no-load and under load JPS error values [$t_{(37)}=2.72$, $p=0.010$]. Under load (2.05 ± 1.86 -degree), absolute error scores were statistically less than no-load (3.50 ± 3.02 -degree). A significant negative correlation was found between age groups and FS error scores. **Conclusion:** The hip JPS improves with the external load. Testing gymnasts' joint position sense acuity under external loads, such as the nature of the sport, may be a more appropriate test criterion. This is especially important in determining the criteria for returning to sports after injury. Those in the higher age group make fewer FS errors. This indicates that strength acuity improves as the age of athletes improves and reveals the contribution of aerobic gymnastics to the development of the sense of force.

Keywords: Joint position sense; force sense; external load; age; aerobic gymnastics

ÖZET Amaç: Bu çalışmada, farklı yaş gruplarındaki genç cimnastikçilerde hedef eklem pozisyon duygusu ve kuvvet duygusu gelişimini araştırmak ve dış yükün pozisyon duygusu üzerindeki etkisini karşılaştırmak amaçlandı. **Gereç ve Yöntemler:** Toplam 38 cimnastikçi 12-14, 15-17 ve 18 ve üzeri yaş grupları olmak üzere yarışma yaşlarına göre 3 gruba ayrıldılar. Katılımcıların 90 derecelik kalça açısında maksimum istemli izometrik kasılma kuvvetleri izokinetik dinamometre ile ölçüldü. İzometrik kuvvet duygusu testi için hedef olarak maksimum istemli izometrik kasılmanın %50'si kullanıldı. Harici yüklü ve yüksüz 2 aktif eklem pozisyonu duygusu testi yapıldı. Yük altında eklem pozisyonu duygusu testi için maksimum istemli izometrik kasılmanın %50'si harici yük olarak uygulandı. Tüm koşullarda hata skorları hedeflenen ve üretilen değerler arasındaki mutlak farktan elde edildi. **Bulgular:** Tekrarlanan ölçümlerin sonuçları, harici yükün önemli bir etkisi olduğunu gösterdi [$F_{(1,37)}=7.41$, $p=0.010$, $\eta^2=0.17$]. Yüksüz ve harici yüklü eklem pozisyonu duygusu hata değerleri arasında önemli farklar bulundu [$t_{(37)}=2.72$, $p=0.010$]. Yük altında, mutlak hata skorları ($2,05 \pm 1,86$ -derece) istatistiksel olarak yüksüz durumdan ($3,50 \pm 3,02$ derece) daha düşüktü. Yaş grupları ile kuvvet duygusu hata puanları arasında anlamlı negatif korelasyon bulundu. **Sonuç:** Bu çalışmada, kalça eklem pozisyon duygusu harici yük altında iyileşti. Cimnastikçilerin eklem pozisyon duygusu keskinliklerinin sporun doğasındaki gibi harici yük altında test etmek daha uygun bir test kriteri olabilir. Bu durum, özellikle sakatlık sonrası spora dönüş kriterlerinin belirlenmesinde önemlidir. Daha yüksek yaş grubundakiler daha az kuvvet algılama hatası yapmaktadır. Bu durum, sporculuk yaşı ilerledikçe kuvvet keskinliğinin iyileştiğinin göstergesidir ve aerobik cimnastiğin kuvvet duygusu gelişimine katkısını ortaya koymaktadır.

Anahtar Kelimeler: Eklem pozisyon duygusu; kuvvet duygusu; harici yük; yaş; aerobik cimnastik

Aerobic gymnastics is the ability to perform continuous high-intensity and complex movement patterns, which originate from traditional aerobic exercises.¹ Gymnasts must demonstrate continuous

movement, flexibility, strength, and the utilization of the basic steps, with perfectly executed difficulty elements. All movements must be performed with maximum precision without errors. The execution

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success requires well-controlled muscle strength with good proprioception in the joints.² In gymnastics, balance and joint control ability are decisive in performing a great variety of elements.^{1,3} Especially hip joint control is critical to success in proper and coordinated body movements. However, force sense (FS) and joint position sense (JPS) tests in the hip joint have never been done before. There is only one study assessing the JPS and FS among adolescent aerobic gymnasts.⁴ While gymnastics is considered to be a fundamental sport, there was little interest in the proprioceptive system that controls force replication, and the contribution of gymnastics training to proprioceptive development has not been studied.^{4,6} These sensory repositioning processes can be influenced by age and sport expertise capabilities, especially in sports where joint control is emphasized, such as aerobic gymnastics.

