Scientific Research Publishing

Advances in Physical Education, 2025, 15(1), 132-147
https://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

High-Intensity Exercise and Landing Technique in Under-15 Subelite Female Soccer Players

Italo Sannicandro[1,2], Nicola Trotta[1]

[1]Experimental and Clinical Medicine Department, University of Foggia, Foggia, Italy
[2]Professional Soccer Strength and Conditioning, Italy
Email: italo.sannicandro@unifg.it

How to cite this paper: Sannicandro, I., & Trotta, N. (2025). High-Intensity Exercise and Landing Technique in Under-15 Subelite Female Soccer Players. *Advances in Physical Education, 15,* 132-147.
https://doi.org/10.4236/ape.2025.151010

Received: January 13, 2025
Accepted: February 24, 2025
Published: February 27, 2025

Abstract

Research is studying the effects of fatigue on various factors that may predispose to the risk of injury during jumping and landing. This study aims to (a) analyze landing technique in subelite young female soccer players, (b) understand whether fatigue negatively affects landing technique, and (c) test whether different metabolic and neuromuscular exercises affect landing technique. The sample is composed of subelite female, young soccer players under 15 (n = 23, (14.22 ± 0.67) years, weight: (64.9 ± 5.6) kg; height: (149.9 ± 4.8) cm). Before and after two exercise protocols aimed at determining a state of fatigue (functional agility short-term fatigue protocol and RSA protocol), the landing technique was assessed using the Landing Error Score System (LESS). The LESS assessment for the pre-fatigue and post-functional agility short-term fatigue protocol condition, respectively, showed a value of 5.44 ± 0.46 and equal to 8.66 ± 0.97 ($p > 0.001$, ES: 1.44). The LESS assessment for the post-RSA protocol condition showed a value of 8.91 ± 0.42; this value was statistically significantly higher than the pre-fatigue condition ($p > 0.001$, ES: 1.56). High-intensity exercises affect the quality of landing control: the modulation of high neuromuscular and metabolic intensity exercises in the weekly micro-cycle can help train young female soccer players with better results and lower injury risk.

Keywords

Female Soccer Player, Injury Prevention, Health, Landing, Fatigue

1. Introduction

Injury prevention in women's soccer is a crucial aspect of ensuring the health and performance of female athletes. As football is a high-intensity sport that combines changes of direction, acceleration, and physical contact, specific strategies must

be adopted to reduce the injury risk.

Recent literature on the subject highlights the relevance of setting up adequate assessment sessions in the preseason phase to reduce the risk of non-contact injuries to female soccer players (Collings et al., 2022; Edison et al., 2022; Saber et al., 2024). High-intensity changes of direction, jumping, and landing constitute two very high-risk movements for female soccer players (Bisciotti et al., 2019; Ziv et al., 2010). In fact, one of the most frequent biomechanical risk factors associated with non-contact anterior cruciate ligament injury is valgus knee (Skouras et al., 2022; Lucarno et al., 2021; Natali et al., 2019).

Young female soccer players starting competitive practice must be assessed on landing skills (Sannicandro et al., 2024).

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 (Sannicandro, 2024; 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).

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

Furthermore, it must be considered that landing strategies are very different and that this movement is often performed on one leg (Tillman et al., 2004).

The duration of an official match and the demands of the soccer performance model require these movements to be maximal, performed at very high intensity and under fatigue conditions (Batalla-Gavalda et al., 2023; Choi & Joo, 2022; Vescovi et al., 2021; Esposito & Raiola, 2020).

For these reasons, research investigating the effects of fatigue on some factors may predispose to injury risk during jumping and landing (Kamitani et al., 2023).

These studies have demonstrated that central and peripheral fatigue can negatively affect landing technique and posture in both elite and youth athletes (Sannicandro et al., 2024; Esposito & Raiola, 2020). Particularly in women's soccer, performance differences are observed when comparing youth and elite female soccer players, leading to the hypothesis that jumping skills are not sufficiently emphasized 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 (Lima et al., 2019a).

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

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

The increase in the number of soccer players in the female population entails the need to monitor movements at risk: furthermore, the increase in the number of young sub-elite football players calls for greater consideration because this type of player does not have the same motor and functional characteristics as elite or professional football players (Vescovi et al., 2021; Choice et al., 2022).

Therefore, the evaluation of the 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 the two-leg 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; Reina Román et al., 2019), 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).

Only recently, researchers turned their attention to fatigue-inducing protocols using drills and movements similar to the soccer performance demands of young female soccer players (Sannicandro et al., 2024).

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

2. Materials and Methods

(a) Participants

The 23 participants (average age: (14.22 ± 0.67) years, weight: (64.9 ± 5.6) kg; height: (149.9 ± 4.8) cm) were youth female soccer players who competed in subelite soccer team in Italy. Participants were included if they were aged 13 - 14 years old and had been training for soccer training and competition for at least 2 years. Exclusion criteria were (a) having suffered a musculoskeletal/articular injury in the 3 months prior to the start of the experimental protocol, (b) having suffered any traumatic event that could hinder high-intensity exercise and evaluation, and (c) having never participated in high-intensity training in the past 2 months.

The study was approved by the club's manager by the 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 signed the informed assent.

