Med Pregl 2024; LXXVII (9-12): 303-308. Novi Sad: septembar-decembar.

KNEE PROPRIOCEPTION OF YOUNG VOLLEYBALL PLAYERS AND BALLERINAS

PROPRIOCEPCIJA KOLENA MLADIH ODBOJKAŠICA I BALERINA

Vladimir RISTIĆ[1], Filip OSTOJIĆ[2], Milan MILOVIĆ[3] and Vukadin MILANKOV[4,5]

ORCID NUMBER
Vladimir Ristić – 0009-0007-8827-5816
Filip Ostojić – 0009-0008-7034-3865
Milan Milović – 0009-0003-8546-0101
Vukadin Milankov – 0000-0001-5009-0372

Subotica General Hospital, Department of Orthopedic Surgery and Traumatology, Subotica[1]
Health Center "Novi Sad", Novi Sad[2]
Vrbas General Hospital - Department of Orthopedic Surgery and Traumatology[3]
University of Novi Sad, Faculty of Medicine Novi Sad[4]
Institute for Health Care of Children and Youth of Vojvodina, Novi Sad[5]

Original study
Originalni naučni rad
UDK 616.728.3:796.012.2/.3
UDK 612.76.08:796.325-055.2; UDK 612.76.08:78.085.5-055.2
https://doi.org/10.2298/MPNS2412303R

Abstract

Introduction. The aim of this study is to evaluate and analyze proprioception in adolescent girls. **Material and Methods.** This retrospective study included 39 girls aged 13 to 19 years, divided into two groups: 22 ballerinas and 17 volleyball players. Participants were tasked with consciously identifying a predetermined position of their lower leg without visual input. A digital goniometer was used to assess both the speed and degree of deviation from the targeted angle. **Results and Discussion.** Ballerinas demonstrated statistically significantly better proprioception in the left leg compared to volleyball players, in terms of both accuracy and intensity of the angular ascent ($p<0.05$). Volleyball players showed weaker and less precise performance in reproducing the left leg position, although their right leg proprioception was significantly better. In contrast, ballerinas exhibited no significant differences between the right and left leg in proprioception performance. **Conclusion.** Knee joint injuries are uncommon in ballerinas, likely due to their superior proprioception compared to volleyball players. Incorporating ballet-based techniques into volleyball and other athletic training programs may enhance proprioceptive ability and contribute to injury prevention.

Key words: Proprioception; Knee; Athletes; Sports; Dancing; Knee Injuries; Accident Prevention; Adolescent

Sažetak

Uvod. Cilj istraživanja predstavlja testiranje i analiziranje propriocepcije tinejdžerki. **Materijal i metode.** Retrospektivna studija je uključila dve grupe devojčica uzrasta od 13 do 19 godina. Od ukupno 39 ispitanica, 22 su balerine, a 17 odbojkašice, sa zadatkom da bez gledanja svesno odrede zadati položaj svoje potkolenice. Za eksperimentalni deo utvrđivanja brzine i stepena greške korišćen je digitalni goniometar. **Rezultati i diskusija.** U grupi balerina ustanovljena je statistički značajno bolja propriocepcija leve noge od grupe odbojkašica, kako u preciznosti, tako i u intenzitetu ugaonog uspona ($p < 0,05$). Odbojkašice su imale slabiju i manje preciznu realizaciju zadatog položaja leve noge, dok im je desnostrana propriocepcija bila značajno bolja. U grupi balerina ne postoje značajne razlike u testiranju obe noge. **Zaključak**. Povrede kolenog zgloba se veoma retko dešavaju među balerinama, jer imaju bolju propriocepciju od odbojkašica, te bi uvođenje baletskih tehnika u trening odbojke i ostalih sportova verovatno bilo efikasno u prevenciji povreda.

