



# The Acute Fatigue Effects of Small-Sided Games on Lower Limb Strength, Inter-Limb Asymmetry and Landing Technique in Young Under-15 Female Soccer Players

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## Abstract

**Background.** The increase in young female soccer players requires understanding the adaptations determined by sport-specific exercises both to enable improvements in sports performance and to reduce injury risk in women's soccer.

**Objectives.** This study aimed to analyze the acute effects of Small-Sided Games (SSG) on landing technique control, lower limb strength and lower limb functional asymmetry in Under-15 female soccer players.

**Materials and Methods.** A total of 18 young female soccer players (age:  $14.04 \pm 0.26$  years, weight:  $51.56 \pm 2.9$  kg; height:  $146.9 \pm 3.22$  cm) randomly performed hop test, Landing Error Scoring System assessment and vertical jump at the end of warm-up (pre-fatigue condition) and post SSG (3vs3, 4 × 4 min on field 24,5m × 24,5 m, post-fatigue condition). The inter-limb asymmetry value was calculated by comparing the two hop tests (left and right) using the formula:  $(\text{highest performing limb} - \text{lowest performing limb} / \text{highest performing limb}) \times 100$ .

**Results.** The hop test and vertical jump results in the pre vs. post-SSG comparing showed a significant performance decrease ( $p < 0.001$ , ES:1.43 and 1.43, respectively). The inter-limb asymmetry value significantly increased ( $p < 0.001$ , ES:1.18) from  $9.07 \pm 2.67\%$  to  $13.42 \pm 7.49\%$ . The landing control value has undergone a substantial decrease from  $5.72 \pm 0.67$  to  $7.83 \pm 0.86$  ( $p < 0.001$ , ES:1.29).

**Conclusions.** The findings indicate that high-intensity soccer drills have an impact on the landing control quality, decrease explosive strength performance, and increase inter-limb asymmetry value. Soccer-specific exercises must be carefully modulated within the training session.

**Keywords:** small-sided games, jump, inter-limb asymmetry, young female soccer player, high-intensity drill.

## Introduction

The growing interest for soccer practice in Italy among female population has been attracting research attention: reports from the Italian Football Federation (FIGC) indicate that there were nearly 18.000 young female soccer players in the 2023-24 season, an increase of about 23.3% from the previous season and about 49.5% from the 2021-22 soccer season (FIGC Report, 2024).

The increase in young female soccer players requires understanding the adaptations determined by sport-specific exercises both to enable improvements in sports

performance (Crossley et al., 2020) and to reduce injury risk in women's soccer (Crossley et al., 2020; Darragi et al., 2024; Randell et al., 2021).

Epidemiological studies point out a different incidence of non-contact Anterior Cruciate Ligament (ACL) injuries between male and female soccer players (Fortington & Finch, 2016; Lucarno et al., 2021). This relevant difference requires careful consideration on the pre-conditions of young female soccer players, as well as the selection of training drills and its overall organization.

It is well known which movements determine a high risk to the integrity ACL in young female soccer player's, including sudden changes of direction, landing and body control during unilateral task (Lucarno et al., 2021; Mancino et al., 2024).

These observations should be taken into account since these movements are commonly performed during an official match and training session (Randell et al., 2021; Lucarno et al., 2021; Mancino et al., 2024).

Besides, the developmental of qualitative control over these movements requires many years. Therefore, it is needed a training programs targeted specifically toward these movement factors in young female soccer players, especially during the early years of sports participation (Angulo-Barroso et al., 2022); in addition, these factors are often affected by the stage of individual maturation (Ramachandra et al., 2024).

To adapt to the demands of the performance model, the drills designed in soccer training are increasing in intensity and volume of sessions. Some drills are adapted and transformed to achieve intensities similar to or even higher than competition intensities (Praça et al., 2022; Makar et al., 2023; Sannicandro & Cofano, 2023).

In particular, SSGs are widely used in both men and women soccer, in high qualification as well as in youth training (López-Fernández et al., 2018; Farhani et al., 2024).

SSGs are drills with smaller numbers of players and reduced space than competitive matches and it is an effective training method to increase both physical adaptations and technical skills in open skills sports (Sannicandro & Cofano, 2023; Asian-Clemente et al., 2021).

