# Biomechanics Lab Report Portfolio

Student Name

University

Course

Professor Name

Date

# Table of Contents

# Biomechanics Lab Report Portfolio

This case study focuses on a 19-year-old male football player (196 cm, 81 kg), who has a documented nemesis hamstring strain. Thus, hamstring injuries are prevalent among athletes (Rudisill et al., 2023). Due to player exposure, the need to assess the risk of injury in football is necessary to implement greater injury prevention. It would contribute to longer performance and overall better health (Hagos et al., 2025). Sprinting, kicking, rapid accelerations, etc. lead to sprinting hamstring injuries in football at a high rate, and past injuries have shown high recurrence by simply performing muscle tests and by overlooking the fact that strength and muscle control is not fully rehabilitated. At the same time, it is vital to consider that hamstring tightness is modifiable factor, meaning injuries can be prevented (Manikandan et al., 2025). Correctly understanding the load as well as muscle's behaviour would lead to designing methods to enhance hamstring injurie prevention, which is vital for professional players (Chebbi et al., 2022). This fact also justifies the need for tests and investigations.

The Nordic hamstring curl (NHC) is designed to determine eccentric knee flexor strength in a lengthened position. It might show how volume of NHC impacts the strengths and muscles (Cholp & Zemková, 2025). At the same time, some simple tests might miss the presenting risks (Liveris et al., 2024). Therefore, the final test required the athlete to perform a drop jump so the evaluators could assess reactive strength, stretch-shortening cycle function, and landing mechanics at the hip, knee, and ankle. Neuromuscular control deficits are essential for landing after hamstring injury, meaning their assessment is vital (Jankaew et al., 2025). The three tests offer a comprehensive assessment of the athlete's hamstring and lower-limb function, and together these findings may guide the clinician's recommendations and course of action regarding the management of the athlete.

# 1. Kinematic Assessment

## Methods

To evaluate flexibility and mobility in hip, knee, and ankle joints during touchdown and takedown, we monitored lower-limb kinematics during bilateral drop jumping. Athletes landed with both feet placed in the middle of the force plate 2019s markings after stepping off the measurement box, which was set 30 cm back from the measurement region. Step off, land with both feet, minimise ground contact time and jump as high as possible, keeping hands on the hips to prevent arm swing. Prior to the measurement, we performed a warm-up, including cycling, jumping and dynamic submaximal stretching. Reflective markers were placed on the anterior superior iliac spine, greater trochanter, lateral femoral condyle, lateral malleolus, and fifth metatarsal head to segment the pelvis, thigh, shank, and foot in a 3D motion analysis. Flexion-extension, or hip and knee motion, was calculated in the sagittal plane for landing control, while inversion-eversion, or ankle motion, was captured in the frontal/medio-lateral plane (Taylor et al., 2023). The method is summarised and presented in Table 1.

