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Impact of Proprioceptive Training on Postural Stability in Adolescent Male Soccer Players: A Single Group Preliminary Study

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Wpływ treningu proprioceptywnego na stabilność posturalną nastoletnich chłopców grających w piłkę nożną: badanie wstępne

Streszczenie

Piłka nożna jest jednym z najbardziej popularnych sportów zespołowych na świecie. Zarówno piłkarze amatorscy, jak i profesjonaliści narażeni są na wystąpienie kontuzji na treningach i meczach. W celu zmniejszenia tego ryzyka przeprowadzono badanie, które skupiło się na treningu poprawiającym stabilność posturalną, istotną dla zapobiegania kontuzjom sportowym. Badanie obejmowało 20 chłopców w wieku 14–15 lat, trenujących w profesjonalnym klubie piłkarskim. Średni wzrost badanych wynosił 172,0 cm, a masa ciała 58,5 kg. Interwencja polegała na dodatkowych treningach, które odbywały się dwa razy w tygodniu przez okres trzech miesięcy, z wykorzystaniem platformy Delos Postura Proprietary System. Pojedynczy trening trwał 15 minut. W ramach badania piłkarze przeszli test „RIVA", który obejmował ocenę stabilności posturalnej z zamkniętymi i otwartymi oczami przed oraz po przeprowadzonej interwencji. Wyniki wykazały istotną statystycznie poprawę w obu próbach, odpowiednio 4,3% i 2,1%. Porównując te wyniki

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z innymi badaniami, można sądzić, że dodatkowy trening w takiej formie może przyczynić się do zmniejszenia liczby kontuzji, szczególnie wśród młodych piłkarzy.

Słowa kluczowe: piłka nożna, stabilność posturalna, zapobieganie urazom, platforma Delos, młodzi sportowcy.

Abstract

Football is one of the most popular team sports globally. Both amateur and professional footballers face the risk of injuries during training and matches. To mitigate this risk, a study was conducted focusing on training to improve postural stability – a crucial element in sports injury prevention. The study involved 20 boys aged 14–15 years, training at a professional football club, with a mean height of 172 cm and a body weight of 58.5 kg. The intervention comprised additional training sessions held twice a week over three months, utilizing the Delos Postural Proprietary System platform. Each training session lasted 15 minutes. As part of the study, the footballers underwent the 'RIVA' test, assessing postural stability with eyes closed and open before and after the intervention. The results revealed a statistically significant improvement in both trials, 4.3% and 2.1%, respectively. When compared with findings from other studies, it is reasonable to conclude that this form of additional training may contribute to a reduction in injuries, especially among young football players.

Keywords: football, postural stability, injury prevention, Delos platform, adolescent athletes.

Introduction

Football is currently one of the most popular sports globally, with children all over the world being trained in it from an early age. It is an extremely complex sport that requires comprehensive preparation, encompassing more than just the development of physical fitness and improvement of technical skills (Basuki et al., 2021; Gioftsidou et al., 2012; Thorborg et al., 2017). In training, greater attention is being given to postural stability in various playing situations. Postural stability plays a crucial role in executing precise and ergonomic movements, maintaining balance, and preventing injuries (Cain et al., 2020; Lee et al., 2020).

A sports injury is defined as any tissue damage that occurs during sports training or competition. The most common criterion for diagnosing a sports injury is the need to miss at least one day of training or competition. The US National Sports Injury Recording System defines an injury as a 'documented injury' that limits the ability to train or play for a minimum of 1 consecutive day and categorizes it into mild (1–7 days), moderate (8–21 days), and severe (more than 21 days). The concept of sports injuries differs from standard injuries in that professional athletes are considered healthy only when they can perform at their best during competition or training. In contrast, non-professional athletes are generally considered healthy if they can perform their daily activities without limitations. The accurate count of sports injuries is often difficult to estimate

as it depends on various factors such as motivation, prompt consultation and injury documentation by a physiotherapist or doctor, the athlete's and coach's level of awareness (Emery & Pasanen, 2019; Sivaratnam et al., 2021; Sprouse et al., 2020). According to a study conducted in England, which involved 243 players from 10 teams in the English professional league (EFL), 473 injuries were recorded during the 2015–2016 season, with an estimated incidence of 9.11 injuries per 1,000 hours of activity. Lower limb injuries accounted for 64.2% of the total, with the thigh area being the most common injury site at 31.7%, followed by the knee joint at 14.6% and the ankle joint at 13% (Jones et al., 2019).

