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Original Article

Comprehensive scientific examination of leg length discrepancy in junior badminton players

KUMAR P[1], RAM MOHAN SINGH R[2], AJITHKUMAR L[3], KASTHURI THILAGAM P[4], TIROUMOUROUGANE K[5]
[1,3] Department of Physical Education and Sports, Central University of Haryana, Mahendergarh, Haryana, INDIA
[2,5] Department of Physical Education and Sports, Pondicherry University, Kalapet, Pondicherry, INDIA
[4] Physical Education Teacher, Government Higher Secondary School, Valanadu, Tiruchirappalli, Tamil Nadu, INDIA

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Abstract
The objective of this research was to conduct a comprehensive analysis of Leg Length Discrepancy (LLD) among in young badminton players with the aim of mitigating back discomfort and reducing injuries in their current training environments. Numerous studies have established a connection between LLD and various musculoskeletal issues in different sports, causing asymmetrical gait and low back pain. Consequently, many players find their daily routines disrupted, leading to burnout or dropout from the sport. To assess the current situation, this study focused on 1502 young badminton players aged 9–12 from the states of Tamil Nadu and Puducherry. LLD can be challenging to diagnose and treat, especially in growing children, and various methods and equipment are available for assessment. In this research, the "Delta Leg" (DL) measuring tool was employed, measuring discrepancies from millimeters to centimeters. The 0–10 Numeric Pain Rating Scale was used to determine the level of pain. The analysis involved the application of percentage techniques ($P = n \times 100 / N$) and Pearson correlation. The results indicated that 218 (15%) of the players had equal-length lower limbs, while 1284 (85%) exhibited LLD in varying degrees. Among the LLD players, 354 (24%) had discrepancies greater than 1 cm, 753 (50%) had discrepancies less than 1–2 cm, 171 (11%) had discrepancies less than 2–3 cm, and 6 (0.40%) had discrepancies less than 3 cm. LLD was notably prevalent among young badminton players aged 9 to 12, warranting careful attention. Even mild LLD should not be overlooked, emphasizing the importance of coaches, physiotherapists, physical education instructors, and doctors in closely monitoring players' leg mechanics. Immediate corrective actions are essential, and continuous monitoring is imperative, because LLD may necessitate intervention before reaching skeletal maturity. The use of insoles is recommended to alleviate muscular and/or joint problems and gait issues in players. Additionally, some players with equal leg lengths exhibited pronation and supination in their ankles, suggesting the need for future research to explore other lower limb issues experienced by badminton players.
Keywords: Badminton Players, Musculoskeletal Disorder, Leg Length Discrepancy, Injuries, Delta Leg.

Introduction

LLD also known as lower limb length discrepancy, leg-length inequality, or gait asymmetry (Bt & Saaid, 2017) or anisomelia, is a condition in which the lengths of the right and left legs differ. LLD can be divided into two categories: structural LLD, which can be directly evaluated in the lower limb bones, and functional LLD brought on by postural problems. (Wang et al., 2020; Zabri et al., 2018). Generally, LLD appears in childhood and causes damage to the growth plate (Stanitski, 1999). Studies by the following authors show that for every 1 in 1000 people (20mm LLD) (Bangerter et al., 2019), 3-15% (Raczkowski et al., 2010), 40% to 70% (Azizan et al., 2018), 60% to 90% of the population (Othman et al., 2018) is exposed to LLD.

This may result due to congenital defects such as hemihypertrophy, childhood illness, post-traumatic, hemihypertrophy (one side too big) bone tumors, lumbar degenerative joint disease (DJD) (Murray et al., 2017), hemi atrophy (one side too small), neurologic condition, fractures or previous injury and inappropriate maintenance. Even bad habits may result in unfavorable weight distribution on the legs. A significant factor could also be unsuitable footwear. LLD leads to changes in spinopelvic alignment, hip osteoarthritis (Ashour et al., 2019) increased stance time on the longer leg, balance, abnormal body posture, the magnitude of mechanical stress, persistent low back pain (Brady et al., 2003) functional scoliosis distracting gait (Gurney, 2002; Assogba et al., 2018; Aiona et al., 2015) discopathy, second peak ground reaction force, difficulty in walking, stress fracture distraction of everyday routine (Salamuddn, N et.al., (2014).