In addition, these exercises can be carried out with several variations and formats to achieve important metabolic and cardiovascular adaptations determined by high exercise intensity (Sannicandro & Cofano, 2023; López-Fernández et al., 2018; Farhani et al., 2024).

In this regard, research has also focused on fatigue induced by SSGs, observed in both men's (Modena & Schena, 2024; Konefal et al., 2023) and women's soccer (López-Fernández et al., 2018 & 2019).

For some authors, exercise-induced fatigue can be described up to many hours after the end of the session: this observation shows that the intensity of these drills is very high (Guard et al., 2022; Luchesi et al., 2023; Calderòn Pellegrino et al., 2020).

The same way in which the exercises are scheduled, as well as rest time between sets, may condition performance and acute effects of fatigue (Branquinho et al., 2021).

Acute effects on hamstring fatigue in young soccer players (Sannicandro et al., 2022) and professional soccer players (Madison et al., 2019) engaged in SSG drills are known: following soccer training loads between 12 minutes and 24 minutes, hamstring eccentric force is reduced in the range of approximately 10% to 14% (Sannicandro et al., 2022; Madison et al., 2019).

The effects of acute fatigue resulting from high-intensity drills in female soccer players is a current topic in the literature: in fact, fatigue alters the control of some sport-specific movements and may represent a risk for non-contact injuries (Sannicandro et al., 2024; Sannicandro & Trotta, 2025; Mancino et al., 2024; Viswanathan et al., 2025).

When assessing the postural control of professional female soccer players performing a drop jump test before and after a high-intensity fatigue-inducing exercise protocol, a significant impairment was observed in hip flexion and ankle dorsiflexion angle (Kamitani et al., 2022).

Furthermore, previous studies evaluating landing control in U15 and U17 female soccer players before and

after high-intensity exercise have reported a considerable deterioration in performance during the post-exercise test (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

However, the most relevant aspect concerns the comparison between a vertical jump performed and a soccer-specific jump (the athlete jumps vertically to hit a ball). In the soccer-specific jump, players adapt and modify some kinematic parameters such as the ankle dorsiflexion angle or the knee bend angle during the landing phase (Mancini et al., 2022).

Based on these observations, deficits in jumping and landing technique represent risk factors for non-contact ACL injuries (Mancini et al., 2022).

Therefore, further studies are needed in the literature aimed in the analysis on high-intensity acute effects and on sport-specific drills in young female soccer players.

So far, the effects of general high-intensity drills on landing technique in young female soccer players (Sannicandro et al., 2024) or the effects of a functional agility-oriented training protocol (Sannicandro & Trotta, 2025) have been investigated.

The LESS evaluation in the post-warm-up and post-functional agility short-term fatigue protocol showed a value of  $5.44 \pm 0.46$  and  $8.66 \pm 0.97$  ( $p > 0.001$ , ES: 1.44), respectively. The LESS assessment for the post-RSA protocol condition showed a value of  $8.91 \pm 0.42$ ; this value was statistically significant ( $p > 0.001$ , ES: 1.56) compared with the post-warm-up condition (Sannicandro & Trotta, 2025).

Besides, this deterioration in the control of landing technique through jump assessment is even more evident in young female soccer players (Westbrook et al., 2020).

However, soccer training is not exclusively based on high-intensity running drills but includes structured training sessions with sport-specific drills such as Large Side Games (Cofano et al., 2021; Sannicandro et al., 2021), transitional games (Asian-Clemente et al., 2024), SSGs with unbalanced (Nunes et al., 2020) and high inferiority teams (Nunes et al., 2020; Asian-Clemente et al., 2022).

Additionally, in recent years, the popularity and use of these soccer-specific drills to structure high-intensity training sessions have increased (Nunes et al., 2020; Asian-Clemente et al., 2022). In contrast, there is a lack of studies analyzing the influence of some key-skills on control, that may provide valuable insights for designing preventive programs in female soccer players (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

The effects of acute fatigue resulting from these exercises could also influence lower limb strength and strength asymmetry, as was observed in men's soccer (Sannicandro et al., 2022; Dello Iacono et al., 2023; Heil et al., 2020).

Decreased lower limb strength and increased lower limb functional asymmetry could describe a complex scenario that leads athlete to non-contact injury risk in sports and soccer (Aldhabi et al., 2024; Bromley et al., 2021; Bishop et al., 2019).

