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The Effects of Fatigue on Landing Performance in Young Female Soccer Players

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Abstract

Objectives. Jumping and landing constitute two movements that are used with a very high frequency in all sports and are two skills that have received a lot of attention in the literature because of their relationship with injury risk. The aim of this study is to analyze the following aspects: (a) to determine whether fatigue negatively affects landing technique after a jump, and (b) to test whether different metabolic and neuromuscular exercises have an effect on the landing technique.

Materials and methods. The sample is composed of young female soccer players Under 14 (n = 29, 13.06 ± 1.27 years, 47.8 ± 2.6 kg; 143.2 ± 3.4 cm). Before and after two training protocols aimed at determining the state of fatigue (functional agility short-term fatigue protocol, and RSA protocol), landing technique was assessed using the Landing Error Scoring System (LESS).

Results. The LESS assessment for the pre-fatigue and post-functional agility short-term fatigue protocol conditions showed a value of 6.78 ± 0.81 and 8.74 ± 0.77 respectively ($p > 0.001$, ES: 1.39). The LESS assessment for the post-RSA protocol condition was 8.52 ± 0.87; this score was statistically significantly higher than the pre-fatigue condition ($p > 0.001$, ES: 1.24).

Conclusions. Intensive exercise, both neuromuscular and metabolic, appears to have an effect on the landing technique of young female soccer players.

Keywords: landing, young female soccer players, injury prevention, fatigue.

Introduction

The process of developing motor skills related to basic fundamental movements such as jumping or running has been related to the possibility of increasing the quantity and quality of motor experiences in developmental age (Tsuda et al., 2020; Gao et al., 2021; Ceruso et al., 2019; Esposito et al., 2019).

The period within which most children develop fundamental movements is completed around puberty, while thereafter the process of refinement begins, spanning into adulthood (D'Elia et al., 2023; Angulo-Barroso et al., 2022; D'Isanto et al., 2021; Lima et al., 2019).

Within the classification of basic functional movements, jumping appears but ground landing, which is the complementary and subsequent movement to jumping, is not mentioned (Chow et al., 2020).

In fact, in sports, athletes resort to jumping, almost always maximal (Ziv & Lidor, 2010), from about 18-23 times per set in volleyball (Lima et al., 2019), to 12-43 jumps in women's basketball depending on the roles on the court (Scanlan et al., 2012; Reina Román et al., 2019), to 21-45 jumps per contest in women's beach volleyball (Natali et al., 2019).

Often, the landing strategy can also vary, and for some Authors, about 50 percent of ground contact holds are performed in one-leg (Tillman et al., 2004).

Almost always these maximal jumping and landing movements occur in a competitive context where metabolic demands, and consequently central and peripheral fatigue levels, are high (Batalla-Gavalda et al., 2023; Choi & Joo, 2022; Vescovi et al., 2021; Esposito & Raiola, 2020).

Particularly in women's soccer, performance differences are observed when comparing young female soccer players and elite female soccer players, leading to the hypothesis that jumping skills are not sufficiently enhanced in the training of female athletes (Castagna & Castellini, 2013).

Data on girls' participation in sports around the world indicate an incremental trend in recent years (Fink, 2015): between 58% in the United States and 21% in Europe (Deng & Fan, 2022; Kwon et al., 2021; Emmonds et al., 2021) are approaching competitive sports so it seems of great relevance to turn attention to the different phases of jumping.

In fact, jumping and landing constitute two movements that are used with a very high frequency in all sports and constitute two skills that have been highly attented in the literature because of their relationship with injury risk (Song et al., 2023; Chijimatsu et al., 2020; Bates et al., 2019).

In fact, it is known how the knee injuries, and anterior cruciate ligament injuries in particular, take on epidemiological significance when looking at the occurrence of such injury in the female population participating in sports (Mandorino et al., 2023; Di Paolo et al., 2023; Larwa et al., 2021; Hägglund & Waldén, 2016).

And great occirence has no-contact injuries in the knee for young female athletes especially in the pre-puberty period (Edison et al., 2022).

Therefore, evaluation of landing technique becomes an indispensable time to intervene in training sessions and introduce effective compensatory exercises for young female athletes (Limroongreungrat et al., 2022; Okoruwa et al., 2022; Beese et al., 2015, Root et al., 2015).

