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Asymmetries in Field Hockey Players: A Narrative Review

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ABSTRACT

Field hockey is one of the most popular sports in the world, characterised by its asymmetric and unilateral nature because players are required to adopt a semi-crouched position, contributing inherently to an inbuilt asymmetry. This narrative review discusses the current understanding and existing knowledge of the asymmetries in field hockey players and emphasizes the importance of reducing asymmetry to lower injury risks and enhance performance. The relevant studies were identified by searching three databases (Scopus, Google Scholar, and PubMed). Results indicate that field hockey is an asymmetric sport dominated by one side of the body and distinguished by highly strict rules and regulations. The game increases morpho-functional asymmetries and produces side-to-side diversification. Asymmetrical training patterns and movements in field hockey led to muscular and postural adaptation asymmetries in players. In light of these findings, future research should focus on developing and implementing training programs specifically for field hockey players to reduce asymmetries, optimise athletic performance, and minimize injuries in field hockey players.

Keywords: Field Hockey, Asymmetry, Sporting asymmetry, Asymmetrical Training, Injury prevention, Performance enhancement

INTRODUCTION

Symmetry is when the size of a variable is the same in both parts, and asymmetry is when the size of a variable differs between the parts (Clark & Mullally, 2019). Body asymmetries can encompass variations between the left and right sides of the body, including the thorax, pelvis, and trunk, as well as differences between the left and right limbs, and these asymmetries can extend to variances between the upper and lower parts of the body, which can be observed through dimensions of

the limbs, body fat percentage, bone mineral density (BMD), lean body mass, muscle mass, and other related factors (Krzykała, 2012). It has been proven that asymmetry is more substantial in the dominant extremity due to its greater use in most daily activities, leading to increased bone dimensions in the specific body segment (Chilibeck et al., 2000; van Santen et al., 2019). However, the more frequent use of one leg leads to more BMD in the particular leg, whether dominant or non-dominant (Nazarian et al., 2010; Sone et al., 2006), and the particular side of the body experiences faster fatigue than the other side (Kadri et al., 2021; Oda & Moritani, 1995), same as regular normal asymmetric usage of the dominant or non-dominant limbs leads to increased BMD asymmetry (Tsorlakis et al., 2022). The difference in function or performance between limbs is called inter-limb asymmetries (Bishop et al., 2016; Bishop et al., 2021; Hewit et al., 2012).

Morphological asymmetry refers to the variation between the left and right sides of the body. This is the result of specific, predominantly asymmetrical movements, and these movements lack proper compensation, which is caused by functional adaptations, wherein muscle groups adjust to the uneven loading (Mala et al., 2020). Morphological factors such as body mass, body height, and body composition are among the most important predictors of sports performance and may have a significant effect on the performance of athletes (Moncef et al., 2012; Ridge et al., 2007). Numerous studies have provided evidence that there is a presence of morphological asymmetry in sports (Hart et al., 2016; Krzykała et al., 2023; Matjaz Zeleznik et al., 2023; Rauter et al., 2017), which adversely affects athletic performance (Bishop et al., 2021; Fort-Vanmeerhaeghe et al., 2020; Fox et al., 2023; Roso-Moliner et al., 2023) and also showed that Inter-limb differences are significant risk factors for sports injuries (Bell et al., 2014; Fort-Vanmeerhaeghe et al., 2022, Mila-Villarroel, et al., 2022; Smith et al., 2015). Moreover, lower limb functional asymmetry was identified as a risk factor for moderate to low-quality sports injuries within various sporting populations (Helme et al., 2021). Surprisingly, some studies showed that females exhibit significantly higher inter-limb asymmetry (Bailey et al., 2015; Pappas & Carpes, 2012) and right-biased than males (Auerbach & Ruff, 2006).

In asymmetric sports, the trunk rotational power of athletes is greater on their dominant side than their non-dominant side, and asymmetrical loading of the trunk muscles develops side-to-side imbalances in the strength and endurance of the rotational muscle (Zemkova et al., 2019). Sahrmann et al. (2017) found that the strength and length of a muscle can be affected by repeated movements and prolonged postures, which gradually change the movement pattern and lead to impairment, asymmetrical and poor dynamic postural control, as well as greater explosive performance, were the factors influencing the risk of injury (Mason et al., 2021; Plisky et al., 2006). The gradual result of musculoskeletal tissue adaptations in the overused limb leads to bilateral skeletal asymmetries in athletes (Krahl et al., 1994; Peters, 1988). Additionally, the directional asymmetry was connected with anatomical adaptations resulting from persistent unilateral biomechanical loads (Kurki, 2017) which, leads to asymmetrical tissue changes in different sports (Bussey, 2010). In several sports, the laterality of engagement has been connected to asymmetrical tissue change (Ducher et al., 2005; Haapasalo et al., 1998; Krahl et al., 1994). Especially in field hockey, structural damage happens to the spine when overloaded. 36% of the hockey players from the Polish national team exhibited degenerative changes in their vertebral bodies, and 68% had intervertebral disc problems from lumbar 1 to lumbar 5 (Bartkowiak et al., 2006).

Field hockey is a unilateral sport involving significant demands on the physiology (Reilly & Borrie, 1992) and physical capabilities (Lythe & Kilding, 2011) of athletes. Whereas in other sports, it is feasible to select a more advantageous limb to conduct a movement (such as kicking in soccer or smashing in volleyball). However, this is not possible in field hockey because players must adapt to the specific requirements of the sport, which is dominated by one side and distinguished by highly strict rules and regulations governing how to hold the hockey stick and strike the ball. The game is exclusively played with the right hand because the sticks are designed for right-handed use and measure approximately 0.91 meters in length and the ball is only allowed to touch the flat side of the stick, which is on the left side and faces the left side of the players (Rules of Hockey Including Explanations Effective from January 2022, 2023), So the game field hockey inherently possesses an inbuilt asymmetry.

Field hockey players cover a great distance and engage in repeated movements such as high-intensity running, and this consists of physical, mechanical, and physiological demands, including frequent tempo changes, peak high-speed running, accelerations, and deceleration by maintaining a semi-crouched body position (Goods et al., 2023; Ji et al., 2023; Lin et al., 2023; Lythe & Kilding, 2011; Noblett et al., 2023). When the players maintain the semi-crouched position for several years, these physical demands affect the musculoskeletal system and lead to a high risk of non-contact injury (Barboza et al., 2019; Ellapen et al., 2011). The repetitive asymmetric loading is more prone to lower back injuries (Konarski, 2010; Van Hilst et al., 2015) and potentially leads to a higher chance of developing kyphosis (Rajabi et al., 2012). Compared to free running, holding a stick in hockey may result in declining sprint acceleration performance due to a restricted stride velocity (Wdowski & Gittoes, 2013).

The unilateral requirements of hockey are an underlying factor behind asymmetric muscle development, flexibility, strength, and bone adaptations (Twomey, 1988). The intensity and style of playing, along with frequent postural stressors, skill requirements, and movement asymmetries (Reilly & Seaton, 1990), leads to the development of sporting asymmetry. This is an additional fourth type of asymmetry, which is likely influenced by limb dominance and magnified by long-standing participation and specific demand for the particular sport (Maloney, 2018). An asymmetry may develop in field hockey based on the execution of the hitting techniques because the movements while hitting the ball were preferred by one side, thus resulting in an unnatural body posture for the players (Reilly & Borrie, 1992). When hitting the ball, Players commonly turn their body from right to left, and upon returning to the starting position, the left leg once again bears the majority of the body weight (Bussey, 2010; Powell J., 2009), which is consistent with the findings of Gorman (2012) noted that the stick swings from right to left during the downswing of the "classic" hit.

Asymmetrical adaptations in bone, muscle girth, as well as flexibility and strength, have been related to the laterality of sports (Ducher et al., 2005; Krahl et al., 1994), However, very few studies have been conducted on asymmetries in the field hockey players, and to the author's knowledge, no studies critically evaluate the asymmetries in field hockey. The aim of this study is to summarise existing research and knowledge about asymmetry in field hockey, as well as provide insight to the practitioners and coaches in the field of physical education and sports science regarding the presence of asymmetry in field hockey. It also highlights the importance of the symmetrization

process during training and consistently monitoring asymmetry across different body parts to enhance athletic performance and potentially mitigate injury risks. Additionally, the study provides valuable recommendations for constructing and providing training programmes specifically designed for field hockey players to reduce asymmetries. Thus, it is hypothesised that field hockey is a unilateral sport that increases the morpho-functional asymmetry, and the game has sporting asymmetry. The morphological asymmetry is closely intertwined with functional asymmetry, which is strongly connected by the rules and regulations of the game.