Ključne reči: propriocepcija; koleno; sportisti; sport; ples; povrede kolena; prevencija povreda; adolescenti

Introduction

Proprioception, often referred to as the "sixth sense", describes the body's ability to perceive its position and movement in space [1]. Conscious proprioception facilitates complex motor tasks, while unconscious proprioception plays a key role in maintaining postural control during static (e.g., sitting and standing) and basic dynamic activities such as walking. Although the precise mechanism remains under debate, there is a general consensus that proprioceptive receptors are located within muscles, joints, ligaments and tendons [1, 2]. These receptors detect stimuli and transmit information to the central nervous system, which then coordinates appropriate motor responses [1, 2].

Women have a 2-8 times greater risk of knee injuries - particularly anterior cruciate ligament injuries – compared to men [3–11]. However, in the Republic of Serbia, men are more frequently injured and undergo surgical treatment for knee injuries [3–8]. Interestingly, knee injuries appear to be relatively rare among skaters, hockey players, ballerinas, and dancers [1, 4–8]. This raises important questions about whether Serbian sports programs are adequately implementing injury-prevention protocols and incorporating proprioception training to reduce non-contact injury risks.

It remains unclear how athletes perform hundreds of identical knee movements during training or competition without injury, while a seemingly identical movement may cause a serious injury. Although ballet is not widely practiced in Serbia, it is often (incor-

✉ Corresponding author: Vladimir Ristić, E-mail: vladimirristic73@gmail.com, vukadin.milankov@mf.uns.ac.rs

Abbreviations

ACL – Anterior Cruciate Ligament
LCA – ligamentum cruciatum anterius
BMI – body mass index
UART – universal asynchronous receiver/transmitter
LESS – Landing Error Scoring System

rectly) perceived as safe with respect to knee injuries [9–11]. Each ballerina performs more than 200 jumps in a 1.5-hour training session, over half of which involve single-leg landing [9] - a particularly high-risk movement for ACL rupture. Despite this, ACL injuries are rare: reported in only 0.2-0.9% of ballerinas and 0.4% of competitive modern dances [9], compared to 1-8% in team sports [5, 10, 12].

Given these considerations, the aim of this study was to evaluate the accuracy of lower leg positioning as a measure of proprioception in adolescent females and to determine whether differences exist between girls actively engaged in volleyball versus ballet. We also reviewed the literature to explore whether elements of ballet training could be beneficially integrated into other sports such as volleyball [1, 13, 14].

Material and Methods

The prospective study was conducted with approval from the Ballet School in Novi Sad and the "NS Volley Team" volleyball club in Novi Sad. The study included two groups of female adolescents aged 13 to 19 years. A total of 39 participants were enrolled through randomized selection: 22 ballerinas and 17 volleyball players. Inclusion criteria were female sex, age between 13 and 19 years, and absence of previous knee injuries or surgeries.

Parents have provided informed consent after being briefed on the study protocol, purpose, and measurement procedures. Both groups were matched for age, body mass index (BMI), physical activity level, and limb dominance. The average BMI was 22.3 kg/m^2 in the volleyball group, and 21.4 kg/m^2 in the ballet group. Limb dominance was right-sided in 31 participants and left-sided in 8.

An original digital goniometer device was used for proprioception assessment [1]. This microcomputer-based measurement and acquisition system consisted of three components: a sensor module affixed to the subject's leg, an electronic processing unit with a basic display, and a software application installed on a personal computer for data capture and storage.

The apparatus transmitted angle data every 200 milliseconds via a universal asynchronous receiver/transmitter (UART) protocol.

The device was metrologically validated in cooperation with the Laboratory for Metrology at the Department of Electrical Measurements, Faculty of Technical Sciences, University of Novi Sad [1].

Proprioception testing focused on the knee joints flexion at a target angle of 35°. Each participant was tested on both limbs in a standardized manner. Subjects lay prone in a quiet room without visual access to their legs or the device display. The examiner passively moved the lower leg from full extension to the target angle, which the participant was asked to memorize and maintain for 30 seconds before relaxing. Immediately afterward, the participant was instructed to actively reproduce the same angle. The protocol was repeated for both legs, with the order randomized.

The results were statistically processed. The basic parameters of the target and reproduced values of the angles, and the difference between the left and right leg in degrees are presented in tables. The verification of the non-parametric characteristics of the target and reproduced values of the angles is shown using χ^2, Kolmogorov-Smirnov and t-test.