(b) Procedures

The two protocols aimed at achieving a fatigue condition were proposed at the same time (5.30 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 assess 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 techniques. In agreement with previous research (Sannicandro et al., 2024; 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, which is in agreement with previous research (Sannicandro et al., 2024).

The sample was randomly assigned in a 1:1 ratio to a functional agility short-term fatigue protocol or to a Repeated 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, and 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), 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 (Sannicandro et al., 2024; 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) was 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 a 5-0-5 drill at a maximal speed run (**Table 1**).

Table 1. The 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 a speed ladder of 3 meters (at 180 bpm - metronome)
6) 5-0-5 drill at maximal speed run

Participants had to perform a total of four sets of the fatiguing protocol with no rest between the sets. Four sets 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 (Gabbett, 2010; Lockie et al., 2020; Bishop et al., 2011) involved performing 6 repetitions of 20m (15 seconds after every 20m and 3 minutes after the 6 repetitions); this exercise was repeated for 3 sets for a total of 360 m (**Table 2**). All exercises were performed requiring all-out intensity.

Table 2. The sequence of exercises introduced in the RSA protocol.

Repeated 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 (% HR max)).

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 (Sannicandro et al., 2024).

(c) 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 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).

3. Results

The LESS assessment for the pre-fatigue and post-functional agility short-term fatigue protocol conditions respectively showed a value of (mean ± ds) 5.44 ± 0.46 and equal to 8.66 ± 0.97 ($p > 0.001$, ES: 1.44).

The load intensity determined by the functional agility short-term fatigue protocol resulted in a peak HR value of (183.44 ± 5.32) bpm and a % HR of 89.21% ± 2.93%.

Load assessment by CR10 Borg Scale showed a value of 8.11 ± 0.52.

The LESS assessment for the post-RSA protocol condition showed a value of 8.91 ± 0 (**Figure 1**); this value was statistically significantly higher than the pre-fatigue condition ($p > 0.001$, ES: 1.56).

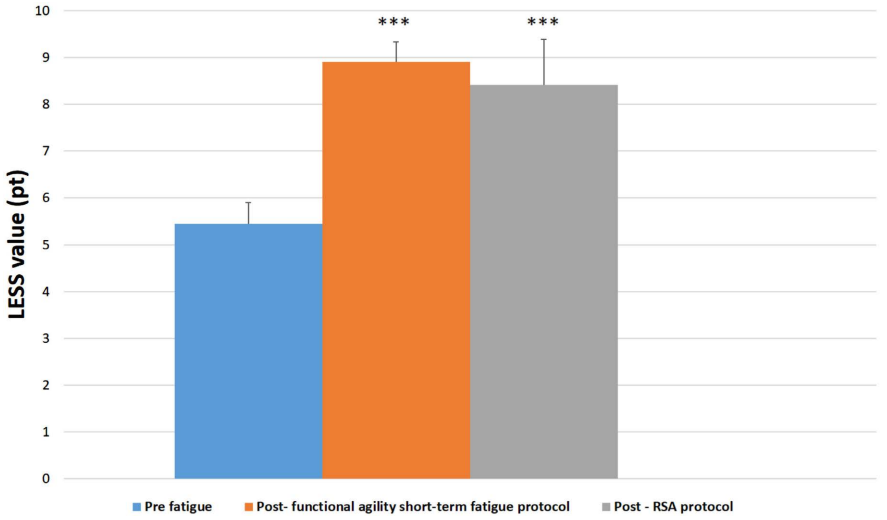

Figure 1. Fewer values in pre-fatigue condition, post-functional agility short-term fatigue protocol conditions, and post RSA protocol (***$p < 0.001$).

The load intensity determined by the RSA protocol resulted in a peak HR value of (170.36 ± 5.15) bpm and a % HR of 82.96% ± 3.86%.

Load assessment by CR10 Borg Scale showed a value of 7.91 ± 0.68.

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**.

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

	Pre-fatigue	Post-functional agility short-term fatigue protocol	*p*-value	ES	Post-RSA protocol	*p*-value	ES
LESS	5.44 ± 0.46	8.91 ± 0.42	0.0005	1.56	8.66 ± 0.97	0.0003	1.44
FC peak		183.41 ± 5.32			170.34 ± 5.15		
% HR		89.21 ± 2.93			82.96 ± 3.86		
CR-10 Borg Scale		8.11 ± 0.52			7.91 ± 0.68		

4. Discussion

The aim of the study was to investigate the landing technique in young U15 subelite female soccer players. Furthermore, the study wanted to analyse whether different protocols aimed at determining fatigue (neuromuscular or metabolic) could influence landing strategies in young female subelite soccer players.

According to the knowledge currently available in the literature, there is only one study that has focused on landing technique under fatigue conditions in young female soccer (Sannicandro et al., 2024).

Certain frequently repeated movements during an official competition or a sport-specific drill (e.g., a one-leg stop or a landing) require careful and frequent assessment by strength and conditioning coaches.

This attention must be maximised especially in women's youth soccer due to

the knowledge of knee injuries (Lucarno et al., 2021).

Indeed, the literature shows that age and gender are two factors that condition lower limb movement patterns between the ages of 11 and 16 (Shultz et al., 2022; Otsuki et al., 2021; Yu et al., 2005).

The comparison of the values obtained in the LESS in resting conditions and post-functional agility short-term fatigue protocol showed a statistically significant decrease in landing technique in young female subelite 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 differences emerged between the neuromuscular and metabolic fatigue conditions.