METHODS

This narrative review thoroughly examines the current understanding of the asymmetries in field hockey players, along with factors contributing to injury risk. Due to the limited research in this field, a narrative review was considered more appropriate methodologically than a systematic review. The review does not impose date boundaries on the papers due to limited research. The relevant studies were identified by searching three databases (Scopus, Google Scholar, and PubMed). The search process was conducted by combining keywords with the Boolean operators "AND", "OR", and "AND NOT". The keywords used for the search included "asymmetry and field hockey", "asymmetry or physical demands in field hockey", "injury" and "injury risk and field hockey asymmetry", "game styles or physical demands and field hockey asymmetry", "muscle imbalance and asymmetry in field hockey and not ice hockey", "spinal asymmetry or spinal imbalance and field hockey" and various other combinations thereof. Based on the keywords, a total of 22 studies were identified, of which 20 were open-access. Eight studies were excluded as they did not clearly explain field hockey asymmetry. Out of the 14 selected studies, only seven specifically addressed asymmetry in field hockey. Five studies focused on injuries in field hockey, but those studies discussed how these injuries led to asymmetry. Additionally, one study each related to how game style, spinal movements, and muscle imbalance, contributed to asymmetry were also included. Figure 1 displays the research methodology, which includes the number of studies identified with the help of keywords and Boolean operators; Figure 2 illustrates the number of studies identifying asymmetries in each category; and Figure 3 shows the Key problems associated with asymmetry in Field Hockey.

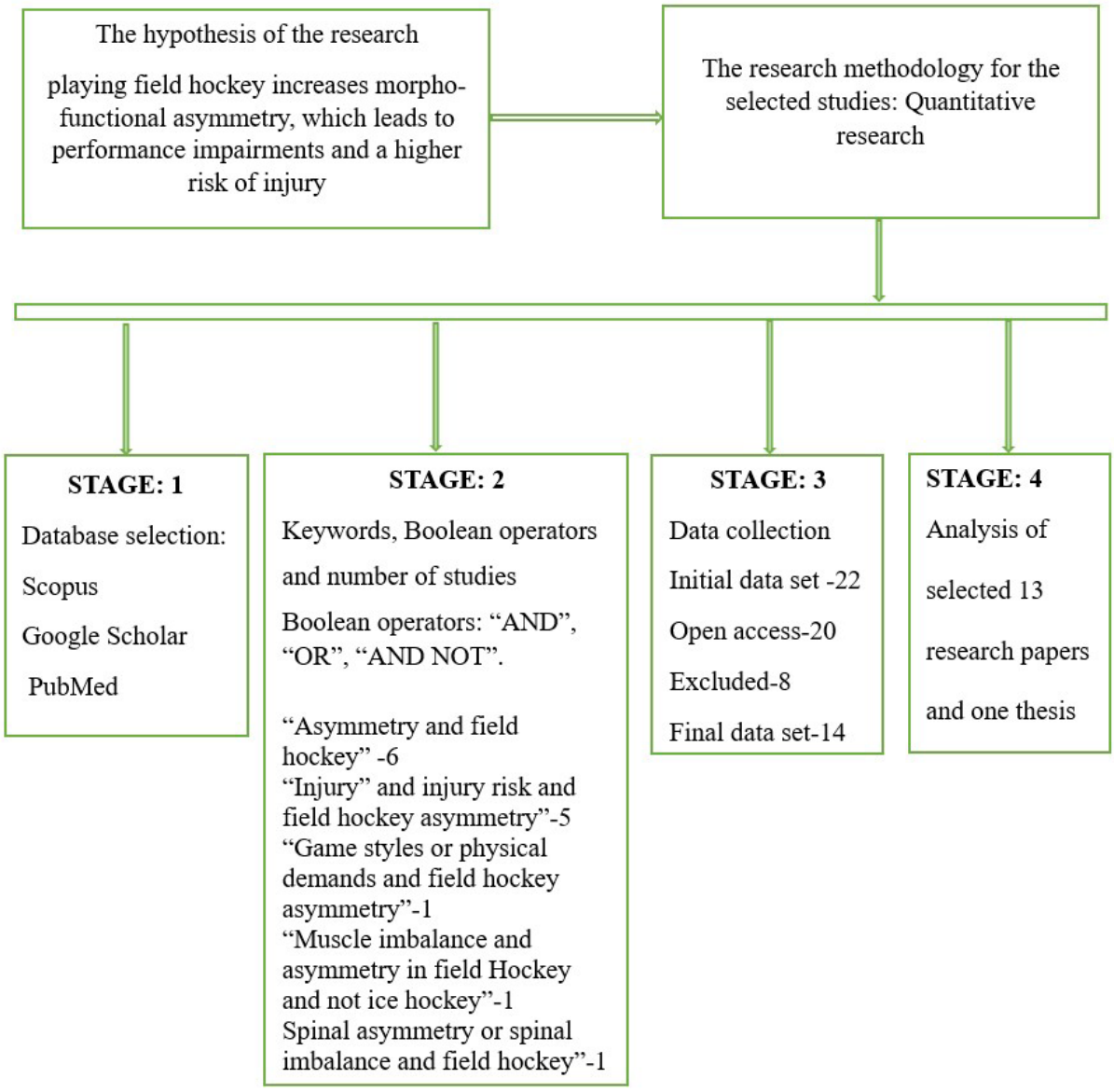

Figure 1. Research methodology design.

RESULTS

The description of this narrative review is given in Table 1. Three articles describe the body composition, bone mineral density (BMD), fat mass, and lean mass asymmetry; five articles investigate muscular asymmetry; four articles examine the postural adaptation asymmetry; and two articles are related to asymmetry in the upper region of field hockey players.

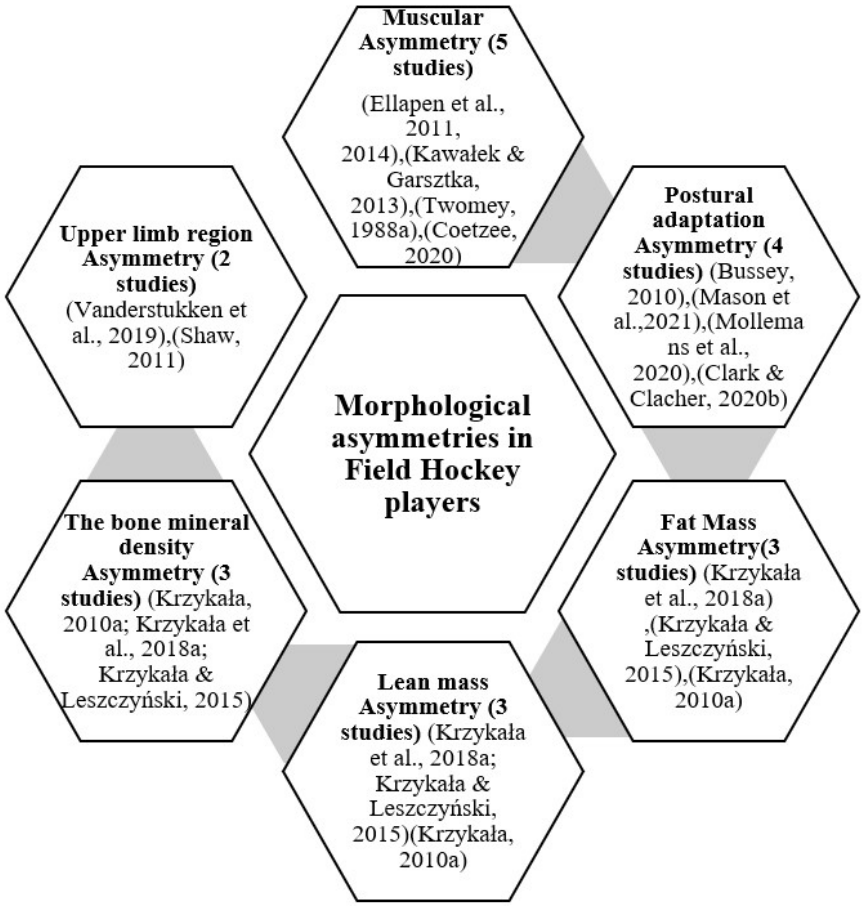

Figure 2. figure illustrates the number of studies identifying asymmetries in each category of field hockey