Classification of LLD

Corresponding Author: KUMAR P, E-mail: kumarp@cuh.ac.in

LLD is divided into three categories mild, moderate, and severe based on the severity of the discrepancy Mild greater than 3 cm, moderate 3-6 cm, and severe less than 6 cm (Zabri et al., 2018), mild greater than 30 mm, moderate 30-60 mm, and severe greater than 60 mm, for less than20mm itself leads to pelvic posture is changed (Ashour et al., 2019), less than 1 cm experienced lower extremity injuries, 2 cm level of the true subject (Othman et al., 2018; Pereiro-Buceta et al., 2021; Akodu & Oluwatomisin Adeoye Akindele, 2020) and biomechanical gait change (Dombroski, 2011) called a disorder (Raczkowski et al., 2010), decreased second peak ground reaction force by 3 cm (Bt & Saaid, 2017; Azizan et al., 2018).

Measurement of LLD

LLD is difficult to diagnose and treat, especially in developing children (Stanitski, 1999); however, LLD can be measured using a variety of techniques, including direct methods like tape measures (Gogia & Braatz, 1986) and indirect ones like pelvic leveling assessments and radiographic method (Brady et al., 2003; Orthopaedics et al., 2017) is the gold standard for measuring LLD (Oliveira & Moreira, 1989) Sometimes, subcutaneous fat deposition on top of the iliac crests' lateral surfaces might lead to measurement errors in radiograph methods (Gross et al., 1998). Other measurement techniques are raster stereography, biplanar CT or MRI scanograms (Ashour et al., 2019), orthoroentgenography, roentgen measurement, laser method (Oosterveld et al., 2007), computed axial tomography, comparison of ultrasound, iliac crest palpation meter, microdose digital radiographs, teleradiography, X-ray, electronic balance (Raczkowski et al., 2010), calliet method, deltaleg method raster stereography among all the clinical methods, the indirect way of evaluating LLD is the most accurate (Oliveira & Moreira, 1989). For assessing playing-related musculoskeletal disorder VISA-A questionnaire (Lee & Yoo, 2012), the nordic musculoskeletal questionnaire, (A. et al., 2022; Munir et al., 2022; Nazir, 2022) are widely accepted (Handaru et al., 2020).

Delta Leg method

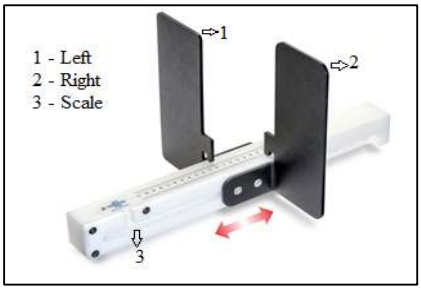
As per the (Oosterveld et al., 2007) study methods LLD was measured through the delta leg. Figure 1 shows a non-invasive manual tool called a Delta Leg which is used to measure lower limb heterometric without any load bearing. It is made up of a bar with two orthogonal footboards; one of them is stationary while the other moves along the bar's longitudinal axis and has a pointer on its upper surface that displays the aetherometry's positive or negative numerical value on a millimetre scale. In relation to the fixed footboard, the value "zero" is set. With a margin of error of only a few millimetres, the instrument's precision structure, the mobile footboard's fine sliding system, and the millimetric scale enable quick and accurate assessment of the variations in lower limb length. A manual for the device is included. Badminton is one of the fastest racket sports in the world (Shariff et al., 2009). It is governed by the Badminton World Federation (BWF), which is also recognized by the International Olympic Committee. The federation's mission is to promote badminton internationally, for this purpose, the federation offers Sports "Science Research Grants" every year. Although badminton is a non-contact sport, it still requires agility (Lee & Yoo, 2012; Hung et al., 2020) strength, speed, coordination, flexibility, power, reaction time, endurance, balance, and other skills for competitive play. Badminton involves a lot of agility-related movements and quick forward lunges throughout game. The tendons in the dominant leg are put under a lot of strain and this might lead to injury of the weight-bearing joints (Lee & Yoo, 2012). As a result of inappropriate play, players may experience a variety of musculoskeletal issues (Iolascon et al., 2022).

The common injuries for badminton players include Achilles tendon rupture (Shariff et al., 2009; Larsson et al., 2022), ankle sprain, strain, (Lee & Yoo, 2012) collateral ligament injuries, patellar tendonitis (Handaru et al., 2020), thrower's shoulder, medial tibial stress syndrome, rotator cuff injury, plantar fasciitis, tennis elbow, back pain, as well as other conditions such as infra and supra lateral malleolar curvature, calcaneal injury, Talar head fracture (Guide, 2005). All these injuries occur due to overloaded, overuse on the weight-bearing joints and stiffer landing (Hung et al., 2020),. When compared to competitions, 86.6% of players had injuries during training or practice sessions.