**Table 1**

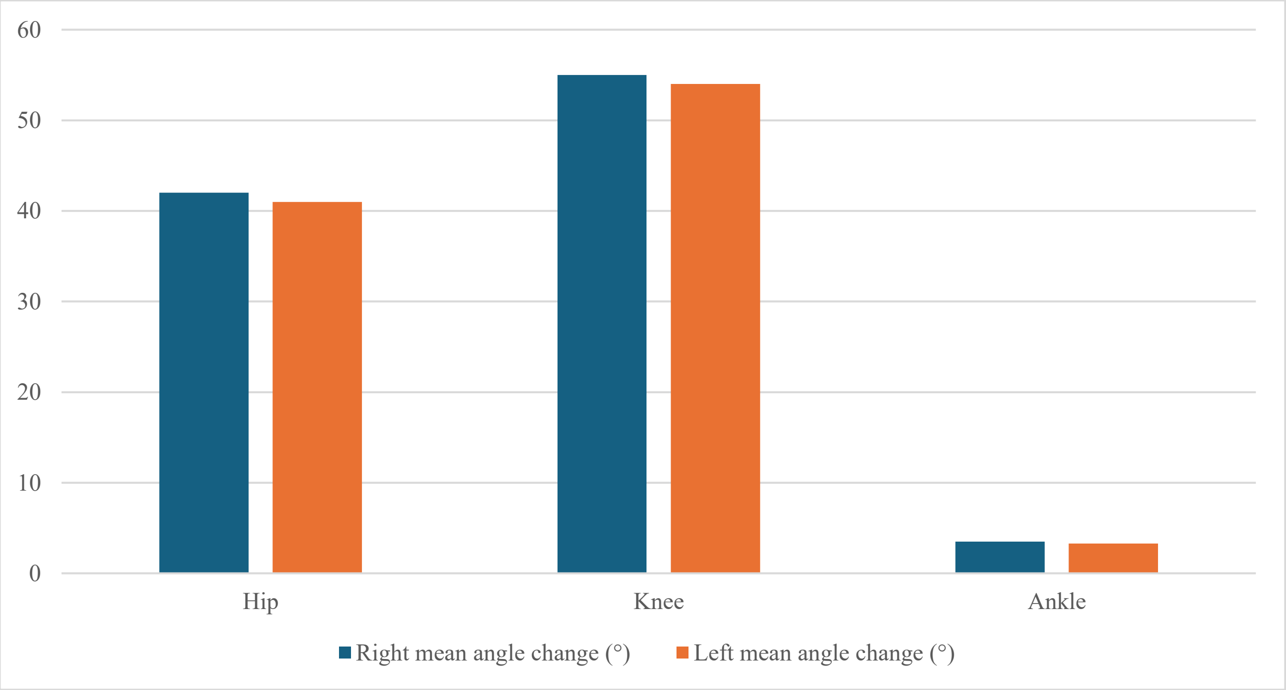
*Method of Kinematic Assessment*

| **Research Object** | **Approach** | **Procedure** | **Data Collection Approach** |
|---|---|---|---|
| Mobility in hip, knee, and ankle joints during touchdown | Lower-limb kinematics during bilateral drop jumping monitoring | Landing with both feet placed in the middle of the force plate 2019s markings after stepping off the measurement box | Reflective markers, foot in a 3D motion analysis |

Data were sampled and synchronised at high rates with the force plates to establish the initial contact. The starting and lowest point angles for the hip, knee, and ankle joints are shown in raw form in Figure 1.

**Figure 1**

*Joint Excursions*



## Results

From the data provided, one is able to identify that the athlete kept an upright position during landing. During the initial stage of contact, hip flexion measured about 2 to 9 degrees, while the knee flexed between 8 to 12 degrees, and the ankle was in a neutral position in the frontal plane (about 2 degrees of inversion/eversion). During the lowest position of the hip flexion countermovement the flection was about 43 to 47 degrees, while the knee flexed to about 60 to 65 degrees on either side, and the ankle frontal plane rotation apart was around 3 to 4 degrees, showing the malleable and stable coordinated structure of the body.

In the first trial, right hip excursion was 42.1 degrees while the left was 40.9 degrees, resulting in a side-to-side difference of 1.2 degrees and a difference of 2.8%. The knee excursion was 54.5 degrees and 53.9 degrees, respectively, resulting in a difference of 0.6 degrees and 1.1%. Ankle excursion was 3.5 degrees on the right and 3.2 degrees on the left, resulting in a difference of 0.3 degrees. 8.6% of the difference in this case was large only because the angles in consideration were small, but this is a difference nonetheless (Table 2). The following trials showed including the minor differences of all limbs, and the knee diff, a difference consistent between the high 40s and 50s. The time-course of motion exhibited smooth, single-peaked flexion patterns at the hip and knee, with concomitant flexion of both limbs during the braking phase and mirrored extension during propulsion.