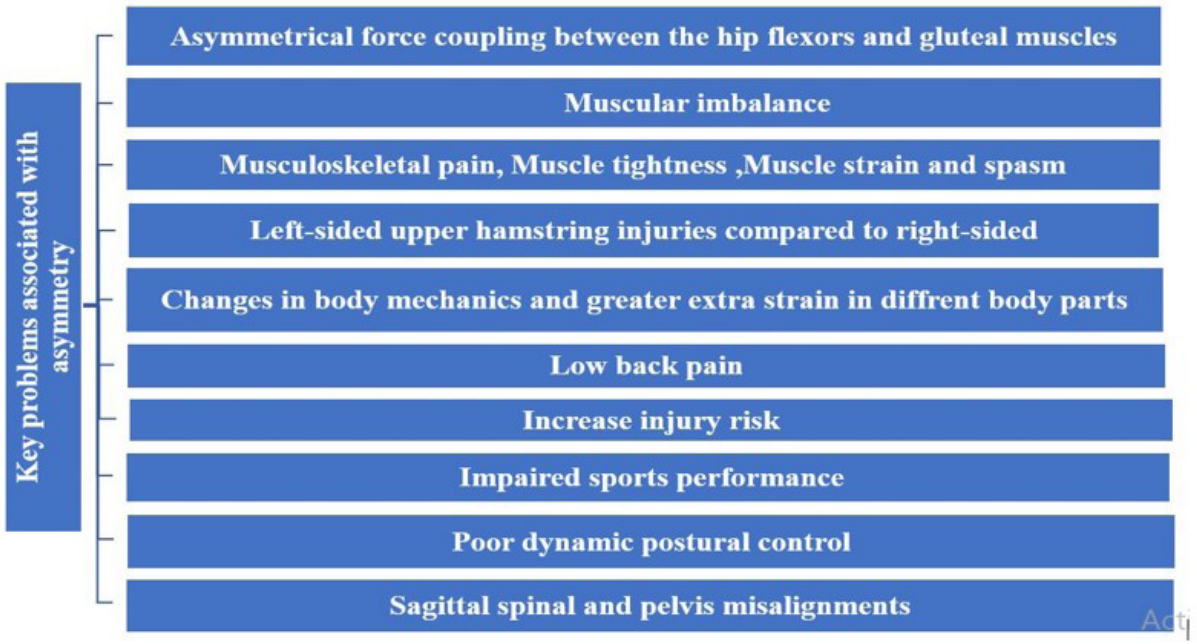

Figure 3. Key problems associated with asymmetry in Field Hockey

Table 1. Summary of asymmetries in field hockey players

Study	Purpose	Gender	Sample size	Level of athlete	Protocol	Result
(Mason et al., 2021)	To determine the factors that can lead to injury in field hockey players	Female	83	Professional and youth hockey players	Measure leg length, weight, and height at baseline standardized report form and preseason neuromuscular performance testing	Asymmetrical and poor dynamic postural control jointly influence risks of injury in field hockey players
(Mollemans et al., 2020) (Theses)	To determine the hip range of motion (ROM) is an inherent risk factor for injuries to the lower limb musculoskeletal system	Male	93	Belgian national hockey teams (U16, U18 and U21)	Injury history data, anthropometrical measurements and Flexion-Adduction-Internal rotation test, the Deep Squat, and hip ROM values were recorded by digital protractor and smartphone application (Rotating Sphere clinometer)	Increased asymmetry in ipsilateral hip rotation has been associated with decreased lower limbs and traumatic injuries.
(Clark & Clacher, 2020)	To determine the differences inright and left sides in terms of the triple-hop-for-distance (THD), anterior reach test (ART), eyes-closed balance (ECB), and six-meter hop-for-time (6MHT)	Female	30	Community-level club	Triple-hop-for-distance (THD), anterior reach test (ART), eyes-closed balance (ECB), and six-meter hop-for-time (6MHT)	No statistically significant differences existed between the right and left sides for the THD test, 6MHT, ECB, and ART.
(Coetzee, 2020) Theses	To identify the occurrence of inherent risk factors associated with hamstring injuries	Male and Female	33 (15 males and 18 females)	Pretoria's Field Hockey Club	Demographic information, injury status, Hamstring Outcome Score questionnaire, and Musculoskeletal tests.	Weaker hamstring strength and flexibility, along with asymmetries in flexibility.
(Vanderstukken et al., 2019)	To assess and compare the isokinetic shoulder girdle performance of elite male field hockey players with a control group of similar characteristics.	Male	25 male hockey players, 25 male control	Belgium male national field hockey team	Biodex system-4 dynamometer	Symmetry in isokinetic glenohumeral strength and asymmetry in scapular muscle strength
(Krzykała et al., 2018)	How asymmetry affects functional and morphological characteristics of field hockey players.	Male	15 male hockey players, 14 male control	Youth national team	Dual-energy X-ray absorptiometry (lean mass, bone mineral density, and fat mass) and Electro goniometric system (cervical, thoracic ROM)	Morphological asymmetry is increased by engaging in field hockey
(Krzykała & Leszczyński, 2015)	To determine whether hockey impacts the regional body composition and distribution of bone mineral density in specific body segments	Female	Total-31 youth team(N-14) National Team (N-17)	National team and youth team	Dual-energy X-ray absorptiometry (DXA) method (fat mass, bone mineral density, and lean mass)	Field hockey impacts laterality in bone mineral density (BMD) and body composition on the left side—experienced players, resulting in a higher degree of asymmetry.

Study	Purpose	Gender	Sample size	Level of athlete	Protocol	Result
(Ellapen et al., 2014)	To determine the characteristics and nature of musculoskeletal injuries in adolescent female field hockey players.	Female	148	KwaZulu-Natal (KZN) Hockey school league	Musculoskeletal injury questionnaire, postural analyses, and Thomas test (hip flexion contracture).	Muscle imbalances occur in asymmetrical force coupling between the gluteal muscles and hip flexors.
(Kawałek & Garsztka, 2013)	To assess the muscular balance of field hockey players	Male	17	Polish national team	Zembaty's functional tests of muscle length and survey	Quadratus lumborum is the asymmetrical hypertonic muscle; muscles in the upper limb area had low and asymmetrical abnormalities. Half of the muscles in the upper region exhibited hypertonic, showing a bias towards the right-hand side.
(Ellapen et al., 2011)	The occurrence of musculoskeletal pain related to field hockey	Female	30	South African female senior national field hockey team	Self-report questionnaire	Musculoskeletal pain in the lower back and hip was linked to an asymmetrical force couple between the gluteal muscles and hip flexors, leading to an imbalance in muscle function asymmetry.
(Shaw, 2011)	To determine how well bilateral asymmetry corresponds to self-reported handedness	Male	15	University of Cambridge and Anglia Ruskin University, Cambridge, UK	Peripheral quantitative computed tomography (PQCT) (bone and surrounding soft tissue two-dimensional images)	Humeral and ulnar bilateral asymmetry found in field hockey players
(Krzykała, 2010)	To determine the significant differences between sides and to evaluate morphological asymmetry of the left and right sides of the body.	Male	20	Senior national Polish level	Dual X-ray Absorptiometry (percent fat, total mass, lean tissue, bone mineral density (BMD) and fat tissue)	Asymmetry in bone mineral density in the legs and trunk on the left side of the body.
(Bussey, 2010)	To assess lateral dominance sports with more spinal flexion and rotation have demonstrated a higher prevalence of pelvic skeletal asymmetry	Female	60 bilateral group-20 unilateral group-20 non-athlete group-20	University-aged elite athletes.	The height and width of the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) were measured by an electromagnetic tracking device with a stylus.	The unilateral group showed a higher prevalence of skeletal pelvic asymmetry compared to both bilateral and non-athlete groups
(Twomey, 1988)	To assess the flexibility of the hamstring, the strength of the trunk's flexor and back extensor muscles, postural characteristics, and mobility of the lumbar spine.	Female and male	32 (15 male and 17 female)	Elite hockey players	1. The lumbarspondylometer assessed sagittal mobility; the lumbar rotameter measured horizontal mobility. 2. Isometric hold position 3. Back pain questionnaire; 4. Postural observations	Back muscles have asymmetry, with a particular emphasis on the right side.

DISCUSSION

Muscular Asymmetry

While playing hockey, persistent hip flexion causes an anterior pelvic tilt, which changes the usual resting length tension connection between the antagonists (gluteal muscles) and agonists (hip flexors) muscles, resulting in musculoskeletal pain (lower back and hip) and asymmetrical force coupling between the hip flexors and gluteal muscles. The gluteal and hip flexor muscle abnormal force coupling led to an asymmetrical muscular imbalance (Ellapen et al., 2011, 2014), same as Coetzee (2020) also observed hip flexor muscle asymmetry in field hockey players. Muscles Shortened can cause muscle imbalances in one or more joints (e.g., intervertebral joints). This imbalance results in uneven tension in the tissues around the joints, leading to pain that impairs the player's performance during a match or training. The majority of the studies stated that field hockey players particularly have hip flexor and gluteal muscle asymmetry, which can be attributed to several factors; firstly, unilateral dominance, which means players often develop one side of their body more than the other, leading to uneven muscle growth in these crucial areas. Secondly, the repetitive movements inherent to field hockey, such as running, dribbling, and striking the ball while maintaining a semi-crouched position impose asymmetrical loads and lead to muscular imbalances.

The quadratus lumborum is one of the muscle exhibiting asymmetrical hypertonicity in field hockey players due to the specific positions required by the sport because the length of the hockey stick is around 36.5–38.5 inches and which is coupled with the right hand being positioned lower than the left, leads to force flexion and side bending to the right, So the taller players tend to exhibit higher levels of muscle hypertonicity (Kawałek & Garsztka, 2013). Twomey (1988) reported asymmetrical erector spine muscle development on the right side in some field hockey players because of the right-hand hitting technique.