Lower limb injuries (63.1%) are more common than other types of injuries (Shariff et al., 2009; Handaru et al., 2020). One of the major conditions in lower limb is called Leg length discrepancy (LLD) (Gross et al., 1998) and is the third-most frequent reason for running injuries (Othman et al., 2018) and another condition called meralgia paresthetica is a condition that produces dysthesia and discomfort in the lateral thigh during hip hyperextension, wearing tight clothing, and when abdominal distension are present. To our knowledge, this has never been explained by a variation in LLD (Goel, 1999).

Material and Methods

Participants of the Study



The study's participants were Young Badminton Players (YBP) from the states of Puducherry and Tamil Nadu. With the aid of a purposeful random sample technique, 1502 YBP were chosen from various badminton tournament venues and academies. Their ages ranged between 9 to 12 years. A non-invasive manual tool called the Delta Leg (DL) was used to assess the LLD when the subject is supine and not bearing any weight. Figure 1 depicts the Delta Leg Tool. Their level of pain was determined using the 0-10 Numeric Pain Rating Scale. For statistical analysis, descriptive statistics and the percentage technique (P = n × 100 / N) were applied. Figure 2 denotes the overall measurement of LLD.

Figure 2. Overall measurement of LLD. (A) Reference image for assessment of LLD, (B, H) Assessment of LLD through Delta Leg, (C & D) The lower leg's length is equal but the leg was supinated/pronated, (E-G) Manual assessment of LLD.

After permission from the computation authority, the purpose of the study was explained to the subjects and the application of standard protocols was followed, especially when obtaining their consent.

Figure. 1. Delta Leg Tool

Procedure

Prior to the placement of the Delta Leg between the participants' legs in a horizontal plane, they were told to sit supinely. After that, one of their legs was fixed in an orthogonal position, and the other was free to move parallel to the tool's longitudinal axis while carrying a pointer that displayed positive or negative readings on the tool's surface in millimeters. The number "zero" denotes the fixed center of the footboard. A difference in the boards' positions was considered abnormal unless both transverse footboards were stationary at "zero" values.

Measurements of LLD were taken, and the outcomes were compared to the various standard norms that the various authors gave. The LLD is broken into three categories based on value categories - mild, moderate, and severe. The researcher asked every subject about their pain level with help of 0-10 Numeric Pain Rating Scale in Figure 3.

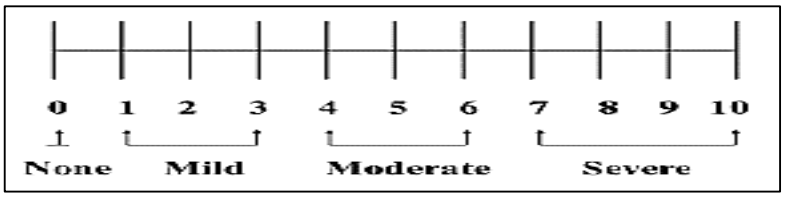


Figure 3. 0-10 Numeric Pain Rating Scale.

Results

The results were obtained based delta leg measurements. According to the stages, the number players with a shorter right leg were 1078 (72%), a shorter left leg were 206 (14%) and the remaining 218 (15%) were normal. The total number of students with and without LLD was displayed in Table 1, Figure 4 indicates LLD Measurements of the selected players. Figure 5 depicts the subjects Normal and Up-normal Leg length, Table 2. Represents the Pain Scale data of the subjects.

Table 1. Percentile for the various categories of LLD measurement results of the badminton players.

