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LOWER LIMB ASYMMETRY IN INDIVIDUALS WITH ACHONDROPLASIA DURING LUNGES: A BIOMECHANICAL ANALYSIS

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ABSTRACT
Background: Lower limb asymmetry affects movement efficiency, stability, and injury risk, particularly in individuals with achondroplasia. Despite its relevance, research on functional asymmetry during dynamic movements in this population remains limited. **Objective:** This study aimed to analyze asymmetry in impact force, contact time, and force impulse during lunges in individuals with achondroplasia. **Methods:** 15 people (12 men and 3 women) participated in the National Paralympic Championship at Tamil Nadu Physical Education and Sports University in Chennai, where data was gathered. A Kistler force plate (Model 9287CA) was used for lunges, and asymmetry indices were calculated. Pearson correlation analysis and a paired t-test were used. **Findings:** Contact time ($p = 0.004$) and force impulse ($p = 0.009$) showed substantial asymmetry, whereas impact force ($p=0.544$) showed no significant asymmetry. Contact time and force impulse asymmetry were shown to be strongly correlated ($r = 0.835$, $p < 0.001$). **Denouement:** Results underscore compensatory neuromuscular adaptations in individuals with achondroplasia and suggest the need for targeted training interventions. Future research should explore training adaptations aimed at reducing asymmetry.
Keywords: impact force, contact time, force impulse, neuromuscular adaptations, dynamic movement, asymmetry indices, training interventions.

INTRODUCTION
Postural stability and functional symmetry are critical components of movement efficiency, injury prevention, and athletic performance (Winter, 2022). Lower limb asymmetry, defined as differences in strength, force production, or movement patterns between the left and right legs, has been linked to reduced stability, increased injury risk, and suboptimal sports performance (Zifchock et al., 2006; Bishop et al., 2018). The lunge, a unilateral lower limb movement, is frequently used in clinical and sports settings to assess dynamic balance, neuromuscular coordination, and strength asymmetry (Gulgin et al., 2014). While asymmetry in movement patterns has been widely studied in athletic and general populations, limited research exists on how individuals with achondroplasia exhibit and compensate for such imbalances.

Achondroplasia, the most communal form of skeletal dysplasia, is categorized by disproportionate short stature, altered limb proportions, joint laxity, and compromised biomechanical alignment (Paulis et al., 2023). These anatomical differences can significantly affect lower limb kinematics, postural stability, and force distribution during dynamic movements (Rosenbaum et al., 2021). Given that individuals with achondroplasia often participate in adaptive sports and physical activities, understanding their movement asymmetries is crucial for designing targeted rehabilitation and training programs (Reeves et al., 2018). However, research on asymmetry in individuals with achondroplasia is scarce, with most existing studies focusing on balance control in static conditions rather than functional movement asymmetry (Hägglund et al., 2020).

To address this gap, the present study investigates lower limb asymmetry in individuals with achondroplasia during lunges, using kinematic and kinetic parameters such as impact force, contact time, and force impulse.

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By analyzing bilateral differences in these variables, this research aims to provide insights into functional imbalances and their potential implications for performance, injury prevention, and training interventions. It is hypothesized that individuals with achondroplasia will exhibit significant asymmetry in force production and contact time, reflecting altered neuromuscular control and load distribution during lunges. These findings will contribute to the limited but growing body of literature on functional biomechanics in populations with skeletal dysplasia and inform evidence-based strength and conditioning strategies tailored for this group.

METHODOLOGY

This study included 15 individuals (12 males, 3 females) with achondroplasia, all of whom were actively engaged in adaptive sports. Participants were recruited during the National Paralympic Championship held at Tamil Nadu Physical Education and Sports University, Chennai, Tamil Nadu. Informed consent was obtained from all participants, and the study adhered to ethical guidelines for research involving human subjects.

To assess lower limb asymmetry, participants performed forward lunges on a Kistler force plate (Model 9287CA, dimensions 1200×600×100 mm), a gold-standard instrument for biomechanical force analysis. The force plate recorded kinetic parameters such as relative impact force (%BW), contact time (s), and total force impulse (%BWs) for both the left and right legs. Using MARS software for accurate measurement and analysis, data was gathered at the Centre of Excellence in Sports Biomechanics and Kinesiology Laboratory, Tamil Nadu Physical Education and Sports University, Tamil Nadu.

Each participant completed three trials of forward lunges per leg in a controlled laboratory environment. Participants were instructed to lunge barefoot, keeping their upper extremities free, and to maintain an upright posture throughout the movement. Trials were conducted in a randomized order to minimize fatigue effects. A 30-second rest interval was provided between trials to prevent muscular fatigue from influencing performance.

The collected data were processed to compute asymmetry indices for impact force, contact time, and force impulse using the formula:

“Asymmetry Index\=((L+R)/2|L−R|)×100”

where L and R stand for the values of the left and right legs, respectively. The performance of the left and right legs was compared using a paired t-test, with $p < 0.05$ being considered statistically significant. Additionally, correlation analysis was conducted to examine relationships between the asymmetry indices.