Interestingly, field hockey players demonstrated considerably greater trunk sway while executing cuts toward their left side because of the particular bend position to maintain in field hockey (Braun et al., 2015). The asymmetry becomes evident when the game demands a flexed and rotated trunk posture during play, which affects the alignment and function and potentially leads to uneven development. Wood et al. (2018) also found a significant rise in left-sided upper hamstring injuries compared to right-sided injuries because of the asymmetrical training load across the lower body in hockey players. Training imbalances in field hockey contribute to asymmetry due to the specific rule about holding the stick and playing the game. This rule unintentionally reinforces asymmetries by emphasizing certain movements, particularly one side of the body, more than the other, leading to unbalanced muscle development.

Postural adaptation asymmetry

The field hockey player's back is characterised as a long, flat thoracolumbar area with muscular asymmetry on the right (Twomey, 1988); this occurred as a result of the asymmetrical training patterns and movements of players as well as the laterality combined with increased spinal flexion and rotation. Coetzee (2020) found that most of the hockey players in his study were right-leg dominant and they preferred their dominant leg to "push-off" from the semi-crouched

position, resulting in hip flexibility asymmetries, such asymmetrical loading in sports leads to bone adaptations influenced by dominant side usage. Also, the higher prevalence of pelvic skeletal asymmetry is displayed in athletes participating in unilateral sports such as field hockey, and it results from asymmetrical load caused by lateral dominance coupled with the flexed and rotated trunk posture in sports, and this makes changes in body mechanics and greater strain on specific body parts (Bussey, 2010). Clark & Clacher (2020) also found clinically significant asymmetries for the eyes-closed-balance test and six-meter hop-for-time.

Upper Limb region

Regarding the upper limb region, elite male field hockey players have symmetric isokinetic glenohumeral muscle strength and asymmetric scapular muscle strength; most hits in hockey need external solid rotation in the left shoulder and internal rotation in the right. Therefore, players also use their arms asymmetrically while playing (Vanderstukken et al., 2019). The repeated unilateral use in field hockey leads to asymmetry in the scapular muscles, resulting in uneven loading and development on one side. Shaw (2011) found a significant humeral and ulnar bilateral asymmetry in hockey players due to the effect of unilateral loading.

The bone mineral density

Three studies assessed the asymmetry of field hockey players related to bone mineral density (BMD). For male field hockey players, Krzykała et al (2018) stated that the BMD was higher in the left leg and left trunk than right because the rotational movement from the right side to the left side with high speed was linked with the higher left leg and left trunk BMD. However, the right arms and right side had higher BMD values overall, which was not statistically significant. Furthermore, same as in male field players, there is a significant asymmetry in bone mineral density in the legs and trunk, favouring the left side. However, the arm and total bone mineral density did not differ significantly between the sides (Krzykała, 2010). For female field hockey players, the lower extremity and trunk bone mineral density displayed a significant left-sided asymmetry, but the upper extremity and total BMD were not significantly asymmetric (Krzykała & Leszczyński, 2015). The bone mineral density asymmetry in field hockey players can occur for several reasons, such as unilateral dominance, long-duration training sessions and years of training, and sports-specific movements.

Lean mass

When examining the results of the three studies related to Lean mass, there was significantly greater lean mass in the left arm, left leg, left trunk, and left total body compared to the right body side for male field hockey players (Krzykała, 2010; Krzykała et al., 2018). In the case of female players, Lean mass analysis of each side reveals significant differences between the right and left sides of the body; there were significantly higher values for the left upper limb, trunk and, in total, for national-level players, the lower extremities did not show any significant difference. However, the left side predominated for youth players with every variable (Krzykała & Leszczyński, 2015).

Fat Mass

The findings related to fat mass distribution in male players showed that the left side displayed dominance, and all differences were statistically significant: legs, arms, trunk, and total antimeres

(Krzykała et al., 2018). Similar results were found by Krzykała (2010) stated that across all body segments, the amount of morphological asymmetry was significantly greater in the left side of the body. In the case of female players, throughout all body segments, there were significant differences in fat mass for the upper extremity, trunk, and total fat mass for both sides, and the left side exhibited dominance (Krzykała & Leszczyński, 2015). The fat mass is greater on the left side in field hockey players, which may be because of unilateral dominance, training and physical conditioning and biomechanical factors, which means field hockey training positioning and repetitive movements could impact fat accumulation differently on each side.

Asymmetrical adaptation and reasons

These outcomes may be attributed to specialized and asymmetrical training designed to meet the specific demands of field hockey along with the high mechanical loading on the body parts during game and training sessions. Hockey players' cervical left bending, lumbar left bending, and thoracic right rotation positively correlate with years of training, and the various spinal motions produce side-to-side diversification (Krzykała et al., 2018). Ogurkowska and Kawałek (2017) also found a strong correlation between functional, structural, and pathological changes in the lumbar spine and the number of training years in field hockey players. According to the overload principle, physical changes may result when stresses are applied to biological tissues greater than those required (Hellebrandt & Houtz, 1956).

The asymmetrical activities have been related to increased risk factors for low back pain (LBP) (Motmans et al., 2006). LBP in athletes has been connected with a wide range of risk factors, including muscle tightness (Moreno-Perez et al., 2019; Vad et al., 2004), asymmetry (Cibulka et al., 2010; Ellenbecker et al., 2007; Fousekis et al., 2011), sagittal spinal and pelvis misalignments (Gandy et al., 2018; Vad et al., 2004). Several studies stated that field hockey players might experience sport-related risk factors of LBP for various reasons, including injuries from collisions or falls; besides these kinds of direct damage, hockey players may have low back pain (LBP) due to excessive stress on the spinal structures caused by the forward-flexed posture (Haydt et al., 2012). In field hockey, bent posture, twisting, turning, and dribbling were contributing factors for LBP, leading to hampered performance (Van Hilst et al., 2015). Individuals with LBP had significantly higher pelvic asymmetry than individuals without LBP. The asymmetry extended to upper limb traits, specifically the ulnar length and bistyloid breadth (Al-Eisa et al., 2004), same as people with LBP show greater asymmetry in hip rotation motion than people without LBP (Van Dillen et al., 2008) and the vertebral asymmetry has also been linked to scoliosis (Goldberg et al., 1997). Nadler et al. (2001) stated that hip muscle extensor strength asymmetry is associated with LBP occurrence in female athletes. Most of the studies stated that asymmetry led to injuries and was detrimental to performance in sports. However, in contrast to these findings, Mollemans et al. (2020) stated that the asymmetrical adaptations could help the players to manage the demands of the sport and prevent injury. Greater asymmetry in the ipsilateral hip rotation is related to the reduction in the rate of lower limb and traumatic injuries.

In sports, injury prevention programs help to prevent future injuries (Thorborg et al., 2017). Some sports and games have already implemented various training methods to reduce asymmetries,

and these studies stated that training programs help to reduce asymmetry in sports. Therefore, it is crucial to critically evaluate asymmetries in field hockey for design and provide appropriate asymmetry-focused training. Table 2 represents the experimental intervention programme implemented for various sports and games to reduce inter-limb asymmetries.

Table 2. Experimental studies to reduce inter-limb asymmetries

Subject	Training	Reference
American Football	Resistance training intervention	(Philipp et al., 2022)
Badminton Players	Integrative neuromuscular training	(Zhao et al., 2021)
	Targeted weaker limb strength training	(Xie et al., 2024)
	Unilateral strength training intervention	(Chen et al., 2023)
Basketball	Flywheel Resistance	(Fort-Vanmeerhaeghe et al., 2022)
	Direction-Specific Training Interventions (unilateral horizontal movements, unilateral lateral movements)	(Gonzalo-Skok et al., 2022)
Fencing	Plyometric training	(Kosova et al., 2022)
Field Hockey	Nordic hamstrings (NH) and eccentric leg curl (ELC) exercises	(Delextrat et al., 2017)
Handball	Isoinertial vs. Cable-Resistance Training	(Madruga-Parera et al., 2022)
Football	Core stability training programme	(Dello Iacono et al., 2016)
	Plyometric jump training	(Sammoud et al., 2024)
	Individual musculoskeletal asymmetry corrective exercise intervention program	(Theodorou et al., 2023)
	Unilateral Strength and Power Training Intervention	(Bettariga et al., 2023)
Soccer	Integrative neuromuscular training protocol vs. FIFA 11+ training	(Arede et al., 2022)
	Eccentric Overload Training	(Moreno-Azze et al., 2021a)
	Three Different Combined Training Intervention	(Moreno-Azze et al., 2021b)
	Combined strength and power training	(Pardos-Mainer et al., 2020)
	FIFA 11+ prevention programme	(Pardos-Mainer et al., 2019)
	Three different Unilateral Strength Training	(Gonzalo-Skok et al., 2019)
Tennis	Neuromuscular training program	(Mainer-Pardos et al., 2024)
	Balance Training	(Sannicandro et al., 2014)
One Rugby Player	Targeted Strength-Training Program	(Brown et al., 2017)
Volleyball Players	Contrast Strength Training Program	(Mesfar et al., 2022)

CONCLUSION

The extensive body of literature suggests that field hockey players have a high prevalence of asymmetry. The number of training years is a significant factor contributing to these hockey-related asymmetries. It is a sport with inherent asymmetry due to its unilateral nature, resulting from functional, postural, and muscular asymmetric patterns. Field hockey increased morpho-functional asymmetry and side-to-side diversification, which led to injuries. Therefore, understanding these asymmetrical adaptations is essential to develop and provide training programs, particularly for field hockey, to reduce injury and enhance performance.

