

Effects of Surgical and Non-Surgical Hamstring Lengthening on Hip and Knee Parameters in Children with Cerebral Palsy

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ABSTRACT

Introduction: This study aims to investigate changes in femoral head anteversion, popliteal angle, and the effect of internal hamstring lengthening on hip rotation in children with CP undergoing surgical and non-surgical interventions.

Methods: This retrospective cross-sectional study included 30 children aged 5-12 years with CP and knee contracture. Patients were divided into two groups: 15 with severe contracture and popliteal angle $>70^\circ$ underwent surgery, and 15 with moderate contracture and popliteal angle $30-70^\circ$ received non-surgical treatment (botulinum toxin injection).

Results: In the surgical group, internal hip rotation decreased by 15° , popliteal angle by 48° , knee extension by 13° , and femoral head anteversion by 10° , while external hip rotation increased by 18° . In the non-surgical group, internal hip rotation decreased by 10° , popliteal angle by 19° , knee extension by 8° , and femoral head anteversion by 19° , while external hip rotation increased by 10° (All p-values=0.001).

Conclusion: Internal hamstring lengthening, both surgical and non-surgical (botulinum toxin injection), improves movement (hip rotation and gait pattern) in children with CP, both surgical and non-surgical medial hamstring lengthening yield significant within-group improvements in hip rotation dynamics, popliteal angles, and knee extension deficits within their respective severity cohorts. Rather than comparing superiority, clinical decision-making should be guided by baseline contracture severity, with surgery reserved for severe structural contractures and botulinum toxin type A utilized for moderate spasticity for children with CP.

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Introduction

Cerebral palsy (CP) is the most common cause of physical disability in children (1, 2). It encompasses a group of neuromuscular conditions caused by abnormal brain development or injury (3). The prevalence of CP is approximately 2 per 1,000 live births (4). Low birth weight, preterm delivery, and multiple pregnancies are the strongest risk factors (5, 6). CP affects body posture and movement, leading to activity limitations and participation restrictions (7). Spastic CP is the most common form, accounting for 80-85% of cases (8).

Gait abnormalities, spasticity, muscle weakness, reduced walking speed, resistance, and immobility are the main causes of impaired movement and function in

patients with CP (9). CP can also result in impaired balance, which is associated with skeletal muscle weakness, hyperreflexia, co-contraction of agonist and antagonist muscle groups, delayed activation of the calf muscles, and a flexed postural alignment (10). To improve spasticity and balance in children with CP, various interventions such as botulinum toxin injection have been used (10).

Persistent internal hip rotation secondary to abnormal muscle forces plays a role in the development of bony deformities. Children with CP typically walk with an in-toeing gait pattern, and the cause is not clearly defined. Hamstring tightness is considered one of the main forces contributing to internal rotation gait. Surgical and

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non-surgical treatments for in-toeing gait in CP usually focus on the hip joint (11, 12).

Medial hamstring lengthening is frequently used in children with spastic cerebral palsy to enhance knee range of motion and promote better knee extension during walking. This surgical procedure typically includes lengthening of the distal tendons of the semitendinosus and gracilis muscles, along with aponeurotomy of the semimembranosus and semitendinosus muscles (13). Injection of botulinum toxin type A (BoNT-A) has also been recognized as a safe and effective non-surgical treatment for managing lower limb spasticity in children with spastic cerebral palsy (14).

Despite the variety of treatment and rehabilitation methods for children with CP, there is still controversy regarding the optimal approach. Moreover, considering the psychological and economic burden of this disabling condition on families and society, effective treatment and rehabilitation are of great importance. Therefore, we aimed to evaluate the changes in femoral head anteversion, popliteal angle, and the effect of internal hamstring lengthening by surgical and non-surgical methods on hip rotation in children with CP.

Methods

This retrospective cross-sectional study was conducted on 30 children aged 5-12 years with CP and knee contracture who were referred to the orthopedic clinic between March 2021 and August 2022. Patients were non-randomly assigned to either surgical or non-surgical hamstring lengthening based on the popliteal angle and the orthopedic specialist's judgment. Children with severe contracture and a popliteal angle greater than 70° underwent surgical medial hamstring lengthening, while those with moderate contracture and a popliteal angle between 30-70° received non-surgical treatment with botulinum toxin injection.

