Biomechanical Assessment of Idiopathic Toe Walking: A Spatio-Temporal and Kinematic Analysis

J. Heredia-Jimenez[1], R. Pozuleo-Calvo[2], A. Serrano-Garcia[2], Y. Archilla-Bonilla[2], A. Ruiz-Zafra[3], M. Noguera-Garcia[3], K. Benghazi-Akhlaki[3], M. Membrilla-Mesa[2] C. DiCaudo[4]

1 Dpt. of Physical Education & Sports. Human Behavior & Motion Analysis Lab (HubemaLab), University of Granada, Spain
2 Physical Medicine and Rehabilitation Department, Hospital Universitario Virgen de las Nieves, Granada, Spain
3 Department of Software Engineering, ETSIIT, University of Granada, Spain
Email: herediaj@ugr.es

Summary

Idiopathic Toe Walking (ITW) is a pediatric gait disorder characterized by persistent toe-to-heel locomotion without underlying neurological or orthopedic conditions. This study aimed to analyze the sagittal plane kinematics and spatio-temporal gait adaptations in children with ITW using Statistical Parametric Mapping (SPM). A comparative evaluation with typically developing (TD) children was conducted to assess differences in gait cycle phases and joint kinematics.

Introduction

ITW is a gait abnormality observed in children beyond three years of age, characterized by the absence of heel strike and full foot contact during walking [1]. While spatio-temporal parameters may appear within normal ranges, kinematic deviations often indicate compensatory neuromuscular adaptations. Previous studies have shown excessive plantarflexion and altered hip and knee flexion patterns in children with ITW [2,3]. This study utilizes SPM to analyze sagittal plane deviations across the gait cycle.

Methods

A cohort of 30 children diagnosed with ITW (mean age: 10.3 ± 2.1 years) and 30 TD peers (mean age: 11.1 ± 1.9 years) participated in the study. Motion capture data were collected using a 3D marker-based system (Qualisys AB, Sweden), following standardized gait analysis protocols [4]. Spatio-temporal parameters (step length, cadence, stride length, walking velocity, single support, and swing phase duration) and sagittal plane kinematics (pelvis, hip, knee, and ankle angles) were analyzed using SPM.

Results and Discussion

Significant differences were found in the ITW group compared to TD children:
Spatio-temporal adaptations: Increased single support ($p<0.05$) and swing phase duration ($p<0.05$) suggest compensatory strategies for stability.
Pelvic kinematics: Reduced anterior pelvic tilt throughout the gait cycle ($p=0.002$) [3].
Hip and knee kinematics: Decreased hip flexion during stance and swing phases ($p<0.001$), along with reduced knee flexion in mid-stance and pre-swing ($p<0.001$) [4].
Ankle kinematics: Excessive plantarflexion at initial contact and terminal swing ($p<0.001$), confirming the toe-walking pattern characteristic of ITW [2].

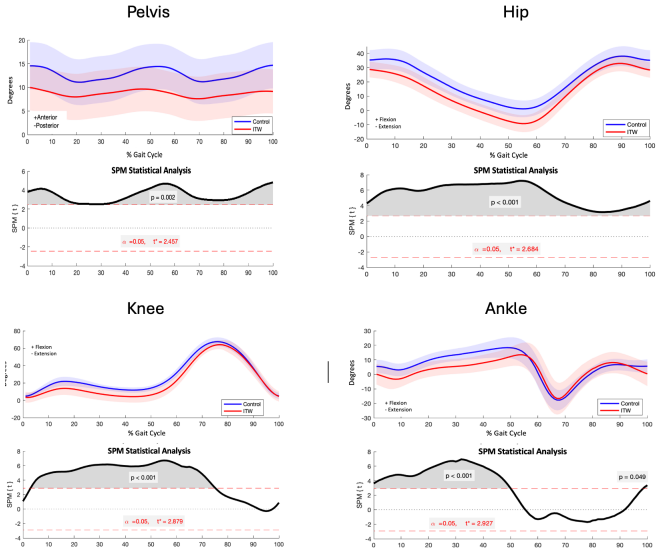

Figure 4. Sagittal plane kinematics (degrees) for control and ITW groups across the gait cycle (upper) and SPM analysis results (lower).

These findings align with previous research highlighting altered neuromuscular control in children with ITW [5].

Conclusions

Children with ITW exhibit distinct kinematic deviations in sagittal plane motion, emphasizing the importance of detailed motion analysis for early diagnosis and intervention. Future research should focus on the long-term musculoskeletal consequences and the efficacy of rehabilitation strategies.

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