LLD	Right Leg short	Left Leg short	Players	Percentages
Normal	218	0	218	14.51%
Less than 1 cm	245	109	354	23.57%
1-2 cm	675	78	753	50.13%
2-3 cm	152	19	171	11.38%
greater than 3 cm	6	0	6	0.40%
Total	1296	206	1502	
Percentage	86%	14%		

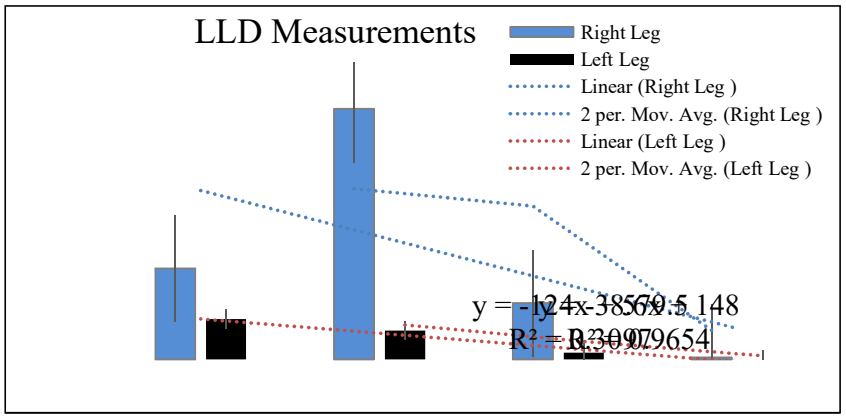


Figure. 4. Based on the deviation, the badminton players' right-leg and left-leg LLD measurement data are shown on a bar plot. The linear line demonstrates how it was calculated for better understanding.

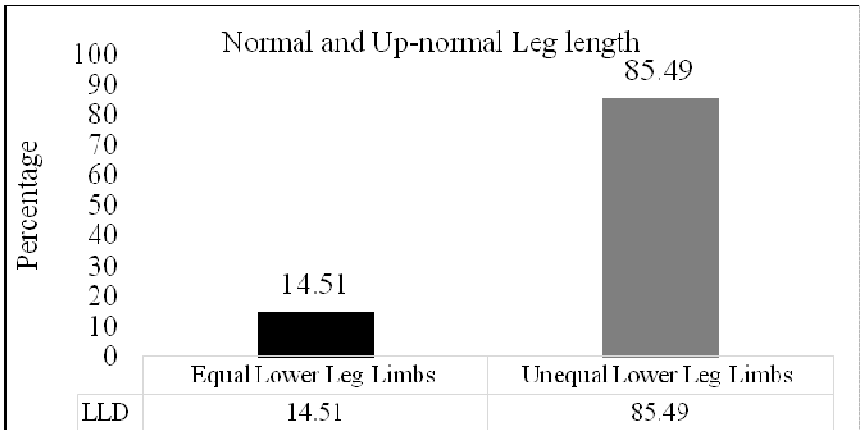


Figure. 5. The bar plot displays the mean difference in the lower limbs comparing participants with normal leg length and LLD. The linear line displays how it has deviated.

Table 2. Data for Pain Scale

Level of LLD	0 - 10 Numeric Pain Rating Scale											
	0	1	2	3	4	5	6	7	8	9	10	
	None	Mild			Moderate				Severe			
Normal	196	13	4	2	2	1	0	0	0	0	0	218
Less than 1 cm	20	148	110	56	5	7	5	2	1	0	0	354
1-2 cm	13	86	79	15	218	269	36	29	5	1	2	753
2-3 cm	0	5	13	28	0	8	7	45	25	29	11	171
Greater than 3 cm	0	0	0	1	0	1	0	0	1	0	3	6
Total	229	252	206	102	225	286	48	76	32	30	16	1502

Afterwards gathering data on junior badminton players' pain levels, the survey had 1502 players in all. According to the questionnaire, 1273 participants reported having pain, while the other 229 players had no pain. In a total of 1273 (85%) of the players, 560 (37.29%) players were suffering mild level pain, 559 (37.21%) players were suffering moderate level pain, the 154 (10.25%) players were suffering severe level pain. Figure 6 indicates level of LLD. Table 3 shows the correlation between LLD and pain level and Figure 7 is a Graphical Representation of the Correlation between 0-10 pain level and LLD.