All participants had a diagnosis of cerebral palsy with clinically documented knee flexion contracture and were evaluated by a pediatric orthopedic specialist. Demographic and clinical information, including age, sex, severity of contracture, and treatment allocation, were obtained from medical records. Surgical medial hamstring lengthening consisted of standard lengthening procedures involving the semitendinosus, gracilis, and semimembranosus muscles as indicated clinically. In the non-surgical group, botulinum toxin type A was administered to the medial hamstring muscles according to standard clinical practice. Outcome measures included internal and external hip rotation, popliteal angle, knee extension deficit, and femoral head anteversion, all of which were assessed using standardized clinical examination techniques during routine follow-up visits. Measurements were recorded before intervention and at one- and six-month follow-up assessments.

Before the interventions and at one- and six-months follow-up, popliteal angle, hip rotation, and femoral head anteversion were measured using a goniometer during clinic visits. Changes in hip rotation, femoral head anteversion, and popliteal angle were extracted from the patients' medical records and analyzed separately for each group.

Due to the small sample size (15 in each group), the non-parametric Wilcoxon signed-rank test was used for data analysis. Statistical analyses were performed using SPSS version 22, and a p-value <0.05 was considered statistically significant.

Results

In the surgical group, after surgery compared to before, internal hip rotation decreased by 15°, popliteal angle by 48°, knee extension by 13°, and femoral head anteversion by 10°, while external hip rotation increased by 18°. All changes were statistically significant ($p < 0.05$). In the non-surgical group (botulinum toxin injection), after treatment compared to before, internal hip rotation decreased by 10°, popliteal angle by 19°, knee extension by 8°, and femoral head anteversion by 19°, while external hip rotation increased by 10°. All changes were statistically significant ($p < 0.05$) (Table 1, and 2).

Table 1. Results of surgical and non-surgical interventions on hip and knee parameters in children with cerebral palsy

Parameter	Surgical Group	Non-Surgical Group
	After	After
Internal Hip Rotation	↓ 15°	↓ 10°
External Hip Rotation	↑ 18°	↑ 10°
Popliteal Angle	↓ 48°	↓ 19°
Knee Extension	↓ 13°	↓ 8°
Femoral Head Anteversion	↓ 10°	↓ 19°

↑ Increase, ↓ Decrease

Table 2. Test statistics and p-values for the comparison of hip and knee parameters before and after interventions in children with cerebral palsy

Parameter	Surgical Group		Non-Surgical Group	
	Test Statistic	P-value	Test Statistic	P-value
Internal Hip Rotation	-3.359	0.001	-3.222	0.001
External Hip Rotation	-3.369	0.001	-3.104	0.001
Popliteal Angle	-3.417	0.001	-3.473	0.001
Knee Extension	-3.447	0.001	-3.520	0.001
Femoral Head Anteversion	-3.400	0.001	-3.423	0.001

The Wilcoxon signed-rank test was used for all comparisons due to the small sample size (15 in each group).

Discussion

This study evaluated the changes in femoral head anteversion, popliteal angle, and hip rotation following internal hamstring lengthening by surgical and non-surgical methods in children with CP. The results showed that both interventions led to significant improvements in hip rotation and knee extension. Both treatment groups demonstrated significant improvements in hip rotation, popliteal angle, knee extension, and femoral head anteversion. However, because treatment allocation was based on baseline contracture severity and patients were not randomly assigned, direct comparisons between groups should be interpreted with caution. Consequently, the present findings support the effectiveness of each intervention within its respective clinical population rather than establishing the superiority of one treatment over the other. This aligns with prior findings indicating that structural soft tissue modifications yield greater changes in joint kinematics compared to chemo-denervation alone (15).