Recommendations for future research

In summary, athletes and coaches often avoid these asymmetries and persist with training, inadvertently placing excessive strain on anatomical structures, which has been directed to pathological changes. Consequently, this leads to changes in muscles, bone structure, and bone mineral density. Despite the wide range of methodological approaches, the current review emphasizes and highlights several key considerations for future research.

1. This review recommends that compensating asymmetry and emphasising the symmetrization process is crucial for improving athletic performance and reducing the risk of injury through a structured training program.
2. Considering the health and performance of players, future research should focus on constructing a specific exercise training program specifically for field hockey players to reduce asymmetries, maximise athletic performance, and potentially minimise injury.
3. Future studies aim to construct and provide separate training programs for beginners and experienced players to address asymmetry based on the percentage of asymmetry.
4. The specific training program should be effectively addressed and help to compensate for imbalances and asymmetries.

Practical Applications

- The training programme to be constructed should be incorporated into the training schedule of experienced and high-performance players.
- Beginners in field hockey should initiate this training program right from the start of their learning process and regularly monitor the degree of asymmetry in different parts of the human body.

REFERENCE

Al-Eisa, E., Egan, D., & Wassersug, R. (2004). Fluctuating asymmetry and low back pain. *Evolution and Human Behavior*, *25*(1), 31–37. https://doi.org/10.1016/S1090-5138(03)00081-3

Arede, J., Fernandes, J., Moran, J., Leite, N., Romero-Rodriguez, D., & Madruga-Parera, M. (2022). Effects of an integrative neuromuscular training protocol vs. FIFA 11+ on sprint, change of direction performance and inter-limb asymmetries in young soccer players. *International Journal of Sports Science and Coaching*, *17*(1), 54–62. https://doi.org/10.1177/17479541211011438

Auerbach, B. M., & Ruff, C. B. (2006). Limb bone bilateral asymmetry: Variability and commonality among modern humans. *Journal of Human Evolution*, *50*(2), 203–218. https://doi.org/10.1016/j.jhevol.2005.09.004

Bailey, C. A., Sato, K., Burnett, A., & Stone, M. H. (2015). Force-production asymmetry in male and female athletes of differing strength levels. *International Journal of Sports Physiology and Performance*, *10*(4), 504–508. https://doi.org/10.1123/ijspp.2014-0379

Barboza, S. D., Joseph, C., Nauta, J., van Mechelen, W., & Verhagen, E. (2018). Injuries in Field Hockey Players: A Systematic Review. In *Sports Medicine* (Vol. 48, Issue 4, pp. 849–866). Springer International Publishing. https://doi.org/10.1007/s40279-017-0839-3

Bartkowiak, P., Lewandowski, J., & Szulc, P. (2006). NMR evaluation of the injuries to the knee joint and vertebral column lumbar segment in field hockey players of the Polish national team. In: Jerzembowski J, Grzybiak M, Piontek J, eds., The Human is the Measure of All Things. Sopot: Tower Press; 2006. 314-317.

Bell, D. R., Sanfilippo, J. L., Binkley, N., & Heiderscheit, B. C. (2014). Lean mass asymmetry influences force and power asymmetry during jumping in collegiate athletes. *Journal of Strength and Conditioning Research*, *28*(4), 884–891. https://doi.org/10.1519/JSC.0000000000000367

Bettariga, F., Maestroni, L., Martorelli, L., Jarvis, P., Turner, A., & Bishop, C. (2023). The Effects of a Unilateral Strength and Power Training Intervention on Inter-Limb Asymmetry and Physical Performance in Male Amateur Soccer Players. *Journal of Science in Sport and Exercise*, *5*(4), 328–339. https://doi.org/10.1007/s42978-022-00188-8

Bishop C, Read P, Chavda S, & Turner A. (2016). Asymmetries of the lower limb: the calculation conundrum in strength training and conditioning. *Strength Cond J*, *38*, 27–32. https://doi.org/10.1519/SSC.0000000000000264

Bishop, C., Read, P., McCubbine, J., & Turner, A. (2021). Vertical and Horizontal Asymmetries Are Related to Slower Sprinting and Jump Performance in Elite Youth Female Soccer Players. *Journal of Strength and Conditioning Research*, *35*(1), 56–63. https://doi.org/10.1519/JSC.0000000000002544

Braun, H. J., Shultz, R., Malone, M., Leatherwood, W. E., Silder, A., & Dragoo, J. L. (2015). Differences in ACL biomechanical risk factors between field hockey and lacrosse female athletes. *Knee Surgery, Sports Traumatology, Arthroscopy*, *23*(4), 1065–1070. https://doi.org/10.1007/s00167-014-2873-0

Brown, S. R., Feldman, E. R., Cross, M. R., Helms, E. R., Marrier, B., Samozino, P., & Morin, J. B. (2017). The potential for a targeted strength-Training program to decrease asymmetry and increase performance: A proof of concept in sprinting. *International Journal of Sports Physiology and Performance*, *12*(10), 1392–1395. https://doi.org/10.1123/ijspp.2016-0590

Bussey, M. D. (2010). Does the demand for asymmetric functional lower body postures in lateral sports relate to structural asymmetry of the pelvis? *Journal of Science and Medicine in Sport*, *13*(3), 360–364. https://doi.org/10.1016/j.jsams.2009.02.010

Chen, J., Yi, Z., & Tian, D. (2023). *A study on the effect of unilateral strength training intervention on lower limb asymmetry in college basketball players*. https://doi.org/10.21203/rs.3.rs-2815017/v1

Chilibeck, P. D., Davison, K. S., Sale, D. G., Webber, C. E., & Faulkner, R. A. (2000). Effect of physical activity on bone mineral density assessed by limb dominance across the lifespan. *American Journal of Human Biology*, *12*(5), 633–637. https://doi.org/10.1002/1520-6300(200009/10)12:5<633::aid-ajhb8>3.0.co;2-w

Cibulka, M. T., Strube, M. J., Meier, D., Selsor, M., Wheatley, C., Wilson, N. G., & Irrgang, J. J. (2010). Symmetrical and asymmetrical hip rotation and its relationship to hip rotator muscle strength. *Clinical Biomechanics*, *25*(1), 56–62. https://doi.org/10.1016/j.clinbiomech.2009.09.006

Clark, N. C., & Clacher, L. H. (2020). Lower-limb motor-performance asymmetries in English community-level female field hockey players: Implications for knee and ankle injury prevention. *Physical Therapy in Sport*, *43*, 43–51. https://doi.org/10.1016/j.ptsp.2020.02.001

Clark, N. C., & Mullally, E. M. (2019). Prevalence and magnitude of preseason clinically-significant single-leg balance and hop test asymmetries in an English adult netball club. *Physical Therapy in Sport*, *40*, 44–52. https://doi.org/10.1016/j.ptsp.2019.08.008

Coetzee, A. C. (2020). The prevalence and risk factors for hamstring injuries among field hockey players at a hockey club in Pretoria, South Africa (Doctoral dissertation). https://wiredspace.wits.ac.za/server/api/core/bitstreams/8bd027f7-9593-4ad7-a62e-74d56a9ecddf/content

Delextrat, A., Bateman, J., Jos, V., & Daniel, C. (2017). Changes In Torque-Angle Profiles Of The Hamstrings And Hamstrings-To-Quadriceps Ratio Following Two Hamstrings Strengthening Exercise Interventions In Female Hockey Players. *British Journal of Sports Medicine*, *51*(4), 311.2-311. https://doi.org/10.1136/bjsports-2016-097372.72

Dello Iacono, A., Padulo, J., & Ayalon, M. (2016). Core stability training on lower limb balance strength. *Journal of Sports Sciences*, *34*(7), 671–678. https://doi.org/10.1080/02640414.2015.10684

Ducher, G., Courteix, D., Même, S., Magni, C., Viala, J. F., & Benhamou, C. L. (2005). Bone geometry in response

to long-term tennis playing and its relationship with muscle volume: A quantitative magnetic resonance imaging study in tennis players. *Bone*, *37*(4), 457–466. https://doi.org/10.1016/j.bone.2005.05.014