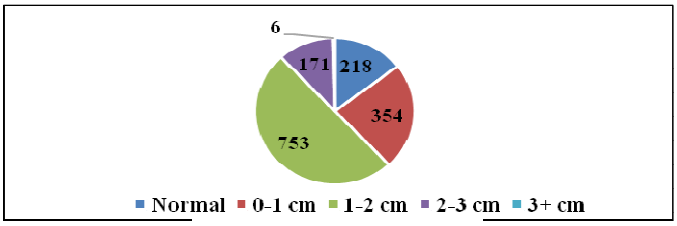
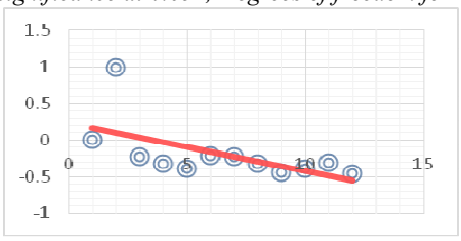


Figure. 6. Level of LLD

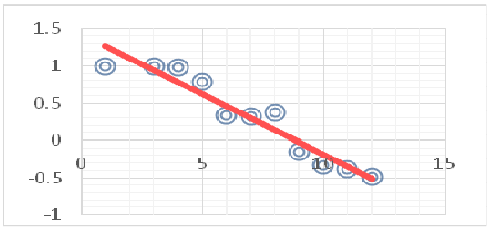
Table 3. Pearson Correlation between Leg Length Discrepancy Level

	Normal	Less than 1cm	1-2cm	2-3cm	Greater than 3cm
Normal	1	.953*	.577*	.245*	.532*
Less than 1cm	.953*	1	.926*	.530*	.423*
1-2 CM	.577*	.926*	1	.163*	.693*
2-3cm	.245*	.530*	.163*	1	.987*
Greater than 3cm	.532*	.423*	.693*	.987*	1

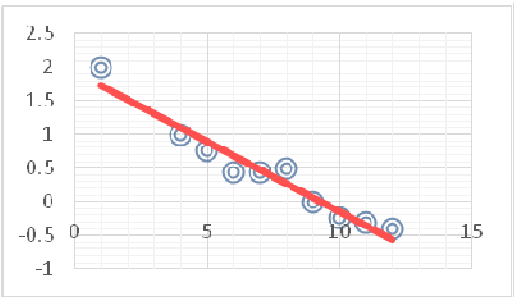
Level of Significance at 0.05, Degrees of freedom for 1501=0.043.*