Lower limb strength asymmetries are sensitive to fatigue (Bromley et al., 2021) and this increase observed after intense soccer-specific exercise should not be underestimated. It is necessary to implement studies in women's soccer as well to provide professionals with more information on performance and injury risk (Bromley et al., 2021; Bishop et al., 2019).

Therefore, further research is needed to understand the effects of soccer-specific drills on movement control, strength and inter-limb asymmetries in young female soccer players involved in both competitive and recreational sports.

The purpose of this study is to analyze the acute effects of Small-side Games on landing technique control, lower limb strength and lower limb functional asymmetry in Under-15 female soccer players.

## Material and Methods

### Study Participants

18 young female soccer players (average age:  $14.04 \pm 0.26$  years, weight:  $51.56 \pm 2.9$  kg; height:  $146.9 \pm 3.22$  cm) playing in first level clubs in Italy were involved in the study.

Inclusion criteria in the study focused on: a) age between 13 and 14 years, b) having a training background of at least 3 years, c) having no injuries or training suspension in the past 3 months, d) not having taken any medications in the last week.

The study was approved by the club's manager, by FIGC regional ethics committee. The study was performed according to the principles expressed in the Declaration of Helsinki. The written informed consent was obtained from the parents, while the young female soccer players have signed the informed assents.

### Study Organization

Assessments aimed at testing the effects of acute fatigue were organized into two different training sessions placed at the same time (4 p.m.) and interspersed 48 hours apart to reduce the effects of inter-session fatigue.

In the two sessions, the same warm-up consisting of 3 minutes of self-activation, 5 minutes of running at 60-65% of HRmax, 5 minutes of dynamic stretching and joint mobility exercises and 5 minutes characterized by soccer-specific runs and submaximal sprints (3x15 meters, rec. 50sec) was presented for a total duration of about 18 minutes.

In the first session, three strength and conditioning soccer coaches with at least 8 years of training experience conducted the tests at the end of the warm-up (pre-fatigue condition). The participants performed the evaluation tests in a random form.

In the second session, the evaluation tests were performed in random form after SSG (3vs3), with 4 x 4min (2min recovery) in a field on measuring 24.5 x 24.5 m (López-Fernández et al., 2018).

To verify if the exercises were performed at high intensity, SSG were monitored with heart rate monitor (Polar Team Pro, Kempele, Finland) and rate of perceived exertion (RPE) was registered through Borg Scale (CR-10) at the end of the same exercises (López-Fernández et al., 2018).

The Landing Error Scoring System (LESS) was performed to assess the landing control: a jump over a landing zone is required from a 30-cm box at a distance equal to 50 percent of the young player's height, followed by a maximum vertical jump (Beese et al., 2015).

LESS protocol requires the detector to evaluate the landing through 17 indicators that consider the execution of movement in the sagittal and frontal plane: errors are

detected through two video cameras that capture the area of execution of the test. Test execution should be videotaped, ensuring that the two cameras are positioned to detect movement in the frontal and sagittal planes (Liveris et al., 2021)..

The cameras (Sony HDR-P675) were placed approximately 4 meters forward and lateral to the box. In agreement with other similar studies, the height of the camera lens was placed about 130 cm above the floor. Higher scores correspond to a greater number of errors and thus to worse performance technique. In agreement with previous research (Beese et al., 2015; Sannicandro et al., 2024), LESS scores are graded for the specific population observed and are defined as excellent (0-3 points), good (4-5 points), moderate (6 points) and poor (>7 points).

The hop test (i.e. horizontal unilateral long jump) was used to assess the explosive strength of the single lower limb (Wiprich et al., 2024; Fox et al., 2023). Single hop test (HT) was performed with free arms and each participant executed two trials for each limb. The best trial was recorded (Fox et al., 2023).

To determine inter-limb asymmetry (ILA), the index was calculated using the formula already adopted in other similar research (Read et al., 2017; Fort-Vanmeerhaeghe et al., 2020):

(Highest performing limb – Lowest performing limb / Highest performing limb)  $\times 100$  (Fort-Vanmeerhaeghe et al., 2020).

For the assessment of explosive strength (vertical component), a Countermovement Jump (CMJ) was used (Fort-Vanmeerhaeghe et al., 2020): the jump was performed with hands at the hips on a conductance platform (Globus, Italy) that measures the elevation value of the center of gravity in cm; each participant performed two tests and the best was recorded.