In the surgical group, the findings were consistent with previous studies demonstrating the effectiveness of medial hamstring lengthening in improving knee extension and gait pattern in children with CP (16-19). The decrease in popliteal angle and increase in knee extension are attributed to the lengthening of the contracted hamstring muscles, which allows for greater knee extension during gait (13).

Similarly, in the non-surgical group, botulinum toxin injection resulted in significant improvements in hip rotation and knee extension. These findings are in line with previous research showing the beneficial effects of botulinum toxin in reducing muscle spasticity and improving gait kinematics in children with CP (14, 20).

The decrease in femoral head anteversion observed in both groups suggests a potential association between hamstring lengthening interventions and changes in proximal femoral alignment. However, the underlying mechanism remains uncertain and cannot be determined from the present study. While alterations in muscle forces, gait mechanics, and loading patterns may contribute to changes in femoral torsion during skeletal growth, these explanations remain hypothetical. Therefore, the observed reduction in femoral head anteversion should be interpreted cautiously, and further prospective studies incorporating advanced imaging and longitudinal biomechanical assessments are needed to clarify the mechanisms involved (21). The greater reduction in anteversion observed in the non-surgical group may reflect a more flexible bone response due to younger skeletal age or differing biomechanical loading adaptations.

While both interventions demonstrated short-term improvements, the durability of these changes is yet to be established. Previous longitudinal studies have reported recurrence of contractures and gait

abnormalities within 1–2 years post-intervention, particularly in rapidly growing children or in the absence of ongoing physiotherapy (22, 23). Future studies should incorporate longer follow-up durations to assess the persistence and clinical relevance of the observed biomechanical changes. The findings of this study should be interpreted in light of its retrospective observational design. Although significant improvements were observed following both surgical and non-surgical interventions, the study design does not permit causal inferences regarding the direct effects of the treatments. The observed changes may have been influenced by additional clinical factors, including rehabilitation programs, patient characteristics, and the natural course of musculoskeletal development. Prospective controlled studies are needed to better establish causal relationships and quantify treatment effects.

Several limitations of this study should be acknowledged. First, the relatively small sample size may restrict the statistical power of the study and limit the generalizability of the results. Second, the retrospective design and absence of a control group restrict the ability to draw causal conclusions regarding treatment effects. Third, selection bias may have been introduced because treatment allocation was based on clinical judgment and baseline contracture severity rather than random assignment. Consequently, the two groups represented different clinical populations and direct comparisons between interventions should be interpreted with caution. In addition, outcome assessments were not performed under blinded conditions, which may have introduced measurement bias. Finally, the relatively brief follow-up duration restricts the assessment of the long-term durability of the observed improvements. Future prospective research involving larger cohorts, randomized group allocation, blinded outcome evaluation, and extended follow-up is needed to confirm and strengthen these results.

Conclusions

In conclusion, both surgical medial hamstring lengthening and botulinum toxin type A injection were associated with significant improvements in hip rotation, knee extension, popliteal angle, and femoral head anteversion among children with cerebral palsy included in this study. However, given the retrospective and non-randomized design, as well as baseline differences between treatment groups, these findings should be interpreted with caution and should not be used to infer causal relationships or the superiority of one intervention over the other. Instead, the results support the potential effectiveness of each intervention within its respective clinical context. Further prospective, randomized, and controlled studies are needed to validate these findings and

better define the relative roles of these treatment approaches in the management of lower-limb musculoskeletal impairments in children with cerebral palsy.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Kerman University of Medical Sciences (IR.KMU.REC.1401.011) and was conducted in accordance with the principles of the Declaration of Helsinki. Because all participants were minors, written informed consent was obtained from their parents or legal guardians. Participation was voluntary, no incentives were offered, and all patient information was kept confidential and used solely for research purposes.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FZ contributed to the study conception and design, patient management, and data collection. MH contributed to data collection and interpretation of the data. AMM performed the data analysis and drafted the manuscript. SI, as the corresponding author, supervised the study, contributed to the conception and design, performed clinical assessments, critically revised the manuscript, and coordinated communication with the journal throughout the submission and review process. All authors read and approved the final manuscript.

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