In particular, the differences in Ground Reaction Force (GRF) in the landing phase between adults and youth are known to lead to bias towards the landing technique itself (Bassa et al., 2022).

The Landing Error Score System (LESS) constitutes an effective and validated diagnostic assessment tool to investigate two-legs landing technique in sports (Limroongreungrat et al., 2022; Okoruwa et al., 2022; Fox et al., 2016, Padua et al., 2015).

The total score obtained through the LESS is a valid predictor of lower limb injury (Rostami et al., 2020; Root et al., 2015)

In fact, through this test it is possible to analyze landing motion and know which positions present mechanics that may be a risk factor for the lower limb (Jimenez-Garcia et al., 2023; Barber-Westin & Noyes, 2017; Root et al., 2015).

The literature through systematic reviews has investigated how fatigue alters landing technique (Santamaria & Webster, 2010) in individuals who are engaged in a return-to-play process (Peebles et al., 2021; Gokeler et al., 2014), in young college athletes (Zhang et al., 2021), in basketball players (Liveris et al., 2021), in female collegiate athletes over 19-years old (Cortes et al., 2012) or during different landing techniques (Heebner et al., 2017).

To date, analysis of the effects of fatigue on landing technique has focused on activities very specific to the sports considered, such as simulated matches or high-intensity exercise (Peebles et al., 2021; Liveris et al., 2021, Vermeulen et al., 2023).

And studies have mainly focused on sports that are performed indoors with a consistently even surface, while sports that are performed outdoors with weather conditions that can vary and affect the firmness and evenness of the playing surface have not been considered (Zhang et al., 2021; Heebner et al., 2017).

Therefore, an open problem remains in the literature: namely, understanding how landing technique can be affected by sport-specific movements in young female soccer players.

Indeed, the performance model imposes a number of metabolic and neuromuscular demands on young female soccer players that could alter the execution technique of some soccer-specific skills.

This study aims to (a) analyze landing technique in young female soccer players, (b) understand whether fatigue negatively affects landing technique, and (c) test whether different metabolic and neuromuscular exercises affect landing technique.

Material and Methods

Partecipants

The 29 participants (average age:13.06±1.27 years, weight: 47.8±2.6 kg; height: 143.2±3.4 cm) were youth female soccer players who competed in élite soccer schools in Italy. Participants were included if they were aged 11–13 years old and had been training for soccer training and competition for at least 2 years. Participants were excluded if they had sustained a musculoskeletal/joint injury within the previous 3 months prior to commencing experimental testing or encountered any other injury that could obstruct their performance at the assessment time.

The study was approved by the club's manager, by FIGC (Federazione Italiana Giuoco Calcio) regional ethics committee and 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.

Procedures

The two protocols aimed at achieving a fatigue condition were proposed at the same time (3.30 PM) and 72 hours apart to avoid biasing the assessments.

For both protocols, the same warm-up (15 minutes) consisting of a running phase at 60% of HRmax (6 minutes), a lower extremity and trunk mobility phase (4 minutes), and a special and soccer-specific running phase (5 minutes) was provided.

At the end of the warm-up, the LESS test was performed under pre-fatigue conditions.

The LESS protocol involves a jump onto a landing zone from a 30 cm box at a distance equal to 50% of the individual's height, followed by a maximum vertical jump (Beese et al., 2015).

The LESS provides for 17 scored items to assessment the landing from both the sagittal and frontal views. The LESS test score is based on the detection of errors on a number of easily observed markers of the jump-landing movement. A higher LESS score indicates more errors and, therefore, modest landing and jumping technique. In agreement with previous research (Beese et al., 2015), LESS scores are categorized 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 execution of the test should be videotaped, ensuring that the two cameras are placed to detect movements in the frontal and sagittal planes (Liveris et al., 2021).

The cameras were mounted on tripods and placed in front and to the side of the jump box and landing area. The lens height of each camera was 121.92 cm from the floor and 345.44 cm from the landing area, in agreement with previous research (Fig.1).