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

The results obtained in this study are consistent with the findings of a research study that used the same fatigue conditions in young prepubescent female soccer players: although with slightly different values, the fatigue conditions led to a decrease in the landing performance quality in younger female soccer players as well (Sannicandro et al., 2024).

In this regard, the literature highlights how the landing technique is sport-specific in young athletes and how it is related to the sport practiced, especially at a young age (Estevan et al., 2020).

In particular, soccer requires young female soccer players to engage in high and very high-intensity activity that involves numerous changes of direction, braking, sprinting, and jumping that induce high peripheral and central fatigue (Randell et al., 2021; Vescovi et al., 2021; Esposito & Raiola, 2020).

In this direction, the literature points out that fatigue negatively affects certain risk factors, showing a reduction of muscle strength, joint control, and stabilisation, and a qualitative reduction in the sensation of joint position (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 59% and 63% leads to the hypothesis of a marked influence of fatigue on this phase of the jump in young female subelite soccer players.

The two training conditions aimed at the onset of fatigue proposed to the young female subelite soccer players met the inclusion criteria because the measurements showed FC values greater than 80% FC max.

However, it must be emphasised that official matches determine cardiovascular stresses greater than these values: and that, consequently, the state of fatigue imposed by official competitions could be even greater than that created in this study (Randell et al., 2021; Choi & Joo, 2022; López-Valenciano et al., 2021).

Even some sport-specific exercises in female soccer achieve far higher exercise intensities than those recreated in this study (De Dios et al., 2022).

Therefore, the role of fatigue in landing technique requires 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 skill, where girls are unable to reduce GRF during landing in high jump trials (Larkin et al., 2023; Holden et al., 2016; Quatman et al., 2006).

Some studies about fatigue and decision-making indicated that a short bout of exercise at a high intensity results in a decrement in cognitive processing (e.g., longer reaction times): for some Authors, such fatigue may persist for up to 24 - 48 hours, with the decrease in voluntary contraction values persisting over this time interval (Thomas et al., 2018; de Diego-Moreno et al., 2022; Smith et al., 2016).

These findings are confirmed by other studies that have described a reduction in knee joint control following soccer-specific fatigue protocol in prepubescent young soccer players (García-Luna et al., 2020).

Fatigue appears to affect joint control and stability in soccer-specific skills, increasing the risk of non-contact injury (García-Luna et al., 2020).

The other aim of the study was to understand whether different protocols targeting the onset of neuromuscular or metabolic fatigue could influence the landing technique. The short-term functional agility fatigue protocol presented agility and neuromuscular exercises, while the RSA protocol was structured only with sprints followed by recovery incomplete recovery. The former aimed to present all types of stresses that occur in official matches and in sport-specific session training, while the second aimed to metabolically stress the young female soccer players.

Observing the peak HR values, the HR percentages, and the CR 10 Borg scale, the two protocols resulted in a very similar effort. Due to this similarity in observed internal load, the two protocols influenced the values and landing technique in the post-fatigue LESS protocol in a very similar pattern.

The values obtained in post-LESS fatigue were very close to those obtained from previous studies, even with different samples (Sannicandro et al., 2024; 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).

Finally, very recently, a Japanese study group showed that fatigue conditions even negatively affect landing posture in professional U23 female players (Kamitani et al., 2023).

5. Conclusion

The focus on preventive interventions in women's soccer must be on youth and subelite areas (Pletcher et al., 2021; Lima et al., 2019b): if there are criticalities in professional female soccer players with high functional prerequisites, for those starting out in this sport the injury risk may probably be higher.

The higher risk in female soccer players is often facilitated by a modest focus on long-term athletic development at a young age (Sannicandro, 2024).

The results of the study may provide some relevant focus to coaches and strength and conditioning in the training session schedule: high-intensity exercises should be introduced progressively; after a high-intensity exercise, it is suggested to schedule a tactical task or core stability and prevention exercises, so as to allow for adequate recovery.

Knowing how young female players adapt to high-intensity loads can help coaches and strength and conditioning coaches plan training sessions more prudently.

The distribution and modulation of high neuromuscular and metabolic intensity exercises in the weekly micro-cycle can help train young female soccer players with better results and lower injury risk.

Further studies may implement these results by including ground reaction force with force mats in the analysis of jumping and landing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Angulo-Barroso, R., Ferrer-Uris, B., Jubany, J., & Busquets, A. (2022). Children's Strategies in Drop-Landing. *Frontiers in Psychology, 13,* Article ID: 982467. https://doi.org/10.3389/fpsyg.2022.982467

Barber-Westin, S. D., & Noyes, F. R. (2017). Effect of Fatigue Protocols on Lower Limb Neuromuscular Function and Implications for Anterior Cruciate Ligament Injury Prevention Training: A Systematic Review. *The American Journal of Sports Medicine, 45,* 3388-3396. https://doi.org/10.1177/0363546517693846

Bassa, E., Adamopoulos, I., Panoutsakopoulos, V., Xenofondos, A., Yannakos, A., Galazoulas, C. et al. (2022). Optimal Drop Height in Prepubertal Boys Is Revealed by the Performance in Squat Jump. *Sports, 11,* Article No. 1. https://doi.org/10.3390/sports11010001