RESULTS

Lower Limb Asymmetry in Lunge Performance

The analysis revealed variations in lower limb asymmetry among participants, particularly in contact time and force impulse, while impact force showed minimal differences.

Each variable's mean, standard deviation, and asymmetry index (%) are shown in Table 1. Furthermore, whereas impact force (p=0.544) did not substantially differ between the left and right legs, the paired t-test findings show significant differences in contact duration (p=0.004) and force impulse (p=0.009).

Table1: Descriptive Statistics, Asymmetry Index, and Paired t-Test Results

Variable	Left Leg (Mean ± SD)	Right Leg (Mean ± SD)	Asymmetry Index (%)	t-value	p-value
Impact Force (%BW)	106.96 ± 20.05	109.54 ± 12.95	14.76	-0.621	0.544(NS)

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Contact Time (s)	2.36 ± 0.39	1.93 ± 0.62	22.27	3.488	**0.004**
Force Impulse (%BWs)	399.48 ± 96.83	313.84 ± 175.56	35.41	3.053	**0.009**

($p < 0.05$ = statistically significant; NS = Not Significant)

Correlation Between Asymmetry Indices

To evaluate the connections between the asymmetry indices, a correlation analysis was performed. Contact time and force impulse asymmetry were shown to be strongly positively correlated ($r = 0.835$, $p < 0.001$), indicating that people with higher contact time asymmetry also had higher force impulse asymmetry.

Table 2 summarizes the correlation coefficients and significance levels between asymmetry indices.

Table 2: Correlation Between Asymmetry Indices

Variable	**Asymmetry Force**	**Asymmetry ContactTime**	**Asymmetry Impulse**
Asymmetry Force	1	0.600*	0.652**
Asymmetry ContactTime	0.600*	1	0.835***
Asymmetry Impulse	0.652**	0.835***	1

(*p<0.05=significant, **p<0.01=highly significant, ***p<0.001=very highly significant)

- Impact Force asymmetry (14.76%) was not statistically significant ($p = 0.544$).
- Contact Time asymmetry (22.27%) was significantly different between the legs ($p = 0.004$). Force Impulse asymmetry (35.41%) was significantly different ($p = 0.009$).
- Higher Contact Time asymmetry correlated strongly with Force Impulse asymmetry ($r=0.835$, $p<0.001$).

DISCUSSION

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The current investigation analyzed lower limb asymmetry in individuals with achondroplasia during lunges, focusing on impact force, contact time, and force impulse. The findings revealed significant asymmetries in contact time and force impulse, while impact force remained relatively balanced between the limbs.

The significant asymmetry observed in contact time ($p = 0.004$) and force impulse ($p = 0.009$) suggests that individuals with achondroplasia rely more on one limb for stability and propulsion during lunges. This aligns with previous findings that individuals with altered limb proportions often exhibit asymmetric weight distribution and neuromuscular adaptations (Reeves et al., 2018). Strong relationship ($r=0.835$, $p<0.001$) among contact time and force impulse asymmetry further indicates that prolonged ground contact on one limb contributes to uneven force production, potentially increasing injury risk and movement inefficiency (Paillard, 2019).

Despite significant differences in contact time and force impulse, impact force asymmetry (14.76%) wasn't statistically significant ($p=0.544$). This implies that while both limbs produce comparable peak forces, differences in propulsion and force absorption add to the overall asymmetry in movement execution (Goble & Baweja, 2018). Studies on athletes with skeletal dysplasia have reported compensatory neuromuscular strategies to maintain stability despite anatomical differences (Rosenbaum et al., 2021).

The findings highlight the need for targeted strength and neuromuscular training to reduce asymmetry and enhance movement efficiency in individuals with achondroplasia. Unilateral strength training, proprioceptive drills, and balance exercises may help mitigate these imbalances (Zifchock et al., 2006). Additionally, force plate assessments should be integrated into rehabilitation and performance programs to monitor asymmetry progression and its impact on functional movement (Winter, 2022).

Practical Training Recommendations

Unilateral Strength Training: Single-leg squats, Bulgarian split squats, and eccentric training to correct imbalances.

Proprioceptive and Balance Training: Single-leg stance drills, perturbation training, and blindfolded balance exercises.

Plyometric Training: Alternating single-leg jumps and lateral hops to improve force application.

Biomechanical Monitoring: Force plate assessments and video-based movement analysis to track asymmetry progression.

CONCLUSION

This study offers fresh perspectives on the asymmetry of the lower limbs in achondroplasia individuals. emphasizing imbalances in contact time and force impulse during lunges. The results suggest that compensatory adaptations are necessary to maintain stability, which has direct implications for injury prevention and training. Future research should explore longitudinal training effects on asymmetry reduction and assess kinematic differences using motion capture systems.

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