Results

Table 1 presents the basic parameters for the target (set) angles, achieved (realized) angles, and corresponding angular differences for the left and right knee of volleyball players.

Due to the relatively small sample size (N=17), the χ^2 test could not confirm a definitive distribution pattern.

However, the Kolmogorov-Smirnov test indicated a potential normal distribution of the differences between the set and realized angles for the left leg ($p = 0.4294 > 0.05$), which was further supported by the χ^2 test.

The Pearson correlation coefficient for the left leg among volleyball players was $r = 0.2025$, indicating

Table 1. Set and realized angles for volleyball players

Values in degrees (°)	N	Mathematical expectation	Minimum	Maximum	Standard deviation
Left default	17	37.6363	35	43	2.1940
Left realized	17	30.1818	25	35	3.1567
Left (D-R)	17	7.4545	0	15	3.4603
Right default	17	36.045	26	40	2.9354
Right realized	17	31.090	21	49	7.2500
Right (D-R)	17	4.9545	-9	14	6.2828

Table 2. Angular ascent intensity of the left and right leg of female volleyball players

Values in (°/msec)	N	Mathematical expectation	Minimum	Maximum	Standard deviation
Left	17	0.040364	0.012	0.082	0.019261
Right	17	0.043955	0.011	0.081	0.021524

Table 3. Differences in the angular ascent value and intensity of a ballerina's legs

Values in degrees (°)	N	Mathematical expectation	Minimum	Maximum	Standard deviation
Left (D-R)	22	7.4545	0	15	3.4603
Right (D-R)	22	4.9545	-9	14	6.2828
Left leg intensity	22	4.2727	-5	9	3.1650
Right leg intensity	22	4.0909	-3	10	3.9268

weak coordination and low accuracy in reproducing the set angle. In contrast, a moderate correlation as observed for the right leg ($r = 0.50995$), reflecting significantly better proprioceptive performance. The difference between the linear correlation coefficients for the left and right leg was statistically significant ($p = 0.00134 < 0.05$), clearly indicating superior right-leg proprioception in volleyball players.

Standard deviation (SD) analysis further supported this finding: SD of the angular error for the right leg ($s = 6.2828^o$) was greater than that of the left leg ($s = 3.4603^o$), suggesting the presence of a subgroup with highly refined right-leg coordination.

Table 2 summarizes the basic parameters for the intensity of the angular ascent in both legs.

A statistically significant difference in the correlation between the set and realized angles and angular ascent intensity was found between the left and right legs ($p = 0.00023 < 0.05$), further indicating a proprioception imbalance favoring the right side.

For ballerinas, **Table 3** presents the differences in realized angles and angular ascent intensities for both legs. The χ^2 test did not verify a definitive distribution. However, the Sign test revealed no statistically significant differences in accuracy between the left and right legs ($p = 0.6276 < 0.05$), indicating balanced proprioceptive performance.

The Sign test was also applied to compare angular distribution between volleyball players and ballerinas. A statistically significant difference was observed for the left leg ($p = 0.000022 < 0.05$), confirming superior left-sided proprioception for ballerinas. No significant difference was found for the right leg ($p = 0.662521 > 0.05$).

Regarding angular ascent intensity, ballerinas showed no statistically significant difference between their left and right legs ($p = 0.522431 < 0.05$). However, comparison between groups revealed a significant difference in left-leg angular ascent intensity ($p = 0.005578 < 0.05$), with ballerinas demonstrating higher values. Right leg ascent intensities were similar between the groups ($p = 0.135593 < 0.05$).

Finally, analysis of the correlation between angular error and angular ascent intensity showed the strongest negative correlation in ballerinas' left leg ($r = -0.3246$), indicating that greater angular ascent was associated with more accurate positioning. This correlation was significantly weaker in volleyball players ($r = -0.0155$; $p = 0.00877 < 0.05$).

For the right leg, no statistically significant difference was found between ballerinas ($r = -0.5640$) and volleyball players ($r = -0.4979$; $p = 0.1194 > 0.05$).