One tool in the effort to reduce injuries during training and competition is the introduction of a training module dedicated to proprioceptive stimulation. Proprioception is the ability to receive signals from various sensory mechanoreceptors to determine the sense of body position and movement, encompassing aspects such as static position, displacement, velocity, acceleration, and muscle force or effort (Pfirrmann et al., 2016; Riemann & Lephart, 2002). It operates on the principle of neuromuscular feedback, with peripheral mechanoreceptors located in joint structures, muscle fibers, the retina, and the vestibular vagus. Sensory receptors responsible for proprioceptive functions are situated in various connective tissues, including the skin, ligaments, tendons (tendinous), joint capsules (articular), and skeletal muscles (muscular). The central component of this system includes key structures in the central nervous system, such as the spinal cord, midbrain, and cerebellum (Moon et al., 2021).

The Delos Postural Proprietary System (DPPS) was utilized as the primary measurement tool for assessing and training body stability. It comprises several instruments, including the Delos Balance Platform (DEB), Delos Postural Assistant (DPA), Delos Vertical Controller (DVC), and Postural System Manager (Delos PSM). This device is capable of evaluating both dynamic and static body stability, visualizing levels of proprioceptive control, and facilitating training to tackle diminished levels of stability. The platform was connected to a computer utilizing specialized software (DPPS). It consisted of an electronic cradle board, an electronic postural reader, an infrared sensor strip, and a display. The infrared sensor strip was equipped with sensors that could detect when the test subject made contact with it for support. The electronic postural reader, known as the Delos Vertical Controller (DVC), was positioned on the sternum and employed a two-dimensional accelerometer to measure trunk tilt in the frontal (x) and sagittal (y) planes. Additionally, an electronic platform called the Delos Rocking Board (DRB) was utilized, providing one degree of freedom in the frontal plane with a range of motion of ±15°. The DRB measured the tilt of its movable plate. The research results were determined using the Stability Index value, which is calculated separately for trials with eyes open and eyes closed. High SI (Stability Index) values in EC (Eye Closed) tests are responsible for improving proprioceptive

tive control and facilitating the expression of effective proprioceptive reflexes that swiftly stabilize the subject in response to vestibular stimuli. Lower SI values in EC studies may be associated with the vestibular system. However, regardless of the case, such values consistently indicate a more pronounced level of proprioceptive control (Labanca et al., 2021).

The study aimed to investigate the impact of proprioceptive training interventions conducted on the Delos platform on the postural stability of boys aged 14 to 15 engaged in soccer.

1. Material and methods

1.1. Participants and study design

The study was designed as a pre/post study, and the study protocol was approved a priori by the ethics committee at the Collegium Medicum of Jan Dlugosz University in Czestochowa, Poland, under the reference number KE-O/61/2022 (approval date: 14.07.2022).

The research involved 20 boys, aged between 14 and 15, who were actively participating in organized football training at the Academy of Football in Poland. The study took place from July to October 2022 and was conducted within the premises of the RKS Raków High School of Sports Championships (Częstochowa, Poland). Throughout the research, the participants maintained their regular soccer training routine, which consisted of five training sessions per week and a weekly match. To be eligible for the study, the young soccer players needed to be injury-free in terms of muscle or bone injuries in the past year, ensuring they could fully participate in training and matches. Additionally, inclusion criteria required a minimum training attendance of 80% and a minimum training duration of three years.