**Table 2**

*Drop Jump Kinematic Assessment*

| **Joint** | **Right Excursion** | **Left Excursion** | **Absolute Difference** | **Relative Difference** |
|---|---|---|---|---|
| Hip | 42.1 | 40.9 | 1.2 | 2.9 |
| Knee | 54.5 | 53.9 | 0.6 | 1.1 |
| Ankle | 3.5 | 3.2 | 0.3 | 8.6 |

## 2. Kinetic Assessment – Strength

### Methods

Isolated and multi-joint force production were evaluated using a multi-modal hamstring strength battery. Thus, players with lower hamstring strength have the increased risks of acute trauma (Moreno-Perez et al., 2024). Using strength battery might help to determine the exact value and avoid complications. The tests performed included hand-held dynamometry (HHD) for knee flexor strength in outer and mid-range positions, the NHC for eccentric hamstring strength, and isokinetic dynamometry (IKD) for concentric quadriceps and hamstring torque (Siddle et al., 2024). Therefore, it is vital to consider that high-velocity eccentric training is also essential (Kamandulis et al., 2023). Thus, for each test, participants completed a universally administered warm-up involving five minutes of light cycling, dynamic stretches of the lower limbs, and submaximal practice contractions pertaining to the test. For HHD, the participant was positioned supine with their pelvis strapped to a plinth. The knee was positioned in either a more extended, “outer-range” flexed position (longer hamstring length) or a “mid-range” flexed position (more flexed). During the Nordic hamstring curl, the athlete bent their knees and placed their shins on a padded surface, with their ankles secured to a stiff rod. When hamstring curls were completed, the force was recorded before the isokinetic knee dynamometer (IKD) flexion testing. The whole procedure is summarised in Table 3 below.

**Table 3**

*Method of Kinetic Assessment – Strength*

| **Research Object** | **Approach** | **Procedure** | **Data Collection Approach** |
|---|---|---|---|
| Isolated and multi-joint force production | Utilisation of multi-modal hamstring strength battery | Participants completed a warm-up: five minutes of light cycling, dynamic stretches of the lower limbs, and submaximal practice contractions | The force was recorded before the isokinetic knee dynamometer (IKD) flexion testing |

## Results

The inner and outer range of motion was achieved in isometric knee flexion (IKD) tests. In the left limb, the force recorded for the outer range were 180, 170, and 270, while the outer range of force in the right limb were 230, 210, and 230 (Table 4). The 3 outer range tests resulted in a mean isometric knee flexion weaker in the left knee by 8%. The left knee was found to have outer range isometric knee flexion with a difference of 17 Newtons. The difference in force in the trials resulted in a range of about 50 N in trial one to 40 N in trial 2, demonstrating a 22% difference of force in the third trial left knee flexion of 40 N.