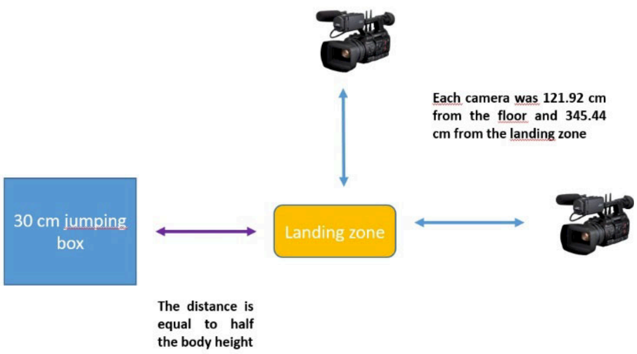

Fig. 1. Landing Error Scoring System data-collection setting

The sample was randomly assigned in a 1:1 ratio to a functional agility short-term fatigue protocol or to a Repetead Sprint Ability (RSA) protocol. Then, each participant followed a) a functional agility short-term fatigue protocol (Cortes et al., 2012), implemented by other soccer-specific skills, b) the RSA protocol (volume: 360 meters).

The functional agility short-term fatigue protocol included: step-ups on a 30-cm box, diagonal run exercise, an "L-drill" exercise (Carvalho et al., 2017), n.5 countermovement maximal jumps with hands bound at the hips, running back and forth on a speed ladder, and a 5-0-5 run.

The functional agility short-term fatigue protocol involved the following succession of exercises: a series of step-up movements on a 30 cm high step for 20 seconds with the metronome set at 160 bpm (McLean et al., 2007); then they performed a repetition of fast "L-drill" running; then they performed diagonal maximal speed run in 6 stretches of 5 meters; after that they performed 5 maximal and consecutive CMJs. After the CMJs they would perform the ladder agility exercise.

The sequence of running patterns on the speed ladder (3 meters) were required as follows: in the first and second repetitions, they touched with both feet in each space of the ladder, while in the third and fourth repetitions, a lateral run (once to the left and once to the right) was required, with both feet touching each space of the speed ladder with a metronome set at 180 bpm (McLean et al., 2007). Each set included the four agility speed ladder drills.

Lastly, they performed 5-0-5 drill at maximal speed run (Tab.1) .

Participants had to perform a total of four sets of the fatiguing protocol with no rest between the sets. Four sets

Table 1. Sequence of exercises introduced in the functional agility short-term fatigue protocol (this sequence was repeated for 4 sets)

Functional agility short-term fatigue protocol (sequence of the exercises)
1) Step-up on a 30 cm high step for 20 seconds (at 160 bpm - metronome)
2) L-drill running at maximal speed
3) Diagonal maximal speed run in 6 stretches of 5 meters
4) 5 maximal and consecutive CMJs
5) 4 repetitions of running on speed ladder of 3 meters (at 180 bpm – metronome)
6) 5-0-5 drill at maximal speed run

were chosen based on similar research in the literature that has been shown to induce an effective fatiguing state (Cortes et al., 2012).

The RSA protocol (Gabbet, 2010; Lockie et al., 2020; Bishop et al., 2011) involved performing 6 repetitions of 20 m (15 seconds after every 20 m and 3 minutes after the 6 repetitions); this exercise was repeated for 3 sets for a total of 360 m (Tab.2). All exercises were performed requiring all-out intensity.

Table 2. Sequence of exercises introduced in the RSA protocol

Repetead Sprint Ability protocol
1) 20 meters × 6 (rest:15 sec)
Rest 3 minutes
2) 20 meters × 6 (rest:15 sec)
Rest 3 minutes
3) 20 meters × 6 (rest:15 sec)
Rest 3 minutes

During the functional agility short-term fatigue protocol and RSA protocol, participants used wireless heart rate (HR) monitors equipped with a telemetry system (Polar Electro Oy, Kempele, Finland) to detect the exercise sequence intensity (peak HR, and a percentage referred to the maximum HR (%HRmax).

At the end of the protocol they reported the RPE value using the CR10 Borg Scale.

To be considered in a fatigued condition, subjects' heart rate had to be at a minimum of 80% of their estimated maximum heart rate.

Immediately upon completion of functional agility short-term fatigue or RSA protocol, participants again performed the LESS post-fatigue assessment.

Statistical Analysis

At first, descriptive statistics analysis was performed. Then, a t-test for dependent samples was carried out, using the level of significance at $p < 0.05$. 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 (Cohen, 1992): as for the effect size index (Effect Size), after calculating the δ index it is possible to convert it into Effect Size: ≤ 0.20 small; 0.50 average; ≥ 0.80 large.