1.2. Measurements

The study was conducted as a research experiment, with measurements taken before the intervention commenced and again immediately after its conclusion. Body height was measured to the nearest 0.5 centimeter using a height gauge, and body weight was obtained using a scale. Based on this data, BMI and the BMI centile were calculated, and the BMI percentile was determined using the reference charts by Niedźwiecka and Palczewska (Palczewska, Niedźwiecka, 1999).

Postural stability static RIVA test was conducted using the Delos platform, with individual assessments conducted for each lower limb, and each assessment comprising smaller components. Single-leg posture stability was evaluated

using the static single-leg posture test. During this test, the participant stood on one leg on a stable surface while a Stance Sensor (DVC) attached to the chest measured the degree of deviation in the X and Y axes. If the person lost their balance during the test and braced against the frame, an additional signal was sent to the Posture Assistant (DPA). The static RIVA test was performed under two conditions: with eyes closed (EC) and with eyes open (EO). The participant was barefoot and instructed to maintain an upright and still position on a stable wooden surface. No feedback was provided during the test regarding postural stability. Each test trial lasted for 20 seconds, followed by a 15-second rest period. The static single-leg posture test comprised six trials, alternating between the left and right limb, including two trials with EO and four trials with EC. The average value of all variables was calculated from both limbs. A short questionnaire was administered to collect additional data, including information on age, training experience, medical history related to musculoskeletal injuries, and any medical or physiotherapeutic interventions received. Stability Index provides percentage values that reflect the state of proper balance. Higher Stability index values are associated with a reduced likelihood of future injuries. A score above 70% signifies a low risk of injury in the future, while a score below 40% indicates a high risk.

1.3. Proprioceptive training

Proprioceptive training, in addition to basic soccer training, was conducted as part of the intervention. This supplementary training took place twice a week over three months, utilizing the Delos Postural Proprietary System platform, with each session lasting 15 minutes. The study group received an additional proprioceptive module during these sessions, focusing on re-educating trunk stability through dynamic postural control exercises on the DEB platform. Each exercise targeted the lower limbs and included three exercises performed in two series, with a 30-second duration for each exercise and a 20-second break between them. There was a 60-second break between particular series. The first exercise required subjects to maintain a stable torso posture, preventing off-axis excursions, measured using the DVC, with real-time feedback visible on a monitor. The second exercise aimed to control foot pivots on the DEB platform, emphasizing a range of foot pronation and supination up to 4 degrees. The third exercise combined maintaining a stable trunk and foot pivot, integrating elements from the first two exercises.

1.4. Data analysis

The analysis of the results was conducted using JASP (Jeffreys's Amazing Statistics Program) v0.17.1 (University of Amsterdam, The Netherlands). Descrip-

tive statistics were performed to assess participant characteristics. Normality distribution tests, specifically the Shapiro-Wilk test, guided the selection of a test for within-group comparisons. The paired *t* test and the Wilcoxon test were subsequently applied. Cohen's *d* was used as the effect size for the paired *t* test, while matched rank biserial correlations served as the effect size for the Wilcoxon test. The level of statistical significance was set at $\alpha < 0.05$.

2. Results

Twenty boys with a mean age of 14.45 were studied. Their mean body height was 172 cm and body weight 58.5 kg. From these data, BMI (mean 19.6) and BMI centile (mean 48.3) were obtained. The football players had average training experience of 5.6 years. The study group demonstrated homogeneity in all measured parameters, except for age, as confirmed by the results of the Shapiro-Wilk test ($p < 0.05$).

Table 1
Participants characteristics, mean (*SD*)

Variable	Overall
n	20
Age, years	14.45± 0.5
Body mass, kg	58.5 ± 10.0
Body height, cm	172.0 ± 9.8
Training experience, years	5.6 ± 1.4
Body mass index, kg/cm^2	19.6 ± 1.6
BMI Centile	48.3 ± 19.5

BMI: Body Mass Index, SD: Standard Deviation.