**Table 4**

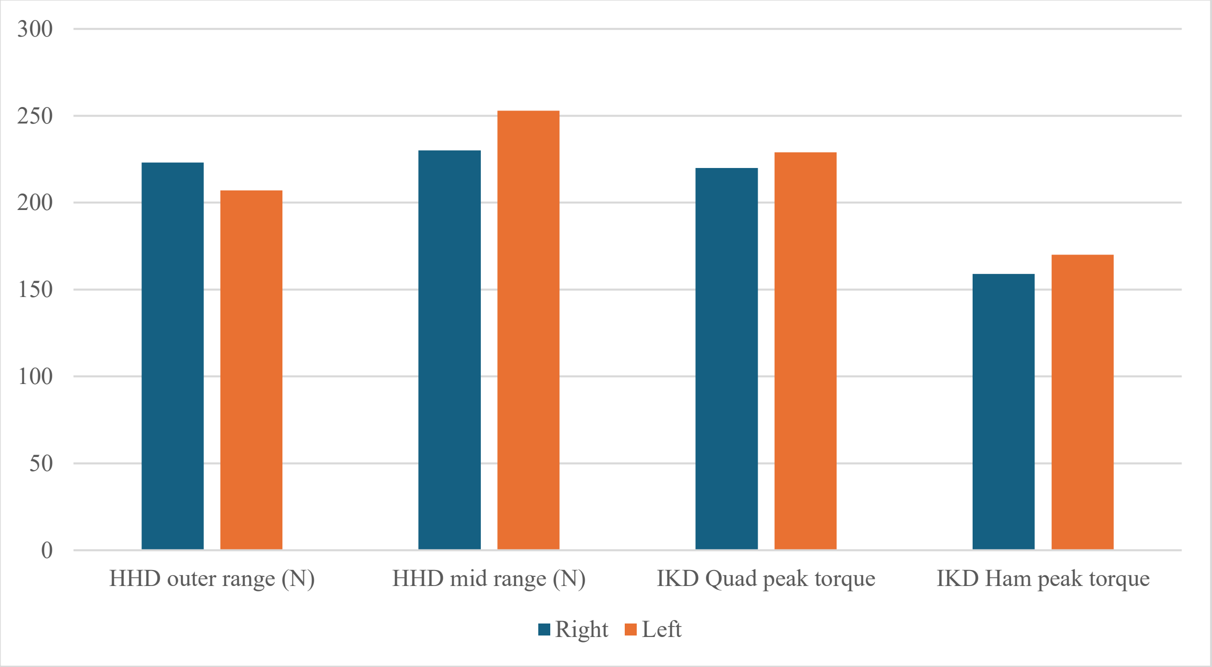
*Kinetic Assessment – Strength*

| **Measure** | **Right (Mean)** | **Left (Mean)** | **Absolute Difference** | **Relative Difference** |
|---|---|---|---|---|
| HHD outer-range knee flexion (N) | 223 | 207 | 16 | 7.2 |
| HHD mid-range knee flexion (N) | 230 | 253 | 23 | 9.1 |
| Nordic hamstring curl peak force (N) | 113 | 94 | 19 | 16.8 |
| IKD quadriceps peak torque | 220 | 229 | 9 | 3.9 |
| IKD hamstrings peak torque | 159 | 170 | 11 | 6.5 |

In the middle-cranial range, right limb is exerting mid-range is 230, 240, and 220 N contrasted with 260, 220 and 280 N to the left side. The average mid-range strength of the right side is 230 N, while the left side is 253 N. There are differences of -30 N in test 1 with left side advantage of about 12%, and +20 N in test 2 with a right-side advantage of about 8%, and -60 N in test 3 and left side advantage of about 21%. Altogether, the HHD data indicate there are small-moderate, albeit inconsistent, asymmetries and these may result from the resistance applied or effort used by the test subject (Figure 2).

**Figure 2**

*HHD & IKD Strength Asymmetry*



The peak Nordic hamstring values have shown a clearer and more consistent pattern, displaying left limb values at 82, 93, and 106 N. The strength asymmetry is essential for the performance of the athlete (Jiang et al., 2023). At the same time, asymmetry in jump tests is common among male football players (Espada et al., 2023). Thus, the right limb values increased 104, 107, and 128 N. The mean NHC values were 94 N to the left side and 113 N to the right side (difference of 19 N, 17% relative, left weaker). The depth of the deficit was analysed with relative difference values of 22, 14, and 22 N with 21, 13, and 17% of each right limb relative difference, 22 N having the largest deficit. Both limbs increased from trial one to trial three with left limb being 29% and right limb being 23% improved from their initial values, likely from a warm-up or learning effect, but the deficit to the left side remained. For IKD, left concentric quadriceps peak torque increased to 229 N·M, with the right 220 N·M. The hamstring peak torque increased to 170 N·M to the left side, while the right side increased to 159 N·M.

## 3. Kinetic Assessment – Ground Reaction Forces

### Methods

Data on ground reaction forces were collected on the same bilateral drop jump protocol as the one used during the kinematic analysis. An athlete stepped off a 30 cm box positioned directly above a pair of force plates and asked to land with both feet on the plates and jump as high and as fast as possible. To ensure the same stance across all three trials, the foot position was and must be standardised to hip-width and taped out (Martínez-Pascual et al., 2023). Vertical ground reaction force (vGRF) of each limb was recorded and exported for analysis. The raw data were filtered and normalised to facilitate comparisons both within and between limbs. For each limb in each trial, we computed the following variables from the vGRF-time curves: peak vGRF (expressed in multiples of BW), time to peak vGRF, and impulse of the braking phase. The absolute limb difference is the absolute value of right minus left. The approach is summarised in Table 5 below.