Statistical analyses were performed using the software Statistical Package for Social Sciences (SPSS 22.0 for Windows).

Results

The LESS assessment for the pre fatigue and post functional agility short-term fatigue protocol condition respectively showed a value of (mean ± ds) 6.78±0.81 and equal to 8.74±0.77 (p>0.001, ES: 1.39).

The load intensity determined by the functional agility short-term fatigue protocol resulted in a peak HR value of 178.76±6.55 bpm and a %HR of 85.04±4.66%.

Load assessment by CR10 Borg Scale showed a value of 7.59±0.68.

The LESS assessment for the post RSA protocol condition showed a value of (mean ± ds) 8.52±0.87; this value was statistically significantly higher than the pre fatigue condition (p>0.001, ES: 1.24).

The load intensity determined by the RSA protocol resulted in a peak HR value of 174.55±4.65 bpm and a %HR of 84.17±6.16%.

Load assessment by CR10 Borg Scale showed a value of 7.55±0.69.

No statistically significant difference was observed between the LESS, peak HR, %HR and CR-10 Borg Scale values in the two post-fatigue conditions.

The values are summarized in Table 3.

Discussion

The aim of the study was to analyze the landing technique in young prepubescent female soccer players. In addition, the study wanted to test whether different protocols aimed at the onset of fatigue could affect landing strategies in young female soccer players.

To the knowledge currently available in the literature, this is the first study that turns attention toward landing technique under fatigue conditions in female youth soccer.

Monitoring the execution technique of certain sport-specific skills such as stopping or landing takes on a strong relevance in the young athlete training, especially if the athlete is a young female soccer player. In fact, the literature points out that age and gender are two factors that condition lower limb motion patterns between 11-16 years old (Shultz et al., 2022; Otsuki et al., 2021; Yu et al., 2005).

Comparison of values obtained in the LESS under resting conditions and post functional agility short-term fatigue protocol showed a statistically significant decrease in landing technique in young female soccer players with a large ES.

A similar result was observed when comparing LESS values under resting conditions and LESS values after the RSA protocol with a large ES.

No statistically significant difference emerged between the two post-fatigue conditions.

The values obtained after the execution of the two protocols aimed at achieving a fatigue state in young female soccer players should direct attention toward the landing technique, so far modestly investigated in the literature in young female athletes (Angulo-Barroso et al., 2022; Zhang et al., 2021).

In this regard, the literature highlights how landing technique is sport-specific in young athletes and how this varies in relation to the sport played especially in prepubertal age (Estevan et al., 2020).

In particular, young female soccer players are engaged in an activity that involves high exercise intensities, frequent changes of direction, and jumps that induce high peripheral and central fatigue (Vescovi et al., 2021; Esposito & Raiola, 2020).

In this direction, the literature argues that fatigue adversely affects some risk factors by showing a reduction in muscle strength, joint control and stabilization, and a reduction in joint position sensation (Verschueren et al., 2020; Vermeulen et al., 2023).

This reduction in postural and joint control represents a worrisome picture for lower limb injury risk because it is known to what extent landing can be affected by the misalignment of different body segments (Vermeulen et al., 2023; De Blaiser et al., 2018; De Ridder et al., 2015).

For example, trunk flexion appears to influence GRF in landing, the proximal segments being crucial in the execution and control of jumping and landing, just as lateral trunk flexion substantially changes the load on the two lower limbs (De Bleecker et al., 2020; Chuter & Janse de Jonge, 2012).

The performance decrease in the control of the landing technique in the two intense exercise conditions between 25% and 29% leads to the hypothesis of a marked influence of fatigue on this phase of the jump in young female soccer players.

The two intense exercise conditions proposed to the participants met the inclusion criteria because they showed a value of 80% HR but it should be remembered how competitions involve cardiovascular stresses even

Table 3. Values of the LESS test and internal load parameters measured under the observed conditions

Indicators	Pre-fatigue	Post- functional agility short-term fatigue protocol	p value	ES	Post - RSA protocol	p value	ES
LESS	6.78±0.81	8.74±0.77	0.0004	1.39	8.52±0.87	0.0005	1.24
FC peak		178.76±6.55			174.55± 4.65		
% HR		85.04±4,66			84.17±6,16		
CR-10 Borg Scale		7.59±0.68			7.55±0.69		

higher than this value; and that the state of fatigue that may be established could be even greater than the condition presented in this study (Choi & Joo, 2022; Vescovi et al., 2021; López-Valenciano et al., 2021).