Proprioception has a crucial role in movement control, fundamental for daily activities and sports.⁷ Good control of joint position and force in aerobic gymnastics is critical for top performance. Poor joint proprioception may induce an increased possibility of injury.⁸

Joint proprioception is usually examined by assessing JPS and FS.⁹⁻¹² The JPS test measures how precisely the joint position is adjusted, and the FS test measures how accurately the movement force is produced. However, JPS and FS tests of proprioception lack ecological validity because the testing conditions are so different from the normal function that they can contribute little to understanding the role proprioception plays in daily and sporting activities.⁷ Joint proprioception studies have focused on JPS evaluation without any loads.¹³ However, in aerobic gymnastics, external loads such as acceleration, deceleration, and jumping to certain heights affect the muscles.¹ Therefore, JPS should be tested under load.

This study aimed to (1) investigate the development of target JPS and FS in young gymnasts at different age groups and (2) compare the effect of external load on position sense. It was hypothesized that the external load improves active joint reposition sense. Additionally, it was hypothesized that the older gymnasts would demonstrate greater accuracy in JPS and FS in comparison to younger gymnasts.

MATERIAL AND METHODS

PARTICIPANTS

The current study was approved by the Health Sciences Ethics Committee of Manisa Celal Bayar University (04/09/2019 - 20.478.486) and conducted in accordance with the principles of the Declaration of Helsinki. For the participants under the age of 18, the voluntary consent form was arranged according to their families. Thirty-eight (17 male and 21 female) competition athletes licensed from Turkey Gymnastics Federation participated in the study. Gymnasts who have been competitively participating in aerobic gymnastics for a minimum of 5 and a maximum of 10 years were included in this study. They were required to abstain from using any medications and have no acute or chronic orthopedic disorders on the hip joint. Participants were informed verbally and in writing about the method and objectives of the study and agreed to volunteer for the study. They were asked not to engage in intense physical activity in the last 24 hours before the study.

Competitions in aerobic gymnastics are held in categories 12-14, 15-17, and 18 years and over. Therefore, volunteers were divided into three groups based on the competition levels. The 12-14 age group consisted of 13 (7 girls and 6 boys) gymnasts, with a 40.92 ± 4.86 kg body weight, 149.85 ± 4.69 cm height, and $13.75 \pm 4.02\%$ body fat ratio. The 15-17 age group consisted of 12 (5 girls and 7 boys) gymnasts, with a 57.21 ± 6.44 kg body weight, 164.50 ± 4.64 cm height, and $16.48 \pm 4.35\%$ body fat ratio. The age group of 18 and over consisted of 13 (5 girls and 8 boys) gymnasts, with a 66.51 ± 14.25 kg body weight, 170.73 ± 9.89 cm height, and $15.43 \pm 4.76\%$ body fat ratio.

STUDY DESIGN AND PROCEDURES

Before the tests, the gymnasts performed a warm-up on the cycle ergometer (Monark 894E, Monark, Sweden) using a crank rate of 60 rev/min and a power output of 1 W/kg.⁴ They were familiarized with the test using different low-force levels and random target angles. Two trials were performed for each condition during the familiarization, and purposefully different angles from 90 degrees were applied so that the results were not affected by the learning effects.

FS, JPS, and maximum voluntary isometric contraction (MVIC) were analyzed on the isoforce isokinetic dynamometer (TUR Therapietechnik GmbH, Berlin, Germany).¹⁴ Evidence that the dynamometer is reliable in the evaluation of many joints was provided in previous studies.¹⁴⁻¹⁶ Participants lay on the dynamometer in a supine position. The hip was fixed to the seat. The axis of the dynamometer was aligned based on the hip joint rotation axis. To determine the dominant limb, participants were asked which leg they used to kick a ball, and the dominant leg was attached to the power arm-this starting position considered 0-degrees for hip flexion.^{14,17} All the error scores were acquired from the absolute difference between the reproduced and targeted values. The lowest error score obtained in two trials was used for analysis.