In summary, ballerinas demonstrated statistically significantly better proprioception in the left leg compared to volleyball players, both in terms of postural accuracy and angular ascent intensity.

Discussion

In our previous studies, over 90% of patients undergoing surgical treatment for knee joint structures were aged between 16 and 35 years [3–8]. Due to the physical demands of elite sports and the overloading of immature knee joints, such injuries are increasingly observed even among adolescents [10, 15, 16]. Consequently, modern sports trauma literature emphasizes the study of etiology, identification of risk groups, risk factors, and injury mechanisms - particularly those related to the anterior cruciate ligament (ACL)- as understanding these elements is crucial for prevention [3–6, 10, 15, 16]. Athletes, especially professionals, are among the highest risk groups for ACL rupture [3–8, 10, 15, 16]. Accordingly, current training and rehabilitation protocols aim to minimize high-risk lower extremity movements associated with these injuries [10, 15–17].

Injury mechanisms are categorized into contact and non-contact types, with 60-80% of ACL ruptures occurring without contact with opposing players [1–3, 5, 15–17]. Direction changes and landing movements are the most frequent causes [1–3, 5, 15–17].

The prevalence of knee injuries varies across sports and regions. In Serbia, soccer players dominate most injury samples [3–8, 18], while in Nordic countries handball players and skiers are more commonly affected [12]. In the United States of America, rugby and basketball players predominate [19], and in Japan, basketball players, wrestlers, and skiers [16]. In contrast, knee injuries are rare among athletes such as hockey players, skaters, and ballerinas, due to minimal surface-footwear friction [2, 9, 17, 18]. In our prior research, only two ballet dancers and one hockey player underwent ACL surgery out of 6,000 patients [3–8, 18]. In the United States, professional dancers and ballerinas experience significantly fewer ACL injuries than athletes in team sports. In a study following 298 professional dancers over five years, only 12 ACL injuries were reported [9]. Notably, 92% of these injuries occurred during single-leg landings, and female dancers were at higher risk than their male counterparts [9]. These trends are attributed to superior coordination, refined jumping techniques, and skilled balance control. Injuries tend to occur late in the day and season, indicating muscle fatigue as a contributing factor [2, 9].

Ballerinas typically exhibit hypermobility, increased hip external rotation, and lumbar lordosis, which may compensate for injury risk [21]. The most common injuries are ankle overuse syndromes from excessive foot inversion during landings [22]. One study found that dancers engaged significantly more hip flexion during blind landing compared to controls, thereby preserving proprioception and reducing injury risk [23]. Gluteal muscle activation and reduced knee valgus angles during landing may further protect the ACL [24]. In our earlier studies [4–6, 25], female volleyball players were frequently injured during landings.

In volleyball, 32.4% of injuries result from landings, with 23.2% occurring during matches, possibly due to fatigue [2]. Muscle fatigue significantly impairs balance, proprioception, and jump performance, particularly in high-risk athlete groups [2, 9]. Knee extensor fatigue decreases jump height and forces reliance on compensatory muscles [2]. Based on the potential for ACL injury, Iranian authors [2] divided 40 female volleyball players by injury risk using the Landing Error Scoring System (LESS). A LESS score below 6 points indicates low risk, and above 6, high risk. They used a goniometer to test the participants to hold the set angle for five seconds with their eyes open firs, after which the examiner moved their leg to reach 60 degrees flexion with their eyes closed. Static balance was tested by standing on one leg, and the maximum height jump and balance maintenance during dynamic tests were also analyzed. Post-fatigue testing showed significantly worse static and dynamic balance, maximum jump height, landing quality, and proprioception in the high-risk group (LESS score 7.20 vs. 3.85 in low-risk group) [2].