Therefore, the role of fatigue on landing technique calls for a careful analysis in young prepubescent female athletes in light of the knowledge derived from the literature: in fact, maturation results in some gender differences in both vertical jump performance and landing ability, where girls are unable to reduce GRF during landing in drop jump trials (Larkin et al., 2023; Holden et al., 2016; Quatman et al., 2006).

The other purpose of the study was to understand whether different protocols aimed at the onset of fatigue could affect landing technique.

The functional agility short term fatigue protocol presented agility and neuromuscular exercises, while the RSA protocol was structured only with sprints followed by incomplete recovery. The former aimed to present all types of demands that occur in competition, while the latter aimed to stress young female soccer players metabolically.

Looking at peak HR values, HR percentages, and CR 10 Borg scale values, the two protocols resulted in very similar engagement: just this similarity for the internal load observed, the two protocols very similarly influenced the values and landing technique in the LESS post protocol.

The values obtained in LESS post fatigue were very similar to those obtained from previous studies even with different samples (Liveris et al., 2021; Gokeler et al., 2014; Cortes et al., 2012).

Moreover, they are consistent with what has been observed in GRF during drop jumps performed under fatigued conditions by young soccer players: the GRF increases significantly under fatigued conditions, due to the reduced ability to attenuate the impact in the landing phase (Oliver et al., 2008).

Conclusions

In conclusion, intense exercise appears to affect landing technique in young female soccer players, both when neuromuscular exercises are presented and when the exercises are metabolic.

Knowing the behavior of young female soccer players during the landing under fatigue conditions can help staffs schedule training sessions more carefully: for example, it might be less risky to place the most intense drills at the end of the session; or, to provide a low-intensity technical drill after planning a small-sided games or a high-intensity metabolic phase.

Further studies will be able to implement this analysis by observing what happens during an official competition or during a tournament involving close matches with few hours of recovery.

In addition, it will be very interesting to expand the study by involving female athletes and soccer players at post-puberty age to understand whether training age or maturation can improve landing technique under fatigue conditions.

Conflict of Interest

The authors declare no conflict of interest.

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Вплив втоми на ефективність виконання приземлення у юних футболісток

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 3 табл., 1 рис., 69 джерел.

Мета дослідження. Стрибок і приземлення представляють собою два види рухів, що використовуються з дуже високою частотою у всіх видах спорту, і є двома навичками, яким приділяється значна увага в літературі через їх взаємозв'язок з ризиком травмування. Метою цього дослідження є аналіз наступних аспектів: (а) визначити, чи має втома негативний вплив на техніку приземлення після виконання стрибка, і (б) перевірити, чи впливають різні метаболічні та нервово-м'язові вправи на техніку приземлення.

Матеріали та методи. Вибірка складалася з юних футболісток віком до 14 років (n = 29, 13,06 ± 1,27 років, 47,8 ± 2,6 кг; 143,2 ± 3,4 см). До і після виконання двох тренувальних протоколів, спрямованих на визначення стану втоми (протокол визначення функціональної здатності при короткочасній втомі та RSA протокол — здатність до повторного спринту), техніку приземлення оцінювали за допомогою Landing Error Scoring System (LESS) — системи оцінки помилок при приземленні.

Результати. Система оцінювання LESS для показників стану здоров'я перед втомою і після виконання протоколу визначення функціональної здатності при короткочасній втомі показала значення 6,78 ± 0,81 і 8,74 ± 0,77 відповідно (p > 0,001, ES: 1,39). Результат LESS для стану після проведення RSA протоколу становив 8,52 ± 0,87; цей показник був статистично значуще вищим, ніж перед станом втоми (p > 0,001, ES: 1,24).

Висновки. Виконання інтенсивних фізичних вправ, як нервово-м'язових, так і метаболічних, впливає на техніку приземлення юних футболісток.

Ключові слова: приземлення, юні футболістки, профілактика травматизму, втома.

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