After the intervention, the following changes were observed in the study group. In the EO trial (Table 2, Figure 1A), improvements were observed in the players' right stability at 2.1%, with a median increase of 1.9%. A decrease in the standard deviation by 23.2% was also observed. In the closed-eye (EC) trial (Table 2, Figure 1B), scores improved by an average of 4.3% and the median increased by 3.5%. A 26.7% decrease in the standard deviation was also observed. This sample also saw a much greater improvement of 3.59 in EC scores than of 1.86 in the EO group. The improvement was seen, by as much as 93% in favor of the EC sample. In the subjective assessment of postural stability (Table 2, Figure 1C), the participants rated an improvement in their stability by 59.2% where the median improved by 100%. Statistically significant changes were observed in all

trials performed. The standard deviation decreased by 50.4%. Correlations were also performed in an attempt to test the relationship between training experience, body weight, body height, and the effect of the intervention. These showed no statistically significant correlations.

Table 2
Intervention results of primary and secondary outcomes

Variable	Statistics	Baseline	Post-intervention	Mean difference	*Effect size (95% CI)*	*P* value
EO	Mean (SD)	89.87 (2.67)	91.73 (2.05)	1.86	-1.14 (-1.70- -0.56)	<0.001[a]
	Median [IQR]	90.55 [2.50]	92.25 [3.50]			
EC	Mean (SD)	84.43 (4.35)	88.02 (3.19)	3.59	-1.34 (-1.94 – -0.72)	<0.001[a]
	Median [IQR]	85.50 [2.85]	88.45 [3.05]			
SS	Mean (SD)	3.55 (1.19)	5.65 (0.59)	2.10	-1.00 (-1.00- -1.00)	<0.001[b]
	Median [IQR]	3.00 [2.00]	6.00 [1.00]			

EO: Eyes Opened; EC: Eyes Closed; SS: Subjective Stability; SD: Standard deviation; IQR: Interquartile range; [a] according to Wilcoxon test; [b] according to paired *t* test.

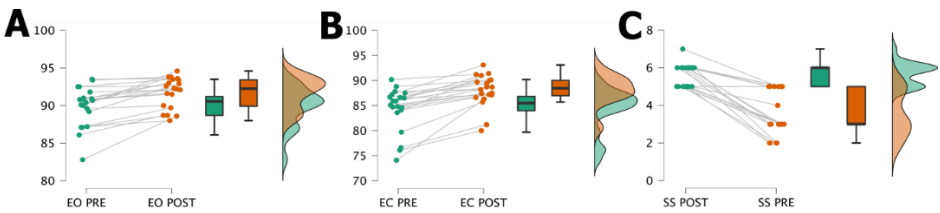

Figure 1
Raincloud plots for (A) eyes opened, (B) eyes closed, and (C) subjective stability

3. Discussion

This study aimed to examine the effect of proprioceptive training interventions carried out on the Delos platform on the postural stability of 14-15 year-old boys playing soccer. The intervention resulted in statistically significant improvements in postural stability, as assessed by the 'Riva' test after a 3-month training period. These improvements were observed in both the Eyes Open and Eyes Closed tests, indicating enhanced proprioceptive strategies and reduced visual dependence, irrespective of the subjects' level of motor training.

The results also indicated statistically significant differences in the subjective assessment of postural stability, suggesting a potential reduction in injuries among athletes. This is supported by a study conducted with the same research and training tool by Riva et al. The study, lasting six years and involving 55 professional basketball team players, demonstrated a remarkable 81% reduction in the incidence of ankle sprains from the first two years to the last two years of the study ($P< 0.001$). Similar reductions were observed for lower back pain, with a 77.8% decrease ($P< 0.005$). Although the reduction in knee sprains was 64.5% (not statistically significant), the comparison of the fourth and sixth year of the study with the level of new athletes showed a significant 72.2% improvement in proprioceptive control ($P< 0.001$). Riva et al.'s study indicated that improvements in proprioceptive control were significantly greater in the last two years of the study compared to new athletes, highlighting the substantial benefits of long-term proprioceptive training on postural stability. These findings suggest that improved proprioceptive control is a crucial factor in effectively reducing the risk of ankle sprains, knee sprains, and lower back pain (Riva et al., 2016).