Batalla-Gavalda, A., Montoliu, R., Beltrán-Garrido, J. V., & Corbi, F. (2023). A New Database of the Analysis of the Physiological Needs in Amateur Female Basketball during Official Matches. *Scientific Data, 10,* Article No. 854. https://doi.org/10.1038/s41597-023-02747-2

Bates, N. A., Schilaty, N. D., Nagelli, C. V., Krych, A. J., & Hewett, T. E. (2019). Multiplanar Loading of the Knee and Its Influence on Anterior Cruciate Ligament and Medial Collateral

Ligament Strain during Simulated Landings and Noncontact Tears. *The American Journal of Sports Medicine, 47,* 1844-1853. https://doi.org/10.1177/0363546519850165

Beese, M. E., Joy, E., Switzler, C. L., & Hicks-Little, C. A. (2015). Landing Error Scoring System Differences between Single-Sport and Multi-Sport Female High School-Aged Athletes. *Journal of Athletic Training, 50,* 806-811. https://doi.org/10.4085/1062-6050-50.7.01

Bisciotti, G. N., Chamari, K., Cena, E., Bisciotti, A., Bisciotti, A., Corsini, A. et al. (2019). Anterior Cruciate Ligament Injury Risk Factors in Football. *The Journal of Sports Medicine and Physical Fitness, 59,* 1724-1738. https://doi.org/10.23736/s0022-4707.19.09563-x

Bishop, D., Girard, O., & Mendez-Villanueva, A. (2011). Repeated-Sprint Ability—Part II: Recommendations for Training. *Sports Medicine, 41,* 741-756. https://doi.org/10.2165/11590560-000000000-00000

Carvalho, H. M., Gonçalves, C. E., Grosgeorge, B., & Paes, R. R. (2017). Validity and Usefulness of the Line Drill Test for Adolescent Basketball Players: A Bayesian Multilevel Analysis. *Research in Sports Medicine, 25,* 333-344. https://doi.org/10.1080/15438627.2017.1314296

Castagna, C., & Castellini, E. (2013). Vertical Jump Performance in Italian Male and Female National Team Soccer Players. *Journal of Strength and Conditioning Research, 27,* 1156-1161. https://doi.org/10.1519/jsc.0b013e3182610999

Ceruso, R., Esposito, G., & D'Elia, F. (2019). Coordination Attached to the Qualitative Aspects of Football. *Journal of Physical Education and Sport, 19,* 1773-1776.

Chijimatsu, M., Ishida, T., Yamanaka, M., Taniguchi, S., Ueno, R., Ikuta, R. et al. (2020). Landing Instructions Focused on Pelvic and Trunk Lateral Tilt Decrease the Knee Abduction Moment during a Single-Leg Drop Vertical Jump. *Physical Therapy in Sport, 46,* 226-233. https://doi.org/10.1016/j.ptsp.2020.09.010

Choi, J., & Joo, C. (2022). Match Activity Profile of Professional Female Soccer Players during a Season. *Journal of Exercise Rehabilitation, 18,* 324-329. https://doi.org/10.12965/jer.2244354.177

Choice, E., Tufano, J., Jagger, K., Hooker, K., & Cochrane-Snyman, K. C. (2022). Differences across Playing Levels for Match-Play Physical Demands in Women's Professional and Collegiate Soccer: A Narrative Review. *Sports, 10,* Article No. 141. https://doi.org/10.3390/sports10100141

Chow, D. H. K., Cheng, W. H. W., & Tam, S. S. M. (2020). A Video-Based Classification System for Assessing Locomotor Skills in Children. *Journal of Sports Science & Medicine, 19,* 585-595.

Chuter, V. H., & Janse de Jonge, X. A. K. (2012). Proximal and Distal Contributions to Lower Extremity Injury: A Review of the Literature. *Gait & Posture, 36,* 7-15. https://doi.org/10.1016/j.gaitpost.2012.02.001

Cohen, J. (1992). A Power Primer. *Psychological Bulletin, 112,* 155-159. https://doi.org/10.1037//0033-2909.112.1.155

Collings, T. J., Diamond, L. E., Barrett, R. S., Timmins, R. G., Hickey, J. T., Du Moulin, W. S. et al. (2022). Strength and Biomechanical Risk Factors for Noncontact ACL Injury in Elite Female Footballers: A Prospective Study. *Medicine & Science in Sports & Exercise, 54,* 1242-1251. https://doi.org/10.1249/mss.0000000000002908

Cortes, N., Quammen, D., Lucci, S., Greska, E., & Onate, J. (2012). A Functional Agility Short-Term Fatigue Protocol Changes Lower Extremity Mechanics. *Journal of Sports*

Sciences, 30, 797-805. https://doi.org/10.1080/02640414.2012.671528

D'Elia, F., D'Isanto, T., Altavilla, G., Esposito, G., & Raiola, G. (2023). Does Training with Visual Occlusion Improve Technical Skills in Under-14 Football Players? *Acta Gymnica, 53,* e2023.004. https://doi.org/10.5507/ag.2023.004

D'Isanto, T., Domenico, F. D., D'Elia, F., Aliberti, S., & Esposito, G. (2021). The Effectiveness of Constraints-Led Training on Skill Development in Football. *International Journal of Human Movement and Sports Sciences, 9,* 1344-1351. https://doi.org/10.13189/saj.2021.090630