### Statistical Analysis

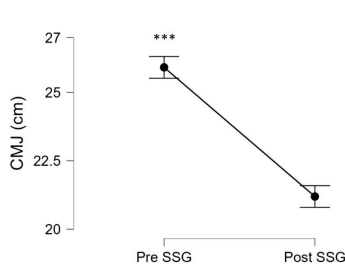
Data are presented as mean and standard deviations (mean  $\pm$  DS). Normality of data distribution was checked using Shapiro Wilk Test. A paired samples t-test was used to examine differences pre-post differences in young female soccer players. If data did not present a normal distribution, Wilcoxon signed-rank test was used to analyze the exercise-induced change observed. The evaluation of the effect prior to and post- short-term fatigue protocol for the tested hypothesis was estimated using the Cohen's d method: as for the effect size index (Effect Size), after calculating the  $\delta$  index it is possible to convert it into Effect Size:  $\leq 0.20$  small; 0.50 average;  $\geq 0.80$  large.

All statistical analysis carried out employing Jasp software (version 0.19.2, Amsterdam, The Netherlands) with level of significance set to  $p < 0.05$ .

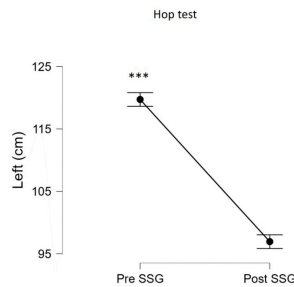
## Results

Comparison of pre SSG and post SSG CMJ values (Fig.1) showed a significant decrease in vertical jump performance ( $25.91 \pm 2.91$  cm vs  $21.19 \pm 2.28$  cm,  $p < 0.001$ , ES:1,47).

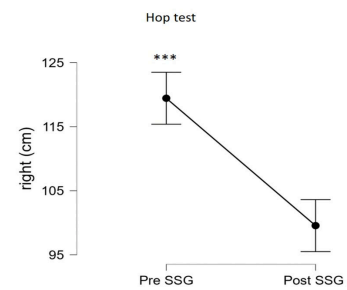
Left and right hop test values (Fig. 2 and 3) showed a significant decrease when comparing pre SSG and post SSG ( $119.72 \pm 5.79$  cm vs  $96.94 \pm 6.31$  cm, for left limb and  $119.44$



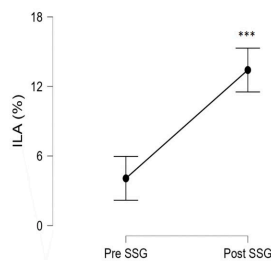
**Fig. 1.** CMJ values in pre-fatigue and post-fatigue conditions



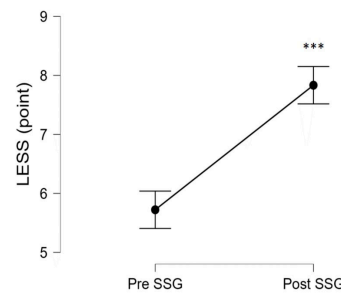
**Fig. 2.** Left hop test values in pre-fatigue and post-fatigue conditions



**Fig. 3.** Right hop test values in pre-fatigue and post-fatigue conditions



**Fig. 4.** Inter-limb asymmetry values in pre-fatigue and post-fatigue conditions



**Fig. 5.** Landing Error Scoring System (LESS) values in pre-fatigue and post-fatigue conditions

± 6.27 cm vs 99.56 ± 12.21 cm for right limb,  $p < 0.001$ , ES:1,36).

The value of functional asymmetry (Fig.4) increased significantly when comparing pre SSG and post SSG values ( $9.07 \pm 2.67\%$  vs  $13.42 \pm 7.49\%$ ,  $p < 0.001$ , ES:1,18).

Landing technique evaluations obtained through the LESS showed a significant decrease in the control of this movement (Fig.5) when comparing pre SSG and post SSG values ( $5.72 \pm 0.67$  vs  $7.83 \pm 0.86$ ,  $p < 0.001$ , ES:1,29).

Evaluation of exercise intensity showed an average heart rate of  $192.5 \pm 5.6$  bpm corresponding to approximately  $93.81 \pm 4.12\%$  of the maximum heart rate; The RPE value recorded at the end of SSGs was  $7.5 \pm 0.7$  u.a.