Improvements in neuromuscular control can also be achieved through strength training. A study by Sihyun Yoo et al. examined the effects of two different training forms on center of pressure (COP) deflections. The study involved thirty-six taekwondo athletes who were divided into three groups: a control group, a group with additional proprioceptive exercises, and a group with strength training. Measurements were taken using a Kistler platform. The results indicated a reduction in COP excursions in both the proprioceptive and strength training groups compared to the control group. Both strength training and proprioceptive training have positive effects on enhancing body balance. Strength training reinforces muscles, leading to greater stability, improved movement control, and better postural maintenance. In contrast, proprioceptive training hones cognitive abilities and the interaction of the neuromuscular system, facilitating improved posture and balance control in dynamic sports situations. Each type of training offers unique advantages and can be effectively incorporated into training programs, depending on the goals and needs of the athletes (Yoo et al., 2018). Proprioceptive training can be valuable not only in reducing the risk of injury but also as an effective component of rehabilitation. This is supported by the results of a study conducted by Ben Moussa Zouitaet al., in which patients recovering from an ankle sprain participated in three workouts per week for eight weeks. The study revealed a statistically significant improvement in proprioception tests, suggesting the potential to break the cycle of recurrent sprains in the future (Ben Moussa Zouita et al., 2013). Postural stability training can also benefit seniors. In a study conducted by Riva et al., a six-week, twice-weekly postural training intervention was administered to a group of 61 individuals aged 65-85 years. The subjects were stratified by gender and assigned to

three training groups: proprioceptive training, treadmill training, and a control group. In both men and women, statistically significant changes were observed in the Stability Index test during both closed-eye and open-eye trials (Riva et al., 2019). Ojeda et al. investigated the effect of proprioceptive training as an injury prevention tool in football. The authors conducted an analysis of 11 scientific papers that focused on football and one of the following keywords: proprioceptive training, balance training, neuromuscular training, or postural control training. The results of the systematic review indicate that proprioceptive training is effective in reducing the risk of injury in football, particularly for knee and ankle injuries. The authors believe that this additional training module is valuable and should be introduced into football training due to its effectiveness, ease of application, and relatively short duration (15-20 minutes) (Ojeda et al., 2019).

Furthermore, it is essential to emphasize that despite the positive effects of proprioceptive training on postural stability, it does not guarantee injury prevention. Sports injuries often result from various factors, including training load, insufficient rest, improper movement patterns, and external factors such as playing field conditions. Therefore, a comprehensive approach to injury prevention is advisable, with proprioceptive training serving as just one tool to reduce injuries. Future research should also consider these aspects and focus on understanding how proprioceptive training can be most effectively integrated into an overall training program for young footballers. This would help determine the optimal training conditions, including frequency, intensity, and the selection of proprioceptive exercises tailored to the needs and skills of the athletes.

3.1. Limitations

One limitation of this study is the absence of a control group. The effects of proprioceptive training would be easier to evaluate if they could be compared to a second group that solely participated in regular soccer training without the additional proprioceptive training module. Another limitation is the group's size. With a larger number of subjects, it might be possible to use different statistical analyses. In future research projects, it would be advisable to consider the inclusion of other forms of neuromuscular control testing for comparison with the results obtained from the Delos platform, such as Kistler platform testing or the star excursion balance test.

Conclusions

The study's results demonstrate improved postural stability in the tested football players in both the closed-eye and open-eye tests. This enhancement has the potential to contribute to both injury reduction and performance im-

provement. Therefore, it is worth considering the introduction of a proprioceptive module as an addition to standard soccer training in both amateur and professional clubs.

Statement of Ethics

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and approved by bioethics committee of the Collegium Medicum of Jan Dlugosz University in Częstochowa (KE-O/61/2022, Czestochowa, Poland). All participants provided written informed consent to participate in this study.

Declaration of Conflicting Interests

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