De Blaiser, C., Roosen, P., Willems, T., Danneels, L., Bossche, L. V., & De Ridder, R. (2018). Is Core Stability a Risk Factor for Lower Extremity Injuries in an Athletic Population? A Systematic Review. *Physical Therapy in Sport, 30,* 48-56. https://doi.org/10.1016/j.ptsp.2017.08.076

De Bleecker, C., Vermeulen, S., De Blaiser, C., Willems, T., De Ridder, R., & Roosen, P. (2020). Relationship between Jump-Landing Kinematics and Lower Extremity Overuse Injuries in Physically Active Populations: A Systematic Review and Meta-Analysis. *Sports Medicine, 50,* 1515-1532. https://doi.org/10.1007/s40279-020-01296-7

de Diego-Moreno, M., Álvarez-Salvago, F., Martínez-Amat, A., Boquete-Pumar, C., Orihuela-Espejo, A., Aibar-Almazán, A. et al. (2022). Acute Effects of High-Intensity Functional Training and Moderate-Intensity Continuous Training on Cognitive Functions in Young Adults. *International Journal of Environmental Research and Public Health, 19,* Article No. 10608. https://doi.org/10.3390/ijerph191710608

De Dios-Álvarez, V., Lorenzo-Martínez, M., Padrón-Cabo, A., & Rey, E. (2022). Small-sided Games in Female Soccer Players: A Systematic Review. *The Journal of Sports Medicine and Physical Fitness, 62,* 1474-1480. https://doi.org/10.23736/s0022-4707.21.12888-9

De Ridder, R., Willems, T., Vanrenterghem, J., Robinson, M. A., & Roosen, P. (2015). Lower Limb Landing Biomechanics in Subjects with Chronic Ankle Instability. *Medicine & Science in Sports & Exercise, 47,* 1225-1231. https://doi.org/10.1249/mss.0000000000000525

Deng, Y., & Fan, A. (2022). Trends in Sports Participation in Adolescents: Data from a Large-Scale Sample in the US Adolescents. *Frontiers in Public Health, 10,* Article ID: 960098. https://doi.org/10.3389/fpubh.2022.960098

Di Paolo, S., Nijmeijer, E., Bragonzoni, L., Dingshoff, E., Gokeler, A., & Benjaminse, A. (2023). Comparing Lab and Field Agility Kinematics in Young Talented Female Football Players: Implications for ACL Injury Prevention. *European Journal of Sport Science, 23,* 859-868. https://doi.org/10.1080/17461391.2022.2064771

Edison, B. R., Pandya, N., Patel, N. M., & Carter, C. W. (2022). Sex and Gender Differences in Pediatric Knee Injuries. *Clinics in Sports Medicine, 41,* 769-787. https://doi.org/10.1016/j.csm.2022.06.002

Emmonds, S., Till, K., Weaving, D., Burton, A., & Lara-Bercial, S. (2024). Youth Sport Participation Trends across Europe: Implications for Policy and Practice. *Research Quarterly for Exercise and Sport, 95,* 69-80. https://doi.org/10.1080/02701367.2022.2148623

Esposito, G., & Raiola, G. (2020). Monitoring the Performance and Technique Consolidation in Youth Football Players. *Trends in Sport Sciences, 27,* 93-100.

Esposito, G., Ceruso, R., & D'Elia, F. (2019). The Importance of a Technical-Coordinative Work with Psychokinetic Elements in the Youth Sectors of Soccer Academies. *Journal of Physical Education and Sport, 19,* 1843-1851.

Estevan, I., Monfort-Torres, G., Farana, R., Zahradnik, D., Jandacka, D., & García-Massó, X. (2020). Children's Single-Leg Landing Movement Capability Analysis According to

the Type of Sport Practiced. *International Journal of Environmental Research and Public Health, 17,* Article No. 6414. https://doi.org/10.3390/ijerph17176414

Fink, J. S. (2015). Female Athletes, Women's Sport, and the Sport Media Commercial Complex: Have We Really "Come a Long Way, Baby"? *Sport Management Review, 18,* 331-342. https://doi.org/10.1016/j.smr.2014.05.001

Fox, A. S., Bonacci, J., McLean, S. G., Spittle, M., & Saunders, N. (2016). A Systematic Evaluation of Field-Based Screening Methods for the Assessment of Anterior Cruciate Ligament (ACL) Injury Risk. *Sports Medicine, 46,* 715-735. https://doi.org/10.1007/s40279-015-0443-3

Gabbett, T. J. (2010). The Development of a Test of Repeated-Sprint Ability for Elite Women's Soccer Players. *Journal of Strength and Conditioning Research, 24,* 1191-1194. https://doi.org/10.1519/jsc.0b013e3181d1568c

Gao, Z., Wen, X., Fu, Y., Lee, J. E., & Zeng, N. (2021). Motor Skill Competence Matters in Promoting Physical Activity and Health. *BioMed Research International, 2021,* Article ID: 9786368. https://doi.org/10.1155/2021/9786368

García-Luna, M. A., Cortell-Tormo, J. M., García-Jaén, M., Ortega-Navarro, M., & Tortosa-Martínez, J. (2020). Acute Effects of ACL Injury-Prevention Warm-Up and Soccer-Specific Fatigue Protocol on Dynamic Knee Valgus in Youth Male Soccer Players. *International Journal of Environmental Research and Public Health, 17,* Article No. 5608. https://doi.org/10.3390/ijerph17155608

Gokeler, A., Eppinga, P., Dijkstra, P. U., Welling, W., Padua, D. A., Otten, E., & Benjaminse, A. (2014). Effect of Fatigue on Landing Performance Assessed with the Landing Error Scoring System (Less) in Patients after ACL Reconstruction. A Pilot Study. *International Journal of Sports Physical Therapy, 9,* 302-311.