**Table 5**

*Kinetic Assessment-Ground Reaction Forces*

| Research Object | Approach | Procedure | Data Collection Approach |
|---|---|---|---|
| Ground reaction forces (Vertical ground reaction force - vGRF) | Bilateral drop jump protocol | An athlete stepped off a 30 cm box positioned directly above a pair of force plates and asked to land with both feet on the plates and jump as high and as fast as possible | vGRF of each limb was recorded. The following variables were computed: from the vGRF-time curves: peak vGRF (expressed in multiples of BW), time to peak vGRF, and impulse of the braking phase |

## Results

The maximum vGRF in each trial from each limb fell consistently in the range of two to three times the body weight expected from the activity of drop jumping. In each of the three trials the right limb was marginally higher than the left in the peak vGRF (Table 6). For all trials, the difference in peak vGRF was small on average, and the asymmetry was well under the expected and stated benchmarks for concern in healthy individuals. It is also vital to remember that fatigue can impact GRF and landing force (Bettariga et al., 2024). In the braking phase, impulsive force also exhibited the same pattern, with the right limb generating marginally more braking impulsive force which suggests a slight tendency to bias the right side more than the left limb.

**Table 6**

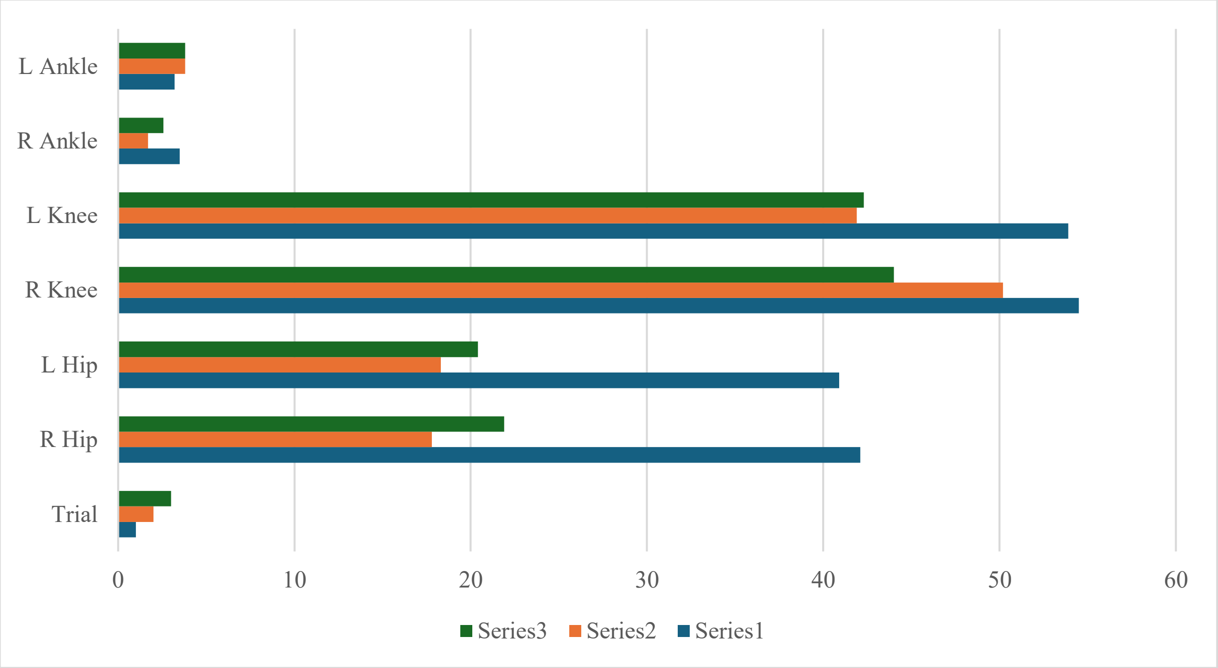
*Ground Reaction Force Assessment*

| Variable | Right (Mean) | Left (Mean) | Absolute Difference | Relative Difference |
|---|---|---|---|---|
| Peak vGRF | 2.7 | 2.6 | 0.1 | 3.7 |
| Braking impulse | 0.32 | 0.30 | 0.02 | 6.2 |
| Time to peak vGRF | 55 | 58 | 3 | 5.2 |

The time taken to peak in each of the vertical ground reaction forces in each trial from each limb was approximately symmetrical and left-right differences were marginal in relation to the overall contact time (Figure 3). The asymmetry was low between the trials with respect to average time taken to peak. Positive braking force was evident from the braking phase of grounding contact and was able to be partitioned with the same braking phase. The overall shape of the force–time curve for each of the stimulus conditions was mainly the same between each side, with small deviations that were not abrupt discharges, double peaks, or other deviations that may have indicated compensatory activity.