## Discussion

The aim of the study was to investigate the effects of acute fatigue following SSGs on strength, inter-limb asymmetries and single-leg explosive strength values in Under-15 female soccer players.

To the best of our knowledge, this is the first study that have investigated the acute effects of soccer-specific drills on the parameters of vertical jump strength, single-leg jump strength, lower limb strength asymmetry and landing technique.

Researchers have focused both on performance-enhancing aspects (Esposito et al., 2024; D'Isanto et al., 2022; D'Elia, 2023) and on studies aimed at the protecting health and maturation process in young soccer players (Raiola et al., 2022; Esposito et al., 2020).

To date, in women's soccer, the importance of performance-enhancing exercises - also oriented in terms of injury prevention - has been considered a central themes in research both in youth (Sannicandro et al., 2024; Mancino et al., 2022; Esposito et al., 2024) and professional soccer environments (Dello Iacono et al., 2023; Beese et al., 2015). The high incidence of injuries in women's soccer is a major and current issue in the literature (Silvers-Granelli, 2021; Horan et al., 2022) and some recent reviews have addressed the analysis of anterior cruciate ligament injury mechanisms in female soccer players (D'Onofrio et al., 2025).

The performance decrease in vertical jump of about 18.3% seems to indicate that the specific-sport load assigned to young female soccer players determine a significant acute fatigue condition.

In similar studies that have investigated the acute effects of SSGs-based training sessions in young elite female soccer players, no significant differences in horizontal jump strength values between pre- and post-exercise were observed (Castillo et al., 2021). Likely, the gender and sports competitive level of the study conducted with young soccer players may have determined these differences.

The performance decrease observed in single-leg jumping for left limb (approximately -19.1%) and right limb (approximately -16.77%) is consistent with that reported in bilateral jumping. Explosive strength capacity appears to be strongly affected by sport-specific exercises in young female soccer players.

This scenario is in agreement with a previous study conducted with Under 23 female soccer players, where a

functional relationship between vertical and horizontal jumping performance was found (Roso-Moliner et al., 2023).

Repeated accelerations and decelerations performed during SSGs likely constitute a significant overload for young female soccer players, as previously observed for some strength-related performance parameters in both young (Hidalgo de Mora et al., 2025) and professional soccer players (Rumpf et al., 2025; Rowell et al., 2018; Hietamo et al., 2021).

Lower limb strength asymmetry values show an increase of approximately 47%, indicating a significant negative impact in preventive terms. The literature suggests that the cut-off of 15% discriminates an athlete at risk of knee injury due to non-contact trauma (Hietamo et al., 2021; Warren et al., 2020; Guan et al., 2022).

The increase of this outcome constitutes a factor that may predispose to the likelihood increased of injury to the ACL due to the soccer-specific skills performed during SSGs and that represent movements predisposing to the injury risk (D'Onofrio et al., 2025).

It is noteworthy that the main characteristic of SSGs is the execution of continuous pressing and re-aggressing movements by the defending team. Marking, intercepting, cutting maneuvers and side-step cuts to reach and to retrieve the ball are performed at high intensity, thus posing a high risk of lower limb injury in the female soccer player (Jones et al., 2016; Della Villa et al., 2021; Della Villa et al., 2025).

The full-field collective and individual pressing required by the technical staff determine in abnormal postures that are occurred due to the qualitative decrease in movement control (D'Onofrio et al., 2025).

Inter-limb asymmetry values identified in this study are much higher than those described in previous studies with male athletes (Bishop et al., 2021), even when different assessments (Ascenzi et al., 2022) were used and the same age range as our sample (Bouafif et al., 2024) was involved.

This aspect highlights to a greater extent the importance of load dosage with young female soccer players subelite: likely, female population need to be approached carefully and progressively to soccer-specific loads, as the literature suggests for the youth context (Mainer-Pardos et al., 2024; Kale et al., 2023; Villanueva-Guerrero et al., 2023).

The worsening in landing control of about 36% confirms that the monitored soccer-specific load may result in altered skills at risk for young female soccer player.

Indeed, previous studies have shown the effects of acute fatigue following high-intensity exercise and Repetead Sprint Ability session in Under 13 female soccer players. The LESS test performed post high-intensity protocol determined a performance decrease of approximately 28%, while the LESS post RSA session produced a decrease in landing control of about 25% (Sannicandro et al., 2024).