Hägglund, M., & Waldén, M. (2016). Risk Factors for Acute Knee Injury in Female Youth Football. *Knee Surgery, Sports Traumatology, Arthroscopy, 24,* 737-746. https://doi.org/10.1007/s00167-015-3922-z

Heebner, N. R., Rafferty, D. M., Wohleber, M. F., Simonson, A. J., Lovalekar, M., Reinert, A. et al. (2017). Landing Kinematics and Kinetics at the Knee during Different Landing Tasks. *Journal of Athletic Training, 52,* 1101-1108. https://doi.org/10.4085/1062-6050-52.11.25

Holden, S., Boreham, C., & Delahunt, E. (2016). Sex Differences in Landing Biomechanics and Postural Stability during Adolescence: A Systematic Review with Meta-Analyses. *Sports Medicine, 46,* 241-253. https://doi.org/10.1007/s40279-015-0416-6

Jimenez-Garcia, J. A., Miller, M. B., & DeMont, R. G. (2023). Effects of Multicomponent Injury Prevention Programs on Children and Adolescents' Fundamental Movement Skills: A Systematic Review with Meta-Analyses. *American Journal of Health Promotion, 37,* 705-719. https://doi.org/10.1177/08901171221146434

Kamitani, A., Hara, K., Fujii, Y., & Yoshida, S. (2023). Landing Posture in Elite Female Athletes during a Drop Vertical Jump before and after a High-Intensity Ergometer Fatigue Protocol: A Study of 20 Japanese Women's Soccer League Players. *Orthopaedic Journal of Sports Medicine, 11,* Article 23259671231171859. https://doi.org/10.1177/23259671231171859

Kwon, S., Letuchy, E. M., Levy, S. M., & Janz, K. F. (2021). Youth Sports Participation Is More Important among Females than Males for Predicting Physical Activity in Early Adulthood: Iowa Bone Development Study. *International Journal of Environmental Research and Public Health, 18,* Article No. 1328. https://doi.org/10.3390/ijerph18031328

Larkin, P., Carlon, T., Sortino, B., Greer, S., Cuttiford, T., Wijekulasuriya, G. et al. (2023).

Anthropometry and Physical Performance in 13-Year-Old Australian Talent-Identified Male and Female Athletes Compared to an Age-Matched General Population Cohort. *Children, 10,* Article No. 212. https://doi.org/10.3390/children10020212

Larwa, J., Stoy, C., Chafetz, R. S., Boniello, M., & Franklin, C. (2021). Stiff Landings, Core Stability, and Dynamic Knee Valgus: A Systematic Review on Documented Anterior Cruciate Ligament Ruptures in Male and Female Athletes. *International Journal of Environmental Research and Public Health, 18,* Article No. 3826. https://doi.org/10.3390/ijerph18073826

Lima, R. A., Bugge, A., Ersbøll, A. K., Stodden, D. F., & Andersen, L. B. (2019a). The Longitudinal Relationship between Motor Competence and Measures of Fatness and Fitness from Childhood into Adolescence. *Jornal de Pediatria, 95,* 482-488. https://doi.org/10.1016/j.jped.2018.02.010

Lima, R. F., Palao, J. M., & Clemente, F. M. (2019b). Jump Performance during Official Matches in Elite Volleyball Players: A Pilot Study. *Journal of Human Kinetics, 67,* 259-269. https://doi.org/10.2478/hukin-2018-0080

Limroongreungrat, W., Mawhinney, C., Kongthongsung, S., & Pitaksathienkul, C. (2022). Landing Error Scoring System: Data from Youth Volleyball Players. *Data in Brief, 41,* Article ID: 107916. https://doi.org/10.1016/j.dib.2022.107916

Liveris, N. I., Tsarbou, C., Tsimeas, P. D., Papageorgiou, G., Xergia, S. A., & Tsiokanos, A. (2021). Evaluating the Effects of Match-Induced Fatigue on Landing Ability; the Case of the Basketball Game. *International Journal of Exercise Science, 14,* 768-778.