Ellapen, T. J., Abrahams, S., Desai, F. A., Narsigan, S., & Van Heerden, H. J. (2011). Prevalence of Musculoskeletal Pain Among the South African Female Senior National Hockey Players. *Advances in Rehabilitation*, *25*(2). https://doi.org/10.2478/rehab-2013-0007

Ellapen, T. J., Bowyer, K., & Van Heerden, H. J. (2014). Common acute and chronic musculoskeletal injuries among female adolescent field hockey players in KwaZulu-Natal, South Africa. *South African Journal of Sports Medicine*, *26*(1), 4. https://doi.org/10.7196/sajsm.482

Ellenbecker, T. S., Ellenbecker, G. A., Roetert, E. P., Silva, R. T., Keuter, G., & Sperling, F. (2007). Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. *American Journal of Sports Medicine*, *35*(8), 1371–1376. https://doi.org/10.1177/0363546507300260

Fort-Vanmeerhaeghe, A., Bishop, C., Busca, B., Aguilera-Castells, J., Vicens-Bordas, J., & Gonzalo-Skok, O. (2020). Inter-limb asymmetries are associated with decrements in physical performance in youth elite team sports athletes. *PLoS ONE*, *15*(3). https://doi.org/10.1371/journal.pone.0229440

Fort-Vanmeerhaeghe, A., Mila-Villarroel, R., Pujol-Marzo, M., Arboix-Alio, J., & Bishop, C. (2022). Higher Vertical Jumping Asymmetries and Lower Physical Performance are Indicators of Increased Injury Incidence in Youth Team-Sport Athletes. *Journal of Strength and Conditioning Research*, *36*(8), 2204–2211. https://doi.org/10.1519/JSC.0000000000003828

Fort-Vanmeerhaeghe, A., Benet-Vigo, A., Montalvo, A., Arboix, A., Buscà, B., & Arboix-Alió, J. (2022). Relationship between Performance and Inter-Limb Asymmetries Using Flywheel Resistance Device in Elite Youth Female Basketball Players. *Biology*, *11*(6). https://doi.org/10.3390/biology11060812

Fousekis, K., Tsepis, E., Poulmedis, P., Athanasopoulos, S., & Vagenas, G. (2011). Intrinsic risk factors of non-contact quadriceps and hamstring strains in soccer: A prospective study of 100 professional players. *British Journal of Sports Medicine*, *45*(9), 709–714. https://doi.org/10.1136/bjsm.2010.077560

Gandy, E. A., Bondi, A., Pigott, T. M. C., Smith, G., & McDonald, S. (2018). Investigation of the use of inertial sensing equipment for the measurement of hip flexion and pelvic rotation in horse riders. *Https://Doi.Org/10.3920/CEP170023*, *14*(2), 99–110. https://doi.org/10.3920/CEP170023

Goldberg, C. J., Fogarty, E. E., Moore, D. P., & Dowling, F. E. (1997). Fluctuating asymmetry and vertebral malformation. A study of palmar dermatoglyphics in congenital spinal deformities. *Spine*, *22*(7), 775–779. https://doi.org/10.1097/00007632-199704010-00014

Gonzalo-Skok, O., Moreno-Azze, A., Arjol-Serrano, J. L., Tous-Fajardo, J., & Bishop, C. (2019). A Comparison of 3 Different Unilateral Strength Training Strategies to Enhance Jumping Performance and Decrease Interlimb Asymmetries in Soccer Players. *International Journal of Sports Physiology and Performance*, *14*(9), 1256–1264. https://doi.org/10.1123/IJSPP.2018-0920

Gonzalo-Skok, O., Sánchez-Sabaté, J., Tous-Fajardo, J., Mendez-Villanueva, A., Bishop, C., & Piedrafita, E. (2022). Effects of Direction-Specific Training Interventions on Physical Performance and Inter-Limb Asymmetries. *International Journal of Environmental Research and Public Health*, *19*(3). https://doi.org/10.3390/ijerph19031029

Goods, P. S. R., Scott, B. R., Appleby, B., Jennings, D., Peeling, P., & Galna, B. (2023). Physical preparation of the Australian national male field hockey team exceeded the movement demands of the Tokyo 2020 Olympic Games tournament. *Journal of Sports Sciences*. https://doi.org/10.1080/02640414.2023.2225025

Gorman, A. J. (2013). The timing and magnitude of muscular activity patterns during a field hockey hit (Doctoral dissertation, University of Lincoln). https://api.semanticscholar.org/CorpusID:108424887

Haapasalo, H., Kannus, P., Sievänen, H., Pasanen, M., Uusi-Rasi, K., Heinonen, A., Oja, P., & Vuori, I. (1998). Effect of long-term unilateral activity on bone mineral density of female junior tennis players. *Journal of Bone and Mineral Research*, *13*(2), 310–319. https://doi.org/10.1359/jbmr.1998.13.2.310

Hart, N. H., Nimphius, S., Weber, J., Spiteri, T., Rantalainen, T., Dobbin, M., & Newton, R. U. (2016). Musculoskeletal Asymmetry in Football Athletes: A Product of Limb Function over Time. *Medicine and Science in Sports and Exercise*, *48*(7), 1379–1387. https://doi.org/10.1249/MSS.0000000000000897

Haydt, R., Pheasant, S., & Lawrence, K. (2012). The incidence of low back pain in ncaa division iii female field hockey players. *International journal of sports physical therapy, 7*(3), 296–305. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3362982/pdf/ijspt-07-296.pdf

Hellebrandt, F. A., & Houtz, S. J. (1956). Mechanisms of muscle training in man: experimental demonstration of the overload principle. *Physical Therapy*, *36*(6), 371-383. https://doi.org/10.1093/ptj/36.6.371

Helme, M., Tee, J., Emmonds, S., & Low, C. (2021). Does lower-limb asymmetry increase injury risk in sport? A systematic review. In *Physical Therapy in Sport* (Vol. 49, pp. 204–213). Churchill Livingstone. https://doi.org/10.1016/j.ptsp.2021.03.001

Hewit, J. K., Cronin, J. B., & Hume, P. A. (2012). Asymmetry in multi-directional jumping tasks. *Physical Therapy in Sport*, *13*(4), 238–242. https://doi.org/10.1016/j.ptsp.2011.12.003

Kadri, M. A., Noé, F., Maitre, J., Maffulli, N., & Paillard, T. (2021). Effects of limb dominance on postural balance in sportsmen practicing symmetric and asymmetric sports: A pilot study. *Symmetry*, *13*(11). https://doi.org/10.3390/sym13112199

Kawałek, K., & Garsztka, T. (2013). An analysys of muscle balance in professional field hockey players. *TRENDS in Sport Sciences , 4(20), 181–187*. http://www.wbc.poznan.pl/Content/316848/PDF/5_Trends_2013_4_181.pdf.

Konarski, J. (2010). Characteristics of chosen parameters of external and internal loads in eastern European high level field hockey players.. *Journal of Human Sport and Exercise*, *5*(1), 43–58. https://doi.org/10.4100/jhse.2010.51.06

Kosova, S., Beyhan, R., & Kosova, M. K. (2022). The effect of 8-week plyometric training on jump height, agility, speed and asymmetry. *Pedagogy of Physical Culture and Sports*, *26*(1), 13–18. https://doi.org/10.15561/26649837.2022.0102

Krahl, H., Michaelis, U., Pieper, H. G., Quack, G., & Montag, M. (1994a). Stimulation of bone growth through sports. A radiologic investigation of the upper extremities in professional tennis players. *The American Journal of Sports Medicine, 22*(6), 751–757. https://doi.org/10.1177/036354659402200605

Krzykała, M. (2010). Dual Energy X-Ray Absorptiometry in Morphological Asymmetry Assessment among Field Hockey Players. In *Journal of Human Kinetics* (Vol. 25). http://www.johk.awf.katowice.pl

Krzykała, M. (2012). *Dxa as a Tool for the Assessment of Morphological Asymmetry in Athletes*. www.intechopen.com

Krzykała, M., Karpowicz, K., Karpowicz, M., Bartkowiak, S., Demuth, A., Czerniak, U., & Janowski, J. (2023). Somatic characteristic, morphological asymmetry and postural stability of youth male canoeists compared to control. A cross sectional study. *PLoS ONE*, *18*(5 May). https://doi.org/10.1371/journal.pone.0285997

Krzykała, M., & Leszczyński, P. (2015). Asymmetry in body composition in female hockey players. *HOMO-Journal of Comparative Human Biology*, *66*(4), 379–386. https://doi.org/10.1016/j.jchb.2015.02.008

Krzykała, M., Leszczyński, P., Grześkowiak, M., Podgórski, T., Woźniewicz-Dobrzyńska, M., Konarska, A., Strzelczyk, R., Lewandowski, J., & Konarski, J. M. (2018). Does field hockey increase morphofunctional asymmetry? A pilot study. *HOMO*, *69*(1–2), 43–49. https://doi.org/10.1016/j.jchb.2018.03.003