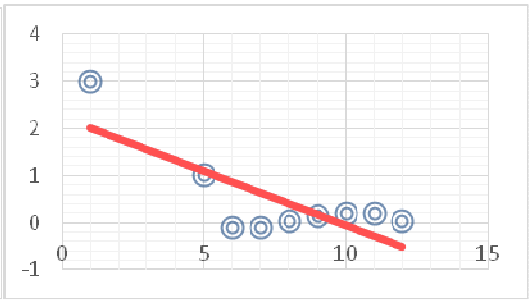
Correlation between 0-1



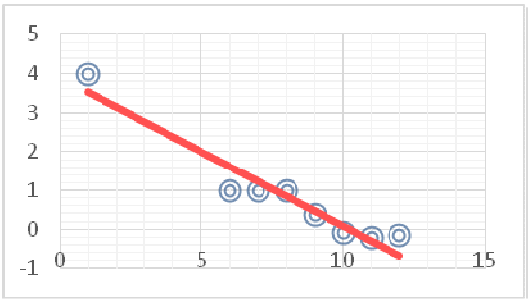
Correlation between 0-2



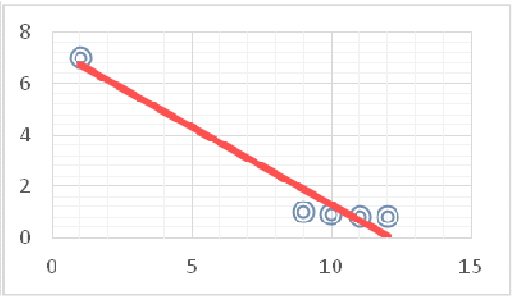
Correlation between 0-3



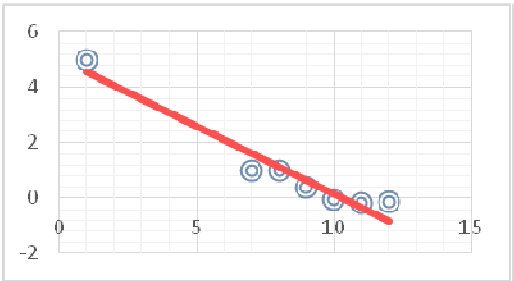
Correlation between 0-4



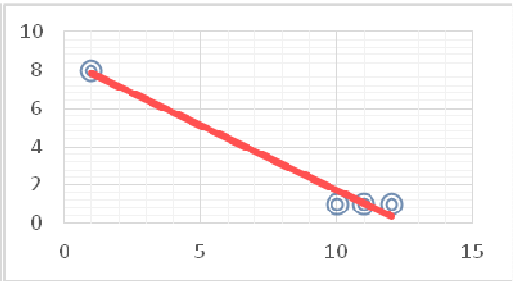
Correlation between 0-5



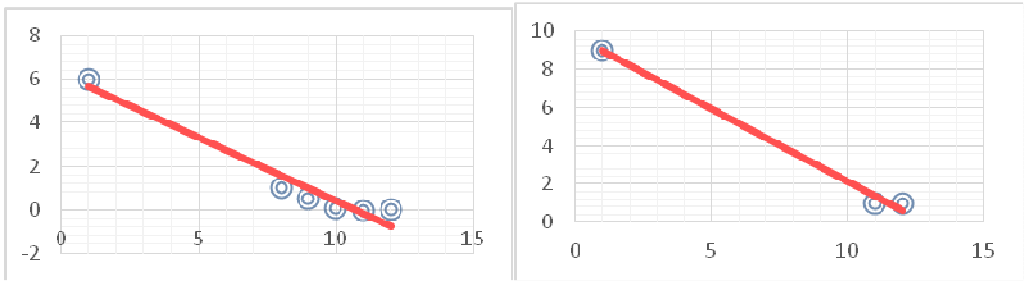
Correlation between 0-8



Correlation between 0-6



Correlation between 0-9



Correlation between 0-7 Correlation between 0-10

Figure 7. Correlation between 0-10 pain level

Discussion

Numerous studies reveal that an LLD link to various musculoskeletal issues in various sports ((Iolascon et al., 2022; Othman et al., 2018; Zabri et al., 2018; Bangerter et al., 2019; Raczkowski et al., 2010; Brady et al., 2003; Gurney, 2002; Akodu & Oluwatomisin Adeoye Akindele, 2020) and its distracting gait symmetric (Bt & Saaid, 2017; Assogba et al., 2018). For this reason, many players are distracted by everyday routines, and some players drop out/burn out of their game. This study assessed 1502 young badminton players from the Tamilnadu and Puducherry regions, because younger children (under 9 years) had a higher risk of LLD and the problem should be treated before skeletal maturity (Flinck et al., n.d.). Numerous problems are brought on by LLD, including reducing our autonomy (Assogba et al., 2018), stress fractures, limb/back discomfort, pelvic tilt, knee arthritis, and others (Wang et al., 2020). Correcting LLD is a difficult task (Othman et al., 2018). The treatment for LLD varies based on its severity. Even though LLD is lower than 20mm, one cannot ignore (Pereiro-Buceta et al., 2021) other ways it may enhance the level of severity. Internal shoe lifts of 0.5 to 1.5 cm, external heel lifts of 1.5 to 2 cm, and surgical equalization ranging from 3 to 20 cm are advised for LLD (Brady et al., 2003). More than 20 cm external prostheses should use. Utilizing orthotic shoe lifts (Bangerter et al., 2019; Akodu & Oluwatomisin Adeoye Akindele, 2020) in the shorter lower limb, (Ashour et al., 2019) is the most popular, safe, and inexpensive (Friberg, 1983; Defrin et al., 2005) therapeutic remedy for LLD in mild (10mm) cases and it reduces chronic low back pain (Defrin et al., 2005) and symmetrical movement (Bandy & Sinning, 1986). If the market insole is not suitable then you have to customize the custom-molded orthotics, cast, or walker brace (Larsson et al., 2022). This is more suitable for running injuries (Mündermann et al., 2003). The alternative corrective techniques include external fixation with a motorized intramedullary nail system (Krieg et al., 2008), Ilizarov limb lengthening in short femoral bone (Moraal et al., 2009), and epiphysiodesis, which refers to temporary or permanent femoral bone growth arrest (Stanitski, 1999). The treatment for joint sprains is Kinesio taping (Lee & Yoo, 2012), immobilization of the damaged ankle, and a cast or walker brace may be used as part of non-surgical treatment. (Larsson et al., 2022)