Lockie, R. G., Liu, T. M., Stage, A. A., Lazar, A., Giuliano, D. V., Hurley, J. M. et al. (2020). Assessing Repeated-Sprint Ability in Division I Collegiate Women Soccer Players. *Journal of Strength and Conditioning Research, 34,* 2015-2023. https://doi.org/10.1519/jsc.0000000000002527

López-Valenciano, A., Raya-González, J., Garcia-Gómez, J. A., Aparicio-Sarmiento, A., Sainz de Baranda, P., De Ste Croix, M. et al. (2021). Injury Profile in Women's Football: A Systematic Review and Meta-Analysis. *Sports Medicine, 51,* 423-442. https://doi.org/10.1007/s40279-020-01401-w

Lucarno, S., Zago, M., Buckthorpe, M., Grassi, A., Tosarelli, F., Smith, R. et al. (2021). Systematic Video Analysis of Anterior Cruciate Ligament Injuries in Professional Female Soccer Players. *The American Journal of Sports Medicine, 49,* 1794-1802. https://doi.org/10.1177/03635465211008169

Mandorino, M., J. Figueiredo, A., Gjaka, M., & Tessitore, A. (2023). Injury Incidence and Risk Factors in Youth Soccer Players: A Systematic Literature Review. Part II: Intrinsic and Extrinsic Risk Factors. *Biology of Sport, 40,* 27-49. https://doi.org/10.5114/biolsport.2023.109962

McLean, S. G., Felin, R. E., Suedekum, N., Calabrese, G., Passerallo, A., & Joy, S. (2007). Impact of Fatigue on Gender-Based High-Risk Landing Strategies. *Medicine & Science in Sports & Exercise, 39,* 502-514. https://doi.org/10.1249/mss.0b013e3180d47f0

Natali, S., Ferioli, D., La Torre, A., & Bonato, M. (2019). Physical and Technical Demands of Elite Beach Volleyball According to Playing Position and Gender. *The Journal of Sports Medicine and Physical Fitness, 59,* 6-9. https://doi.org/10.23736/s0022-4707.17.07972-5

Okoruwa, E. T., Abbott, A., Stamm, M., & Mulcahey, M. K. (2022). Sport Specialization Classification and Injury Risk in Female Athletes. *Sports Health: A Multidisciplinary Approach, 14,* 797-804. https://doi.org/10.1177/19417381221123532

Oliver, J., Armstrong, N., & Williams, C. (2008). Changes in Jump Performance and Muscle Activity Following Soccer-Specific Exercise. *Journal of Sports Sciences, 26,* 141-148.

https://doi.org/10.1080/02640410701352018

Otsuki, R., Benoit, D., Hirose, N., & Fukubayashi, T. (2021). Effects of an Injury Prevention Program on Anterior Cruciate Ligament Injury Risk Factors in Adolescent Females at Different Stages of Maturation. *Journal of Sports Science and Medicine, 20,* 365-372. https://doi.org/10.52082/jssm.2021.365

Padua, D. A., DiStefano, L. J., Beutler, A. I., de la Motte, S. J., DiStefano, M. J., & Marshall, S. W. (2015). The Landing Error Scoring System as a Screening Tool for an Anterior Cruciate Ligament Injury-Prevention Program in Elite-Youth Soccer Athletes. *Journal of Athletic Training, 50,* 589-595. https://doi.org/10.4085/1062-6050-50.1.10

Peebles, A. T., Williams, B., & Queen, R. M. (2021). Bilateral Squatting Mechanics Are Associated with Landing Mechanics in Anterior Cruciate Ligament Reconstruction Patients. *The American Journal of Sports Medicine, 49,* 2638-2644. https://doi.org/10.1177/03635465211023761

Pletcher, E. R., Dekker, T. J., Lephart, S. M., & Sell, T. C. (2021). Sex and Age Comparisons in Neuromuscular and Biomechanical Characteristics of the Knee in Young Athletes. *International Journal of Sports Physical Therapy, 16,* 438-449. https://doi.org/10.26603/001c.21358

Quatman, C. E., Ford, K. R., Myer, G. D., & Hewett, T. E. (2006). Maturation Leads to Gender Differences in Landing Force and Vertical Jump Performance: A Longitudinal Study. *The American Journal of Sports Medicine, 34,* 806-813. https://doi.org/10.1177/0363546505281916

Randell, R. K., Clifford, T., Drust, B., Moss, S. L., Unnithan, V. B., De Ste Croix, M. B. A. et al. (2021). Physiological Characteristics of Female Soccer Players and Health and Performance Considerations: A Narrative Review. *Sports Medicine, 51,* 1377-1399. https://doi.org/10.1007/s40279-021-01458-1

Reina Román, M., García-Rubio, J., Feu, S., & Ibáñez, S. J. (2019). Training and Competition Load Monitoring and Analysis of Women's Amateur Basketball by Playing Position: Approach Study. *Frontiers in Psychology, 9,* Article No. 2689. https://doi.org/10.3389/fpsyg.2018.02689

Root, H., Trojian, T., Martinez, J., Kraemer, W., & DiStefano, L. J. (2015). Landing Technique and Performance in Youth Athletes after a Single Injury-Prevention Program Session. *Journal of Athletic Training, 50,* 1149-1157. https://doi.org/10.4085/1062-6050-50.11.01

Rostami, A., Letafatkar, A., Gokeler, A., & Khaleghi Tazji, M. (2020). The Effects of Instruction Exercises on Performance and Kinetic Factors Associated with Lower-Extremity Injury in Landing after Volleyball Blocks. *Journal of Sport Rehabilitation, 29,* 51-64. https://doi.org/10.1123/jsr.2018-0163

Saber, B., Bridger, D., & Agrawal, D. K. (2024). A Critical Analysis of the Factors Contributing to Anterior Cruciate Ligament Injuries in Female Athletes. *Journal of Orthopaedics and Sports Medicine, 6,* 203-209. https://doi.org/10.26502/josm.511500163