The Heart Rate measured during the exercises, as well as the RPE value obtained, indicate that SSGs constitute high intensity exercise. These findings are consistent with other studies that have reported similar decrease in LESS performance tests in young female soccer players (Sannicandro et al., 2024; Sannicandro & Trotta, 2025).

This study contributes to the knowledge available to coaching staff who train young female soccer players at both elite and sub-elite levels. The acute effects of soccer-specific post-exercise fatigue should induce staff to carefully plan and to implement these exercises.

The introduction of SSGs must consider the cardiorespiratory demands elicited in young female soccer players and must be carefully placed within training session, as specified in the literature (Sanchez-Sanchez et al., 2018).

The scheduling of training sessions must adapt to the age, gender and sports competitive level of the participants (Esposito & Raiola, 2020).

Although this study provides interesting insights on training load in young female soccer players, some limitations should be considered: firstly, training age soccer specific to the participants was not detected. Indeed, this factor could affect the strength values of young female soccer players and, as a result, the intensity observed during SSGs. Secondly, there were no familiarization sessions with the proposed and monitored drills: this aspect may have conditioned the performance and intensity of the exercise proposed. Finally, a maximal aerobic test was not presented, which would have allowed more accurate measurement of each participant's FCmax value.

Further studies may investigate the effects of different volumes of soccer-specific exercises in order to provide information on the most suitable duration for young female soccer players. In addition, the assessment of CMJ through force platforms will be able to supplement the data obtained in this study with values for peak strength, muscle power, and ground reaction force in the landing phase.

## Conflict of Interest

The authors declare that there is no conflict of interest.

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# Вплив проявів гострої втоми при використанні ігор неповними складами на силу нижніх кінцівок, асиметрію між кінцівками та техніку приземлення у юних футболісток вікової категорії до 15 років

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 рис., 75 джерел.

**Історія питання.** Зростання кількості юних футболісток вимагає розуміння адаптаційних процесів, що визначаються специфічними для цього виду спорту вправами як для покращення спортивної результативності, так і з метою зменшення ризику травматизму у жіночому футболі.

**Мета дослідження.** Мета цього дослідження полягала в проведенні аналізу безпосереднього впливу ігор неповними складами (ІНС) на контроль техніки приземлення, силу нижніх кінцівок та функціональну асиметрію нижніх кінцівок у футболісток віком до 15 років.

**Матеріали та методи.** Загалом 18 юних футболісток (вік:  $14.04 \pm 0.26$  років, вага:  $51.56 \pm 2.9$  кг; зріст:  $146.9 \pm 3.22$  см) рандомізовано виконували комплекс тестів зі стрибків на одній нозі, використовуючи систему оцінювання помилок приземлення (Landing Error Scoring System) та вертикальний стрибок наприкінці розминки (у стані перед втомою) та після проведення ІНС (3 на 3, 4 × 4 хв на полі 24,5 м × 24,5 м, стан після втоми). Значення асиметрії між кінцівками було розраховано шляхом порівняння двох тестів зі стрибків на одній нозі (лівою та правою кінцівками) за формулою: (кінцівка з найвищим показником результативності – кінцівка з найнижчим показником/кінцівка з найвищим показником) × 100.

**Результати.** Результати тестів з виконання стрибків на одній нозі та вертикального стрибка на етапах порівняльного аналізу перед та після проведення ІНС показали значне зниження результативності ( $p < 0.001$ , ES: 1.43 та 1.43 відповідно). Значення асиметрії між кінцівками суттєво підвищилося ( $p < 0.001$ , ES:1.18) з  $9.07 \pm 2.67\%$  до  $13.42 \pm 7.49\%$ . Значення контролю приземлення зазнало істотного зниження показників з  $5.72 \pm 0.67$  до  $7.83 \pm 0.86$  ( $p < 0.001$ , ES:1.29).

**Висновки.** Результати дослідження свідчать про вплив високоінтенсивних футбольних тренувань на якість контролю приземлення, зниження результативності вибухової сили та підвищення значення асиметрії між кінцівками. Специфічні футбольні вправи мають бути ретельно модульовані в рамках тренувального заняття.

**Ключові слова:** ігри неповними складами, стрибок, асиметрія між кінцівками, юна футболістка, тренування високої інтенсивності.

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