Compared to volleyball players, ballerinas are more focused on technique during risky movements, while volleyball players prioritize gameplay actions such as scoring, defense, and rapid landings, often on an opponent's foot [18, 25]. Ballerinas also tend to have optimal body mass indices (BMIs below 25) [9], while volleyball players in low- and high-risk groups average BMIs 22.2 and 22.7 respectively [2]. The average BMI for female athletes is 22.4, and 23.6 for males [25]. The rarity of knee injuries among ballerinas is likely multifactorial, including precise movement patterns, daily training of standardized motor skills, and minimal influence from external factors such as opponents or playing surfaces [9, 25].

Preventive training – particularly involving plyometric drills, core stabilization, neuromuscular control, strength training and proprioceptive exercises – has been shown to significantly reduce ACL injury risk [9–11, 22, 24–26]. Such exercises improve knee flection, reduce valgus angles and sudden directional changes, and promote safe landings and body awareness. Exercise programs include single- and double-leg squats, pelvic lifts, bench and ball exercises, and controlled landings, and have demonstrated reductions in injury incidence by nearly two-thirds over three years [10, 15, 16, 24].

Conversely, studies by Czech and American researchers [19, 27] found no significant differences in balance between professional dancers and controls during single-leg stance tests (with or without turns, eyes closed). Ballerinas showed superior performance only after 10 full-body rotations, likely due to trained, repetitive movements. These authors emphasize vestibular, rather than proprioceptive dominance in maintaining posture and dynamic balance [19, 27]. Others attribute dancers' resistance to dizziness after pirouettes to vestibular rather than muscular adaptation [28].

However, other studies have reported better bipedal balance in ballerinas [11, 29]. Janura et al. [10] noted that single-leg balance requires greater attention and motor control. Turkish authors [30] observed improvements in vertical jump performance, flexibility, dynamic balance, coordination, and proprioception in ballet and modern dance students after a two-month core stabilization program. The exercise program designed for 45-60 minutes a day, three days a week [30]. Additional studies confirmed the effectiveness of neuromuscular control exercises involving the hips, knees, and ankles, which included standing,

running, stopping, jumping, and landing, with use of balls and unstable surfaces [31, 32].

Our study sample consisted of 39 adolescent girls: 22 ballerinas and 17 volleyball players. Since proprioception declines with age [1], examining a young cohort strengthens these findings. Moreover, as female sex is associated with higher ACL knee injury risk [2, 9, 10, 15], limiting the sample to girls enhances the specificity of our conclusions. All participants had similar age and BMI profiles and no prior knee injuries, eliminating confounding variables.

Proprioception is clinically measured using two standard methods [1, 2]: detection of passive motion or active reproduction of a passively set joint position, the latter being used in our study. Similar to our goniometric study, research has shown that ballet training enhances joint position sense [33]. Turkish authors using similar methods with upper limbs also reported greater accuracy of hand joint position among ballerinas than controls [34].

The clinical relevance of proprioception is further highlighted in postoperative rehabilitation. After ACL reconstruction, a return to sports is typically not recommended before six months due to proprioceptive deficits [1, 8, 35].

Interestingly, during the COVID-19 pandemic, rugby and soccer players in South Africa incorporated ballet techniques into training and reported improvements in flexibility, coordination, dynamic balance, and muscle endurance through exercises involving stretching, lunging, landing, turning, and dance movements [13, 14]. These findings support the potential for incorporating ballet techniques into volleyball and other sports to reduce injury risk.

Limitations include the small sample size and lack of access to advanced proprioception testing methods. The limited number of ballerinas reflects the underrepresentation of ballet in Serbia. We were also unable to compare additional anthropometric parameters. Future research should examine other sports and investigate why proprioception appears to be worse in the non-dominant left leg, particularly in volleyball players – possibly due to reflex dominance in right-handed athletes. Despite evidence suggesting no difference in reflexive muscle contraction between dominant and non-dominant leg [1], this aspect warrants further investigation. Our study included only adolescent females, and the scarcity of male ballet dancers in Serbia.