Kurki, H. K. (2017). Bilateral Asymmetry in the Human Pelvis. *Anatomical Record*, *300*(4), 653–665. https://doi.org/10.1002/AR.23546

Lin, L., Ji, X., Zhang, L., Weng, H., & Wang, X. (2023). Physical, physiological demands and movement profiles of elite men's field hockey games. *Kinesiology*, *55*(1), 73-84. https://doi.org/10.26582/k.55.1.8

Lin, L., Ji, X., Zhang, L., Weng, H., & Wang, X. (2023). Peak Running, Mechanical, and Physiological Demands of Professional Men's Field Hockey Matches. *Journal of Human Kinetics*, *87*, 133–141. https://doi.org/10.5114/jhk/161551

Lythe, J., & Kilding, A. E. (2011). Physical demands and physiological responses during elite field hockey. *International Journal of Sports Medicine, 32*(7), 523–528. https://doi.org/10.1055/s-0031-1273710

Madruga-Parera, M., Bishop, C., Beato, M., Fort-Vanmeerhaeghe, A., Gonzalo-Skok, O., & Romero-Rodríguez, D. (2021). Relationship between Interlimb Asymmetries and Speed and Change of Direction Speed in Youth Handball Players. *Journal of Strength and Conditioning Research*, *35*(12), 3482–3490. https://doi.org/10.1519/JSC.0000000000003328

Madruga-Parera, M., Bishop, C., Fort-Vanmeerhaeghe, A., Beato, M., Gonzalo-Skok, O., & Romero-Rodríguez, D. (2022). Effects of 8 Weeks of Isoinertial vs. Cable-Resistance Training on Motor Skills Performance and Interlimb Asymmetries. *Journal of Strength and Conditioning Research*, *36*(5), 1200–1208. https://doi.org/10.1519/JSC.0000000000003594

Madruga-Parera, M., Bishop, C., Fort-Vanmeerhaeghe, A., Beato, M., Gonzalo-Skok, O., & Romero-Rodríguez, D. (2022). Effects of 8 Weeks of Isoinertial vs. Cable-Resistance Training on Motor Skills Performance and Interlimb Asymmetries. *Journal of Strength and Conditioning Research*, *36*(5), 1200–1208. https://doi.org/10.1519/JSC.0000000000003594

Madruga-Parera, M., Bishop, C., Fort-Vanmeerhaeghe, A., Beltran-Valls, M. R., Skok, O. G., & Romero-Rodríguez, D. (2019). *Interlimb Asymmetries in Youth Tennis Players: Relationships With Performance*. www.nsca.com

Mainer-Pardos, E., Villavicencio Álvarez, V. E., Moreno-Apellaniz, N., Gutiérrez-Logroño, A., & Calero-Morales, S. (2024). Effects of a neuromuscular training program on the performance and inter-limb asymmetries in highly trained junior male tennis players. *Heliyon*, *10*(5). https://doi.org/10.1016/J.HELIYON.2024.E27081

Mala, L., Maly, T., Cabell, L., Hank, M., Bujnovsky, D., & Zahalka, F. (2020). Anthropometric, body composition, and morphological lower limb asymmetries in elite soccer players: A prospective cohort study. *International Journal of Environmental Research and Public Health*, *17*(4). https://doi.org/10.3390/ijerph17041140

Maloney, S. J. (2019). The relationship between asymmetry and athletic performance: A critical review. *The Journal of Strength & Conditioning Research*, *33*(9), 2579-2593. https://doi.org/10.1519/JSC.0000000000002608

Mason, J., Wellmann, K., Groll, A., Braumann, K. M., Junge, A., Hollander, K., & Zech, A. (2021). Game Exposure, Player Characteristics, and Neuromuscular Performance Influence Injury Risk in Professional and Youth Field Hockey Players. *Orthopaedic Journal of Sports Medicine*, *9*(4). https://doi.org/10.1177/2325967121995167

Mesfar, A., Hammami, R., Selmi, W., Gaied-Chortane, S., Duncan, M., Bowman, T. G., Nobari, H., & van den Tillaar, R. (2022). Effects of 8-Week In-Season Contrast Strength Training Program on Measures of Athletic Performance and Lower-Limb Asymmetry in Male Youth Volleyball Players. *International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 6547*, *19*(11), 6547. https://doi.org/10.3390/IJERPH19116547

Mollemans, A. (2020). Hip range of motion as a risk factor for lower extremity injuries in elite male hockey players: a retrospective and prospective approach (Doctoral dissertation, Ghent University). https://libstore.ugent.be/fulltxt/RUG01/002/836/769/RUG01-002836769_2020_0001_AC.pdf

Moncef, C., Said, M., Olfa, N., & Dagbaji, G. (2012). Influence of Morphological Characteristics on Physical and Physiological Performances of Tunisian Elite Male Handball Players. In *Asian Journal of Sports Medicine* (Vol. 3, Issue 2). https://doi.org/10.5812%2Fasjsm.34700

Moreno-Perez, V., Lopez-Valenciano, A., Ayala, F., Fernandez-Fernandez, J., & Vera-Garcia, F. J. (2019). Comparison of hip extension and rotation ranges of motion in young elite tennis players with and without history of low back pain. *Journal of Back and Musculoskeletal Rehabilitation*, *32*(4), 629–638. https://doi.org/10.3233/BMR-181296

Moreno-Azze, A., Arjol-Serrano, J. L., Falcón-Miguel, D., Bishop, C., & Gonzalo-Skok, O. (2021a). Comparison of Three Eccentric Overload Training Strategies on Power Output and Interlimb Asymmetry in Youth Soccer Players. *International journal of environmental research and public health, 18*(16), 8270. https://doi.org/10.3390/ijerph18168270

Moreno-Azze, A., Arjol-Serrano, J. L., Falcón-Miguel, D., Bishop, C., & Gonzalo-Skok, O. (2021b). Effects of three different combined training interventions on jump, change of direction, power performance, and inter-limb asymmetry in male youth soccer players. *Sports*, *9*(12). https://doi.org/10.3390/sports9120158

Murtaugh, K. (2001). Injury patterns among female field hockey players. *Medicine and Science in Sports and Exercise*, *33*(2), 201–207. https://doi.org/10.1097/00005768-200102000-00005

Murtaugh, K. (2009). Field hockey injuries. In *Curr. Sport Med. Rep* (Vol. 8, Issue 5). http://journals.lww.com/acsm-csmr

Nazarian, A. B., Khayambashi, K. H. , & Rahnama, N. (2010). Dominant and Non-Dominant Leg Bone Mineral Density in Professional Soccer Players and Non-Athlete Subjects. *World Journal of Sport Sciences*, *3*(1), 28–32. https://www.idosi.org/wjss/3(1)10/5.pdf

Ng, L., Sherry, D., Loh, W. B., Sjurseth, A. M., Iyengar, S., Wild, C., & Rosalie, S. (2016). The prevalence and severity of injuries in field hockey drag flickers: A retrospective cross-sectional study. *Journal of Sports Sciences*, *34*(18), 1746–1751. https://doi.org/10.1080/02640414.2015.1136072

Noblett, H., Hudson, S., Killey, J., & Fish, M. (2023). The Physical and Physiological Match-Play Locomotor Activity Profiles of Elite Domestic Male Field Hockey. *Journal of Sports Science and Medicine*, *22*(2), 273–280. https://doi.org/10.52082/jssm.2023.273

Oda, S., & Moritani, T. (1995). Cross-correlation of bilateral differences in fatigue during sustained maximal voluntary contraction. *European Journal of Applied Physiology and Occupational Physiology*, *70*(4), 305–310. https://doi.org/10.1007/BF00865027/METRICS

Ogurkowska, M. B., & Kawałek, K. (2017). Evaluation of functional and structural changes affecting the lumbar spine in professional field hockey players. *Acta of Bioengineering and Biomechanics*, *19*(2), 51–58. https://doi.org/10.5277/ABB-00654-2016-02

Ogurkowska M, & Kawałek K. (2016). Pathological changes in the lumbar intervertebral discs among professional field hockey players. *J. Sports Med. Phys. Fitness*, *56*(1–2), 85–91. https://pubmed.ncbi.nlm.nih.gov/25389638/

Pappas, E., & Carpes, F. P. (2012). Lower extremity kinematic asymmetry in male and female athletes performing jump-landing tasks. *Journal of Science and Medicine in Sport*, *15*(1), 87–92. https://doi.org/10.1016/j.jsams.2011.07.008

Pardos-Mainer, E., Casajús, J. A., Bishop, C., & Gonzalo-Skok, O. (2020). Effects of combined strength and power training on physical performance and interlimb asymmetries in adolescent female soccer players. *International Journal of Sports Physiology and Performance*, *15*(8), 1147–1155. https://doi.org/10.1123/IJSPP.2019-0265

Pardos-Mainer, E., Casajús, J. A., & Gonzalo-Skok, O. (2019). Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries. *Biology of Sport*, *36*(3), 199–207. https://doi.org/10.5114/biolsport.2019.85453

Peters, M. (1988). Footedness: Asymmetries in Foot Preference and Skill and Neuropsychological Assessment of Foot Movement. *Psychological Bulletin*, *103*(2), 179–192. https://doi.org/10.1037/0033-2909.103.2.179

Philipp, N. M., Crawford, D. A., Garver, M. J., & Strohmeyer, H. S. (n.d.). *Evaluating Novel Methods of Classifying Interlimb Asymmetries Within Collegiate American Football Players*. http://www.intjexersci.com

Powell J. (2009). *Hockey. Skills, Techniques, Tactics*. Wiltshire Crowood Press Ltd.