MVIC was tested with test times of 5 s three times, with 5 minutes of rest between attempts.¹¹ The highest peak torque from three trials was taken for analysis and was used to calculate the target force for FS testing. The hip joint FS was assessed using 50% of MVIC.¹¹ The gymnast tried the target force twice by visual feedback on the computer screen and maintained the force reproduction isometrically for 5 s. They were then asked to replicate the target force two times as blindfolded, and maintain it for 5 seconds. Participants rested for 90 seconds between trials to avoid fatigue.^{4,18}

Fifty percent load of the MVIC was applied for the JPS test under external load by the dynamometer. First, the gymnasts tried the 90-degree hip flexion by seeing at the dynamometer screen. They then tried target hip flexion in the blindfolded condition. In each load condition, participants performed 2 experimental trials. Participants were allowed to get rest for 90-seconds between JPS attempts to eliminate the effect of fatigue. The order of the experimental tasks was counterbalanced among the participants except for no-load JPS, which was always performed first.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS 20.0 (SPSS Inc., Chicago, IL). Normal distribution was tested with Kolmogorov-Smirnov for age, height, body weight, and body fat ratio variables ($p>0.05$). In order to explore whether JPS errors may vary as a result of load conditions, repeated measures of

ANOVA was carried out. To see the significant main effect of load, multiple comparisons were conducted with Bonferroni correction. With and without load JPS error scores were compared with paired sample t-tests. The level of significance was set at $\alpha=0.05$ in all tests.

RESULTS

There is no established criterion to assess the quality of JPS error results, but low absolute error values are considered to be “good” and high error values are considered “poor” proprioception.^{7,19} JPS test outcomes of the entire sample according to their age groups and load conditions are shown in Figure 1. The figure presents the absolute deviation values from the target angle in the JPS test. JPS error values with external load decreased significantly in all age groups.

FS test outcomes of the entire sample according to their age groups are shown in Figure 2. The figure

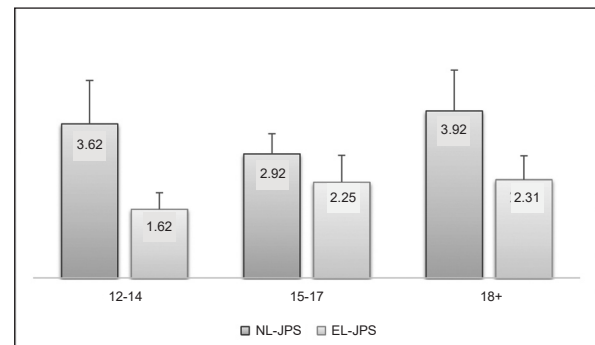


FIGURE 1: Joint position sense test outcomes of the entire sample according to their age groups.

NL: No-load; EL: External load; JPS: Joint position sense.

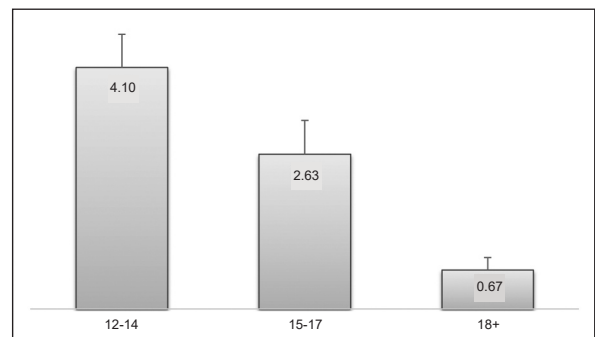


FIGURE 2: Force sense test outcomes of the entire sample according to their age groups.

presents the absolute deviation values from the target force replication in the FS test. As age increased, FS error values decreased significantly.

A significant relationship was found between neither FS error values nor JPS error values and gender. No significant relationship was found between absolute error values and age, age group, and gymnastics participation year in JPS tests performed under different load conditions (Table 1). However, a negative correlation was found between FS absolute error values and age ($r=-0.584$, $p=0.000$), age group ($r=-0.660$, $p=0.000$), and gymnastics participation year ($r=-0.494$, $p=0.002$). In other words, FS absolute error values decrease as the age, age group, and year of gymnastics participation increase (Table 1).

The JPS absolute error mean of the participants was 3.50 ± 3.02 -degree without load and 2.05 ± 1.86 -degree under load. Results of repeated measures indicated the significant main effect of loads [$F_{(1,37)}=7.41$, $p=0.010$, $\eta^2=0.17$]. Significant differences were found between under load JPS and no-load JPS error values [$t_{(37)}=2.72$, $p=0.010$]. Overall, results suggested that the load may give rise to fewer error values in JPS.