Conclusion

In this study, young ballerinas demonstrated statistically significantly better proprioception of the left leg, both in terms of positional accuracy and angular ascent intensity. In contrast, volleyball players exhibited poorer coordination and less precise execution of the set angle with the left leg, while the right leg showed statistically significantly better proprioceptive performance. Among ballerinas, no statistically significant differences were observed in between the left and right leg in reproducing the set position. The rarity of knee injuries among ballerinas may be attributed to their superior proprioceptive abilities compared to volleyball players. These findings suggest that incorporating ballet-based techniques into volleyball and other sports training programs could have a preventive effect and potentially reduce the risk of lower extremity injuries.

References

1. Matijević R. Mehanizmi povređivanja LCA i propriocepcija. In: Milankov V, Krstić V, editors. Prednja ukrštena veza kolena. Novi Sad: Futura; 2024. p. 77-99.

2. Darabi HA, Ali Nasab Firouzjah EM, Roshani S. The impact of a volleyball-specific fatigue protocol on the balance, proprioception, and performance of volleyball players at high and low risk for ACL injuries. Journal of Rehabilitation Sciences and Research. 2025;12(1):37-44.

3. Karan S, Baljak B, Vukosav N, Gvozdenović N, Ninković S. Mechanisms of anterior cruciate ligament injury. Med Pregl. 2023;76(1-2):42-8.

4. Ristić V. Ko i kako povređuje prednji ukršteni ligament u Srbiji? Medicinski Arhiv Kosova i Metohije. 2022;(23-24):1-12.

5. Ristić V, Ninković S, Harhaji V, Milankov M. Causes of anterior cruciate ligament injuries. Med Pregl. 2010;63(7-8):541-5.

6. Ristić V, Ristić S, Maljanović M, Đan V, Milankov V, Harhaji V. Risk factors for bilateral anterior cruciate ligament injuries. Med Pregl. 2015;68(5-6):192-7.

7. Ristić V, Ninković S, Harhaji V, Stanković M, Savić D, Milankov M. Reconstruction of anterior cruciate ligament by using two different techniques. Med Pregl. 2010;63(11-12):845-50.

8. Milankov M, Miličić A, Savić D, Stanković M, Ninković S, Matijević R, et al. Revision anterior cruciate ligament reconstruction due to knee instability. Med Pregl. 2007;60(11-12):587-92.

9. Liederbach M, Dilgen FE, Rose DJ. Incidence of anterior cruciate ligament injuries among elite ballet and modern dancers: a 5-year prospective study. Am J Sports Med. 2008;36(9):1779-88.

10. Allen MM, Pareek A, Krych AJ, Hewett TE, Levy BA, Stuart MJ, et al. Are female soccer players at an increased risk of second anterior cruciate ligament injury compared with their athletic peers? Am J Sports Med. 2016;44(10):2492-8.

11. Michalska J, Kamieniarz A, Fredyk A, Bacik B, Juras G, Słomka KJ. Effect of expertise in ballet dance on static and functional balance. Gait Posture. 2018;64:68-74.

12. Myklebust G, Holm I, Maehlum S, Engebretsen L, Bahr R. Clinical, functional and radiologic outcome in team handball players 6-11 years after anterior cruciate ligament injury: a follow-up study. Am J Sports Med. 2003;31(6):981-9.

13. Solomons J, Kraak W, Kidd M, Africa E. The effect of a rhythmic movement intervention on selected bio-motor skills of academy rugby players in the Western Cape, South Africa. Int J Sports Sci Coach. 2020;16(1):91-100.

14. Maleki M, Rund P, Stirton K, Lockard M. Improving balance, flexibility, and agility using ballet training for football players: a pilot study. Int J Exerc Sci. 2019;8(7):45.

15. Alentorn-Geli E, Myer DG, Silvers JH, Samitier G, Romero D, Làzaro-Haro C, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: mehanisms of injury and underlying risk factors. Knee Surg Sports Traumatol Arthrosc. 2009;17(7):705-29.

16. Griffin LY, Albohm MJ, Arendt EA, Bahr R, Beynnon BD, Demaio M, et al. Understanding and preventing non-contact anterior cruciate ligament injuries. Am J Sports Med. 2005;34(9): 1512-32.