Rajabi, R., Mobarakabadi, L., Alizadhen, H., & Hendrick, P. (2012). Thoracic kyphosis comparisons in adolescent female competitive field hockey players and untrained controls. *The Journal of sports medicine and physical fitness, 52*(5), S. 545-550, PMID: 22976742 https://pubmed.ncbi.nlm.nih.gov/22976742/

Rauter, S., Vodicar, J., & Simenko, J. (2017). Body Asymmetries in Young Male Road Cyclists. *International Journal of Morphology*, *35*(3), 907–912. https://doi.org/10.4067/S0717-95022017000300018

Rees, H., Shrier, I., McCarthy Persson, U., Delahunt, E., Boreham, C., & Blake, C. (2020). Transient injuries are a problem in field hockey: A prospective one-season cohort study. *Translational Sports Medicine*, *3*(2), 119–126. https://doi.org/10.1002/tsm2.126

Reilly, T., & Borrie, A. (1992). Physiology applied to field hockey. *Sports Medicine (Auckland, N.Z.)*, *14*(1), 10–26. https://doi.org/10.2165/00007256-199214010-00002

Reilly, T., & Seaton, A. (1990). Physiological strain unique to field hockey. *The Journal of sports medicine and physical fitness, 30*(2), 142-146.

Ridge, B. R., Broad, E., Kerr, D. A., & Ackland, T. R. (2007). Morphological characteristics of Olympic slalom canoe and kayak paddlers. *European Journal of Sport Science*, *7*(2), 107–113. https://doi.org/10.1080/17461390701478357

Roso-Moliner, A., Lozano, D., Nobari, H., Bishop, C., Carton-Llorente, A., & Mainer-Pardos, E. (2023). Horizontal jump asymmetries are associated with reduced range of motion and vertical jump performance in female soccer players. *BMC Sports Science, Medicine and Rehabilitation*, *15*(1). https://doi.org/10.1186/s13102-023-00697-1

Rules of Hockey including explanations Effective from January 2022. (2023).

Sahrmann, S., Azevedo, D. C., & Dillen, L. Van. (2017). Diagnosis and treatment of movement system impairment syndromes. In *Brazilian Journal of Physical Therapy* (Vol. 21, Issue 6, pp. 391–399). Revista Brasileira de Fisioterapia. https://doi.org/10.1016/j.bjpt.2017.08.001

Sammoud, S., Negra, Y., Bouguezzi, R., Ramirez-Campillo, R., Moran, J., Bishop, C., & Chaabene, H. (2024). Effects of plyometric jump training on measures of physical fitness and lower-limb asymmetries in prepubertal male soccer players: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, *16*(1). https://doi.org/10.1186/S13102-024-00821-9

Sannicandro, I., Cofano, G., Rosa, R. A., & Piccinno, A. (2014). Balance training exercises decrease lower-limb strength asymmetry in young tennis players. *Journal of sports science & medicine*, *13*(2), 397–402, https://pubmed.ncbi.nlm.nih.gov/24790496

Shaw, C. N. (2011). Is "hand preference" coded in the hominin skeleton? An in-vivo study of bilateral morphological variation. *Journal of Human Evolution*, *61*(4), 480–487. https://doi.org/10.1016/j.jhevol.2011.06.004

Smith, C. A., Chimera, N. J., & Warren, M. (2015). Association of Y balance test reach asymmetry and injury in Division I Athletes. *Medicine and Science in Sports and Exercise*, *47*(1), 136–141. https://doi.org/10.1249/MSS.0000000000000380

Sone, T., Imai, Y., Joo, Y. I., Onodera, S., Tomomitsu, T., & Fukunaga, M. (2006). Side-to-side differences in cortical bone mineral density of tibiae in young male athletes. *Bone*, *38*(5), 708–713. https://doi.org/10.1016/j.bone.2005.10.002

Theodorou, E., Tryfonidis, M., Zaras, N., & Hadjicharalambous, M. (2023). Musculoskeletal Asymmetries in Young Soccer Players: 8 Weeks of an Applied Individual Corrective Exercise Intervention Program. *Applied Sciences (Switzerland)*, *13*(11). https://doi.org/10.3390/app13116445

Tsorlakis, N., Koidou, I., Grigoropoulou, M., & Grouios, G. (2022). Limb Preference and Limb Bone Mineral Density: an Overview of Empirical Findings. In *Clinical Reviews in Bone and Mineral Metabolism* (Vol. 20, Issues 1–4, pp. 10–17). Springer. https://doi.org/10.1007/s12018-022-09284-3

Twomey, L. (1988). Spinal Mobility and Trunk Muscle Strength in Elite Hockey Players. *Australian Journal of Physiotherapy*, *34*(3), 123–130. https://doi.org/10.1016/S0004-9514(14)60604-8

Vad, V. B., Bhat, A. L., Basrai, D., Gebeh, A., Aspergren, D. D., & Andrews, J. R. (2004). Low Back Pain in Professional Golfers. *Https://Doi.Org/10.1177/0363546503261729*, *32*(2), 494–497. https://doi.org/10.1177/0363546503261729

Van Dillen, L. R., Bloom, N. J., Gombatto, S. P., & Susco, T. M. (2008). Hip rotation range of motion in people with and without low back pain who participate in rotation-related sports. *Physical Therapy in Sport*, *9*(2), 72–81. https://doi.org/10.1016/j.ptsp.2008.01.002

Van Hilst, J., Hilgersom, N. F. J., Kuilman, M. C., Kuijer, P. P. F. M., & Frings-Dresen, M. H. W. (2015). Low back pain in young elite field hockey players, football players and speed skaters: Prevalence and risk factors. *Journal of Back and Musculoskeletal Rehabilitation*, *28*(1), 67–73. https://doi.org/10.3233/BMR-140491

Van Santen, J. A., Pereira, C., Sanchez-Santos, M. T., Cooper, C., & Arden, N. K. (2019). Dominant vs. non-dominant hip comparison in bone mineral density in young sporting athletes. *Archives of Osteoporosis*, *14*(1). https://doi.org/10.1007/s11657-019-0605-2

Vanderstukken, F., Jansen, N., Mertens, T., & Cools, A. M. (2019). Elite male field hockey players have symmetric isokinetic glenohumeral strength profiles, but show asymmetry in scapular muscle strength. *Journal of Sports Sciences*, *37*(5), 484–491. https://doi.org/10.1080/02640414.2018.1507238

Wdowski, M. M., & Gittoes, M. J. R. (2013). Kinematic adaptations in sprint acceleration performances without and with the constraint of holding a field hockey stick. *Sports Biomechanics*, *12*(2), 143–153. https://doi.org/10.1080/14763141.2012.749507

Wood, M. L., Althorpe, T., Hatch, M., Ness, S. L., Mcphee, R., & Minchinson, S. (2018). A multifactorial appraisal of injury data of upper hamstring and hip injuries in elite field hockey players. *Journal of Science and Medicine in Sport* , 57–98. https://doi.org/10.1016/j.jsams.2018.09.183

Xie, H., Hongsaenyatham, P., & Rittisom, S. (2024). Reducing Limb Asymmetry in Females Collegiate Basketball: A Randomized Trial. *International Journal of Sociologies and Anthropologies Science Reviews*, *4*(1), 417–426. https://doi.org/10.60027/IJSASR.2024.3702

Zeleznik, M., Cuk, I., & Pocrnjic, M. (2023). Morphological Characteristics and Bilateral Differences of Youth U13, U15, U17 and U19 Male Football Players. *International Journal of Morphology*, *41*(1). http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0717-95022023000100257

Zemkova, E., Poor, O., & Jele, M. (2019). Between-side differences in trunk rotational power in athletes trained in asymmetric sports. *Journal of Back and Musculoskeletal Rehabilitation*, *32*(4), 529–537. https://doi.org/10.3233/BMR-181131

Zhao, W., Wang, C., Bi, Y., & Chen, L. (2021). Effect of Integrative Neuromuscular Training for Injury Prevention and Sports Performance of Female Badminton Players. *BioMed Research International*, *2021*. https://doi.org/10.1155/2021/5555853

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