Table 1. Summarizing results showed that among the 1502 players, 218 (14.51%) of players had equal-length lower limbs, which is in line with similar research that reported 10% of individuals among 573 participants had equal-length lower limbs (Pereiro-Buceta et al., 2021). 1284 of them (85%) had LLD of more than one millimeter; a related study found that 75% of participants had LLD (Akodu & Oluwatomisin Adeoye Akindele, 2020) while other studies show that 1 in 1000 persons had LLD. (Azizan et al., 2018) . Out of 1284 (85%) LLD players (Figure 3), 354 (24%) had a greater than 1 cm difference. Even mild variations in the lower leg influence the vertical ground reaction force and change the gait variables (Dombroski, 2011). 753 (50%) had less than1-2 cm difference in their lower leg and a similar study concluded that more than 2 cm changes the biomechanical gait (Azizan et al., 2018), and sometimes it's called a disorder (Raczkowski et al., 2010). 171 (11%) had less than 2-3 cm, and 6 (0.40%) were less than 3 cm respectively as shows (Figure 2). As per the 0–10, Pain Scale questionnaire assessment 77% of the players experienced more physical discomfort in their lower extremities and felt pain in their spine during practice as well as match in situations.

The findings of this research also evidenced that even though equal-length lower limbs were found by many players 218 (14.51%) among some players ankles were pronated or supinated, and their legs were found to have mild knock-knee and bow legs. According to the "use and disuse" concept, most of the right-hand players often placed more weight on their right leg when launching and extra movement while placing less weight on their left leg. As a result, certain players' right legs are more often shorter, similar to other studies (Akodu & Oluwatomisin Adeoye Akindele, 2020; Oliveira & Moreira, 1989). Incorrect gait factors may be avoided by wearing appropriate footwear (Akodu & Oluwatomisin Adeoye Akindele, 2020) and lifting the insole/shoe (Wang et al., 2020; Bangerter et al., 2019; Akodu & Oluwatomisin Adeoye Akindele, 2020). Proper agility training will minimize musculoskeletal injury (Handaru et al., 2020). There are a few players who might not aware of such minor issues and never had the opportunity to rectify them. Therefore, the best treatment is to catch them early. The results of this study helped increase awareness of LLD and its implications on a player's performance. Avoiding acute injuries and reducing chronic ones, particularly to the lower extremities and spine, are the immediate effects of this study. This paper will also help the YBP to achieve its goal without any

physical discomfort. Future research should focus more on the badminton players lower limbs and concentrate on constricting the specific insole/shoe (Ashour et al., 2019) for specific sports following the particular LLD level so that the lower limbs can adapt and further injury can be prevented (Kim et al., 2016).

Conclusions

The conclusion of the study highlights several important findings and recommendations based on the research conducted on young badminton players and their prevalence of leg length discrepancies (LLD). These findings can be elaborated as follows: Prevalence of LLD: The study reveals that LLD is relatively common among young badminton players. This is a significant finding as it underscores the need to pay close attention to this issue within the sport. Musculoskeletal Injuries: The presence of LLD has been linked to a range of musculoskeletal injuries, particularly causing discomfort in the lower back. This highlights the potential serious consequences of untreated or undiagnosed LLD. Impact on Posture and Gait: LLD not only contributes to physical discomfort but also affects a player's posture alignment and gait symmetry. This can have a detrimental impact on their performance and overall physical health. Benefit of Insoles: The study demonstrates that the use of insoles can be an effective intervention for players with LLD. These insoles alleviate muscular and joint problems and lead to an improvement in gait.

This suggests a practical solution for addressing LLD in young badminton players. Importance of Early Intervention: The conclusion emphasizes that even mild LLD should not be ignored. It stresses the importance of vigilance from various stakeholders, including coaches, physiotherapists, physical education instructors, and doctors, in monitoring and addressing players' leg mechanics from an early stage. Timely Corrective Actions: The researchers suggest that corrective actions should be taken without delay. This means that when LLD is identified, appropriate measures should be put in place promptly to prevent the worsening of the condition and the associated musculoskeletal issues. Therapy before Skeletal Maturity: It's noted that some cases of LLD may require therapy even before the players reach skeletal maturity. This underscores the importance of early intervention in the development of young athletes. Additional Lower Limb Issues: The conclusion also raises the question of other lower limb issues, such as pronation and supination of the ankles, which may affect badminton players. It calls for further research to explore these issues and to find effective solutions, in addition to addressing LLD in young badminton players. It highlights the potential for insoles as a solution and suggests that a comprehensive approach, involving various stakeholders and timely interventions, can help young athletes maintain better physical health and enhance their performance. Additionally, it encourages ongoing research to explore other lower limb issues that may affect players and find suitable solutions for them.

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Conflicts of Interest

The author(s) declared there is no conflicts of interest.

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