17. Koga H, Muneta T, Bahr R, Engebretsen L, Krosshaug T. ACL injury mechanisms: lessons learned from video analysis. In: Musahl V, Karlsson J, Kuroda R, Zaffagnini S, editors. Rotatory knee instability. Cham: Springer; 2016. p. 27-36.

18. Ristić V, Šumar V, Milankov V, Harhaji V, Milović M. The effects of age and gender on the quality of life after anterior cruciate ligament reconstruction. Med Pregl. 2020;73(1-2):13-20.

19. Dodson CC, Secrist ES, Bhat SB, Woods DP, Deluca PF. Anterior cruciate ligament injuries in national football league athletes from 2010 to 2013. Orthop J Sports Med. 2016;4(3):2325967116631949.

20. Takahashi S, Okuwaki T. Epidemiological survey of anterior cruciate ligament injury in Japanese junior high school and high school athletes: cross-sectional study. Res Sports Med. 2017;25(3):266-76.

21. Iunes DH, Elias IF, Carvalho LC, Dionísio VC. Postural adjustments in young ballet dancers compared to age matched controls. Phys Ther Sport. 2016;17:51-7.

22. Kadel NJ. Foot and ankle injuries in dance. Phys Med Rehabil Clin N Am. 2006;17(4):813-26.

23. Volkerding KE, Ketcham CJ. Biomechanical and proprioceptive differences during drop landings between dancers and non-dancers. Int J Exerc Sci. 2013;6(4):289-99.

24. Turner C, Crow S, Crowther T, Keating B, Saupan T, Pyfer J, et al. Preventing non-contact ACL injuries in female athletes: what can we learn from dancers? Phys Ther Sport. 2018;31:1-8.

Rad je primljen 26. I 2025.
Recenziran 31. III 2025.
Prihvaćen za štampu 1. IV 2025.
BIBLID.0025-8105:(2024):LXXVII:9-10:303-308.

25. Ristić V, Šumar V, Rašović P, Milankov V. The impact of body mass index on the results of reconstruction of anterior cruciate ligament. Med Pregl. 2021;74(11-12):354-61.

26. Ingersoll CD, Grindstaff TL, Pietrosimone BG, Hart JM. Neuromuscular consequences of anterior cruciate ligament injury. Clin Sports Med. 2008;27(3):383-404.

27. Kiefer AW, Riley MA, Shockley K, Sitton CA, Hewett TE, Cummins-Sebree S, et al. Lower-limb proprioceptive awareness in professional ballet dancers. J Dance Med Sci. 2013;17(3):126-32.

28. Lin CW, Chen SJ, Su FC, Wu HW, Lin CF. Differences of ballet turns (pirouette) performance between experienced and novice ballet dancers. Res Q Exerc Sport. 2014;85(3):330-40.

29. Stins JF, Michielsen ME, Roerdink M, Beek PJ. Sway regularity reflects attentional involvement in postural control: effects of expertise, vision and cognition. Gait Posture. 2009;30(1):106-9.

30. Kalaycioglu T, Apostolopoulos NC, Goldere S, Duger T, Baltaci G. Effect of a core stabilization training program on performance of ballet and modern dancers. J Strength Cond Res. 2020;34(4):1166-75.

31. Blackburn T, Guskiewicz KM, Petschauer MA, Prentice WE. Balance and joint stability: the relative contributions of proprioception and muscular strength. J Sport Rehabil. 2000;9-(4):315-28.

32. Schiftan GS, Ross LA, Hahne AJ. The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: a systematic review and meta-analysis. J Sci Med Sport. 2015;18(3):238-44.

33. Chatzopoulos D. Effects of ballet training on proprioception, balance, and rhythmic synchronization of young children. J Exerc Phys Online. 2019;22(2):26-37.

34. Esen A, Rudarli Nalcakan G, Varol SR. Joint position sense in Turkish professional ballet dancers. Nigde University Journal of Physical Education and Sport Sciences. 2013;7(1):60-7.

35. Ristić V, Ristić S, Maljanović M, Milankov V, Harhaji V, Đuričin A. Quality of life after bilateral anterior cruciate ligament reconstructions. Med Pregl. 2015;68(9-10):308-15.