DISCUSSION

One of the two main findings of this study was that the accuracy of angular repositioning of the hip was more precise under load compared to the no-load JPS. Reposition sense of the hip was less erroneous in under load than the no-load JPS. The higher accuracy observed during JPS testing under load may be due to greater stimulation of mechanoreceptors in parallel with increased muscle contractions.^{20,21} The sense of effort contributes to JPS accuracy.²² If this improved

accuracy is, in fact, derive from more mechanoreceptor stimulation leading to conscious awareness of joint position, external loaded movements may provide an advantage over no-load movements.^{23,24} The load might increase the proprioceptive sensation, and hence JPS errors may have been reduced.

JPS or FS tests on the hip joint have never been performed before in the reviewed literature. The absolute error data obtained in this study can be used to evaluate the hip position and force sense of healthy gymnasts returning to sports after injury. Reduced JPS errors under the external load are valuable findings for return to sports. After the injury heals, people return to their daily lives. However, the athletes return to competitions and intensive training. This method may be a more appropriate lower extremity screening tool to the nature of the sport.

Previously researchers assessed JPS with the knee in the weight-bearing position.^{13,15} They found a better angular repositioning in the weight-bearing position than the non-weight-bearing position. However, the weight-bearing differs from the external load application and cannot be compared directly to each other. The weight is a load on the knees. On the other hand, the effect of the load differs when the body position changes during movements.²⁵ Therefore, measuring JPS under the influence of external load may be a more accurate assessment method in aerobic gymnastics.

Suprak et al. and Phillips and Karduna examined the effect of the external load in the shoulder joint.^{22,26} Suprak et al. reported that shoulder JPS improves with the external load.²⁶ On the other hand, Phillips and Karduna have not observed the same effect.²² Similarly, Kaynak et al. and Altun reported that knee

TABLE 1: Force sense and joint position sense correlations.

	FS Absolute error		No-load JPS Absolute error		Under load JPS Absolute error	
	r value	p value	r value	p value	r value	p value
Age	-0.584**	0.000	0.114	0.494	0.228	0.169
Age group	-0.660**	0.000	0.043	0.799	0.156	0.349
Participation year to the gymnastics	-0.494**	0.002	0.170	0.307	0.001	0.995
Gender	-0.175	0.293	0.222	0.180	-0.084	0.618

** : $p < 0.01$. FS: Force sense; JPS: Joint position sense.

JPS improves with the external load.^{15,16} The findings of the current study are in line with the results of the study on other joints. It showed that the hip JPS improved when an external load was applied.

The second major finding of this study is that target force replication accuracy in gymnasts improves with age. Muscle strength and nerve-muscle coordination develop with age.²⁷ The senses of effort, force, and heaviness are considered by some researchers to be components of proprioception.^{27,28} However, the relationships between movement-related and force-related aspects of proprioception are still unclear.⁷ As muscle spindles are the primary proprioceptors involved in JPS and are also involved in FS, there may be a relationship between these 2 aspects of proprioception and muscle strength.^{4,29-32} Previously, strength training was shown not to improve the sense of force.³³ However, Altun and Kaynak et al. showed that the higher maximal force disrupts the sense of force.^{15,16} Butz et al. reported that dynamic balance ability is directly related to chronological age.³⁴ The reason why the sense of force in this study develops with age seems to be related to the improvement of nerve-muscle coordination rather than the increase in muscle strength with age.

The finding of this study showed that active JPS accuracy was not affected by gender (male and female). Results were the same, both no-load and under load tasks. Herrington demonstrated that gender does not have a significant effect on the error value.³⁵ Similar to this study, Struzik et al. did not find any significant differences between the groups stratified by age, gender, and sport.³⁶ Previous researches support our findings.^{15,16,35,36}

CONCLUSION

Based on the findings of this study, it can be said that hip JPS acuity improves with external load. Testing gymnasts' joint position acuity under external loads, such as the nature of the sport, may be a more appropriate test criterion. This is especially important in determining the criteria for returning to sports after injury. Those in the higher age group make fewer FS errors. This indicates that strength acuity improves as the age of athletes improves and reveals the contribution of aerobic gymnastics to the development of the sense of force.

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: Deniz Tıkız, Muammer Altun; Design: Muammer Altun; Control/Supervision: Muammer Altun; Data Collection and/or Processing: Deniz Tıkız; Analysis and/or Interpretation: Muammer Altun; Literature Review: Deniz Tıkız; Writing the Article: Muammer Altun; Materials: Muammer Altun, Deniz Tıkız.

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