**Figure 3**

*Trial-by-Trial Line Graph*



Overall, asymmetries between the limbs as shown in the FGRF variables are present but small. There was consistently a greater peak force and braking impulse on the right (uninjured) limb, while on the left (injured) limb the values were lower. However, the left limb displayed comparable values and timing characteristics. This all suggests that while the athlete has restored symmetrical global displacement patterns, they still have a global load on the right limb, to a small degree, in high landings.

## Summary

There is some evidence that suggests this test battery can best represent an athlete's status after a single-leg hamstring injury. There are some underlying mechanisms that reveal the predisposition to injury (Andrews et al., 2025). In terms of kinematics, the drop jump analysis demonstrated impressive symmetry in the hip and knee range of motion; in the sagittal, frontal, and transverse planes there were no complicit differences in joint angles greater than 10%, also there was also no evidence of a knee valgus. These results support the idea that the injured athlete has regained adaptive control of the lower extremity during the landing phase of the drop jump. In the broader context, it is essential for organising the practice with reduced risks (Ekstrand et al., 2023). Adding eccentric training can improve neuromuscular control and reduce risks (Manescu & Manescu, 2025). In contrast, the kinetic profile tells a different story, suggesting that some of these asymmetries are more serious. While there were lower-extremity dynamometry side-to-side differences, these were of small gaps and were mostly in the isometric flexor range. The left limb that had an injury was also showed even concentric values in the quadriceps and hamstring.

## References

Andrews, M. H., Shield, A. J., Lichtwark, G. A., & Pincheira, P. A. (2025). Hamstring injury mechanisms and eccentric training-induced muscle adaptations: Current insights and future directions. *Sports Medicine, 55*(10), 2429-2443. https://doi.org/10.1007/s40279-025-02291-6

Bettariga, F., Bishop, C., Martorelli, L., Turner, A., Lazzarini, G., Algeri, C., & Maestroni, C. (2024). Acute effects of a fatiguing protocol on peak force and rate of force development of the hamstring muscles in soccer players. *Journal of Science in Sport and Exercise*, *6*(2), 177-185. https://doi.org/10.1007/s42978-023-00228-x

Chebbi, S., Chamari, K., Van Dyk, N., Gabbett, T., & Tabben, M. (2022). Hamstring injury prevention for elite soccer players: A real-world prevention program showing the effect of players' compliance on the outcome. *Journal of Strength and Conditioning Research*, *36*(5), 1383-1388. https://doi.org/10.1519/JSC.0000000000003505

Cholp, J., & Zemková, E. (2025). Effect of high vs. low volume of the Nordic hamstring curl on hamstring muscle architecture and eccentric strength in soccer players: A systematic review and meta-analysis. *Frontiers in Physiology*, *16*, 1631205. https://doi.org/10.3389/fphys.2025.1631205

Ekstrand, J., Ueblacker, P., Van Zoest, W., Verheijen, R., Vanhecke, B., van Wijk, M., & Bengtsson, H. (2023). Risk factors for hamstring muscle injury in male elite football: Medical expert experience and conclusions from 15 European Champions League clubs. *BMJ Open Sport & Exercise Medicine*, *9*(1), e001461. https://doi.org/10.1136/bmjsem-2022-001461

Espada, M. C., Jardim, M., Assunção, R., Estaca, A., Ferreira, C. C., Pessôa Filho, D. M., Verardi, C. E. L., Gamonales, J. M., & Santos, F. J. (2023). Lower limb unilateral and bilateral strength asymmetry in high-level male senior and professional football players. *Healthcare*, *11*(11), 1579. https://doi.org/10.3390/healthcare11111579