Sannicandro, I. (2024). How Can Games Be Functional in the Implementation of Long-Term Athletic Development (LTAD) in Youth Sports? Exploratory Learning Experiences and Opportunities to Increase Physical Efficiency. *Advances in Physical Education, 14,* 27-45. https://doi.org/10.4236/ape.2024.142003

Sannicandro, I., Esposito, G., D'Onofrio, R., & Cofano, G. (2024). The Effects of Fatigue on Landing Performance in Young Female Soccer Players. *Physical Education Theory and Methodology, 24,* 254-262. https://doi.org/10.17309/tmfv.2024.2.09

Santamaria, L. J., & Webster, K. E. (2010). The Effect of Fatigue on Lower-Limb Biomechanics during Single-Limb Landings: A Systematic Review. *Journal of Orthopaedic &*

Sports Physical Therapy, 40, 464-473. https://doi.org/10.2519/jospt.2010.3295

Shultz, S. J., Cruz, M. R., Casey, E., Dompier, T. P., Ford, K. R., Pietrosimone, B. et al. (2022). Sex-Specific Changes in Physical Risk Factors for Anterior Cruciate Ligament Injury by Chronological Age and Stages of Growth and Maturation from 8 to 18 Years of Age. *Journal of Athletic Training, 57,* 830-876. https://doi.org/10.4085/1062-6050-0038.22

Skouras, A. Z., Kanellopoulos, A. K., Stasi, S., Triantafyllou, A., Koulouvaris, P., Papagiannis, G. et al. (2022). Clinical Significance of the Static and Dynamic Q-Angle. *Cureus, 14,* e24911. https://doi.org/10.7759/cureus.24911

Smith, M., Tallis, J., Miller, A., Clarke, N. D., Guimarães-Ferreira, L., & Duncan, M. J. (2016). The Effect of Exercise Intensity on Cognitive Performance during Short Duration Treadmill Running. *Journal of Human Kinetics, 51,* 27-35. https://doi.org/10.1515/hukin-2015-0167

Song, Y., Li, L., Hughes, G., & Dai, B. (2023). Trunk Motion and Anterior Cruciate Ligament Injuries: A Narrative Review of Injury Videos and Controlled Jump-Landing and Cutting Tasks. *Sports Biomechanics, 22,* 46-64. https://doi.org/10.1080/14763141.2021.1877337

Thomas, K., Brownstein, C. G., Dent, J., Parker, P., Goodall, S., & Howatson, G. (2018). Neuromuscular Fatigue and Recovery after Heavy Resistance, Jump, and Sprint Training. *Medicine & Science in Sports & Exercise, 50,* 2526-2535. https://doi.org/10.1249/mss.0000000000001733

Tillman, M. D., Hass, C. J., Brunt, D., & Bennett, G. R. (2004). Jumping and Landing Techniques in Elite Women's Volleyball. *Journal of Sports Science & Medicine, 3,* 30-36.

Tsuda, E., Goodway, J. D., Famelia, R., & Brian, A. (2020). Relationship between Fundamental Motor Skill Competence, Perceived Physical Competence and Free-Play Physical Activity in Children. *Research Quarterly for Exercise and Sport, 91,* 55-63. https://doi.org/10.1080/02701367.2019.1646851

Vermeulen, S., Bleecker, C., Blaiser, C., Kilinç, Ö. O., Willems, T., Vanrenterghem, J., Roosen, P., & Ridder, R. (2023). The Effect of Fatigue on Trunk and Pelvic Jump-Landing Biomechanics in View of Lower Extremity Loading: A Systematic Review. *Journal of Human Kinetics, 86,* 73-95. https://doi.org/10.5114/jhk/159460

Verschueren, J., Tassignon, B., De Pauw, K., Proost, M., Teugels, A., Van Cutsem, J. et al. (2020). Does Acute Fatigue Negatively Affect Intrinsic Risk Factors of the Lower Extremity Injury Risk Profile? A Systematic and Critical Review. *Sports Medicine, 50,* 767-784. https://doi.org/10.1007/s40279-019-01235-1

Vescovi, J. D., Fernandes, E., & Klas, A. (2021). Physical Demands of Women's Soccer Matches: A Perspective across the Developmental Spectrum. *Frontiers in Sports and Active Living, 3,* Article ID: 634696. https://doi.org/10.3389/fspor.2021.634696

Yu, B., McClure, S. B., Onate, J. A., Guskiewicz, K. M., Kirkendall, D. T., & Garrett, W. E. (2005). Age and Gender Effects on Lower Extremity Kinematics of Youth Soccer Players in a Stop-Jump Task. *The American Journal of Sports Medicine, 33,* 1356-1364. https://doi.org/10.1177/0363546504273049

Zhang, Q., Ruan, M., Singh, N., Huang, L., Zhang, X., & Wu, X. (2021). Progression of Fatigue Modifies Primary Contributors to Ground Reaction Forces during Drop Landing. *Journal of Human Kinetics, 76,* 161-173. https://doi.org/10.2478/hukin-2021-0052

Ziv, G., & Lidor, R. (2010). Vertical Jump in Female and Male Basketball Players—A Review of Observational and Experimental Studies. *Journal of Science and Medicine in Sport, 13,* 332-339. https://doi.org/10.1016/j.jsams.2009.02.009