Hagos, A., Merchant, A. A., Kayani, B., Yasen, A. T., & Haddad, F. S. (2025). Risk factors and injury prevention strategies for hamstring injuries: A narrative review. *EFORT Open Reviews*, *10*(8), 636–645. https://doi.org/10.1530/EOR-2024-0135

Jankaew, A., Wang, P. C., Jan, Y. K., Hwang, I. S., & Lin, C. F. (2025). Hamstring activation deficits during Double-Leg Jump-Landing tasks in athletes with hamstring strain injuries using EMG Time-Frequency analysis. *Journal of Biomechanics*, *179*, 112475. https://doi.org/10.1016/j.jbiomech.2024.112475

Jiang, D., Liu, Z., Ling, X., Dai, J., Long, L., Lu, Y., & Zhou, S. (2023). Investigating the impact of inter-limb asymmetry in hamstring strength on jump, sprint, and strength performance in young athletes: Comparing the role of gross force. *Frontiers in Physiology*, *14*, 1185397. https://doi.org/10.3389/fphys.2023.1185397

Kamandulis, S., Cadefau, J. A., Snieckus, A., Mickevicius, M., Lukonaitiene, I., Muanjai, P., Satkunskiene, D., Molina, V., de Blas Foix, X., & Conte, D. (2023). The effects of high-velocity hamstring muscle training on injury prevention in football players. *Frontiers in Physiology*, *14*, 1219087. https://doi.org/10.3389/fphys.2023.1219087

Liveris, N. I., Tsarbou, C., Papageorgiou, G., Tsepis, E., Fousekis, K., Kvist, J., & Xergia, S. A. (2024). The complex interrelationships of the risk factors leading to hamstring injury and implications for injury prevention: A group model building approach. *Applied Sciences*, *14*(14), 6316. https://doi.org/10.3390/app14146316

Manescu, D., & Manescu, C. O. (2025). Eccentric hamstring training enhances sprint performance and neuromuscular stability in university football players: A controlled intervention study. *Preprints*. https://doi.org/10.20944/preprints202507.0411.v1

Manikandan, N. M. S., Elayaperumal, S., & Paneerselvam, A. (2025). Prevalence of hamstring tightness and associated risk factor among non-professional football players. *Journal of Neonatal Surgery*, *14*(6), 84-91. https://doi.org/10.52783/jns.v14.2844

Martínez-Pascual, D., Catalán, J. M., Blanco-Ivorra, A., Sanchís, M., Arán-Ais, F., & García-Aracil, N. (2023). Estimating vertical ground reaction forces during gait from lower limb kinematics and vertical acceleration using wearable inertial sensors. *Frontiers in Bioengineering and Biotechnology*, *11*, 1-13. https://doi.org/10.3389/fbioe.2023.1199459

Moreno-Perez, V., Sotos-Martínez, V., Lopez-Valenciano, A., Lopez Del-Campo, R., Resta, R., & Coso, J. D. (2024). Hamstring muscle injury is preceded by a short period of higher running demands in professional football players. *Biology of Sport*, *41*(1), 227–233. https://doi.org/10.5114/biolsport.2024.127387

Rudisill, S. S., Varady, N. H., Kucharik, M. P., Eberlin, C. T., & Martin, S. D. (2023). Evidence-based hamstring injury prevention and risk factor management: A systematic review and meta-analysis of randomized controlled trials. *The American Journal of Sports Medicine*, *51*(7), 1927–1942. https://doi.org/10.1177/03635465221083998

Siddle, J., Weaver, K., Greig, M., Harper, D., & Brogden, C. M. (2024). A low-volume Nordic hamstring curl programme improves change of direction ability, despite no architectural, strength or speed adaptations in elite youth soccer players. *Research in Sports Medicine*, *32*(1), 49-60. https://doi.org/10.1080/15438627.2022.2079984

Taylor, J. B., Wright, E. S., Waxman, J. P., Schmitz, R. J., Groves, J. D., & Shultz, S. J. (2023). Ankle dorsiflexion affects hip and knee biomechanics during landing. *Sports Health*, *14*(3), 328-335. https://doi.org/10.1177/19417381211019683