

408.454 Advancing Markerless Gait Analysis with Machine Learning: New Results in Distinguishing Toe-Walking from Normal Gait in Autistic Individuals

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Background: Toe-walking (TW) is frequently observed in autistic children, affecting 20–30% of cases. Sometimes it resolves spontaneously, but in other cases it persists, which can lead to musculoskeletal issues. In previous studies, we developed and tested a markerless gait analysis system (MGAS) based on the OpenPose framework and machine learning algorithms to distinguish toe-walking from normal gait in autistic individuals. These preliminary results demonstrated the feasibility of an automated, non-invasive, and objective method for a quantitative assessment of TW during gait assessment.

Objectives: The present study aimed to: (1) improve the performance and robustness of the MGAS-based classification pipeline through an expanded dataset and updated training methodology; (2) validate the approach against manual assessment; and (3) evaluate its ability to discriminate between toe-walkers and non-toe-walkers in a pilot clinical test.

Methods: Step 1 – Classifier training and optimization. Fifteen neurotypical participants (mean age 10.3 ± 3.1 years; 6 males) simulated TW during a standardized gait task, transporting an object from a therapist to a table 3 metres back and forth ten times. Sagittal-plane videos were acquired according to an established protocol. Skeletons were extracted using OpenPose, and kinematic features were computed. A TWIST-based feature selection identified the most relevant parameters. Five classifiers (SVM, KNN, Naïve Bayes, Random Forest, XGBoost) were trained using a nested cross-validation framework to improve generalization and reduce overfitting. Performance metrics, including accuracy, sensitivity, specificity, and area under the ROC curve (AUC), were calculated.

Step 2 – Clinical validation. A pilot study was conducted on eight autistic individuals (four TW and four non-TW). Diagnosis followed DSM-5 criteria and was confirmed via the Childhood Autism Rating Scale – Second Edition (CARS-2). A trained therapist visually assessed videos, calculating the percentage of toe steps. MGAS-derived results were compared with the manual reference using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Spearman's rho. Group differences between TW and non-TW participants were analyzed using the Mann–Whitney U test to evaluate the classifier's discriminatory ability.

Results: Step 1: A total of 1.793 gait steps were analyzed (825 on tip-toe). Fourteen relevant kinematic features were selected using the TWIST algorithm (Figure 1). Among the classifiers, Naïve Bayes achieved the highest performance across all metrics (accuracy: 86.28%, specificity: 92.93%, sensitivity: 78.18%, AUC: 0.935), demonstrating strong generalization.

Step 2: The mean age of the eight participants was 9.16 ± 2.32 years (6 males). The mean CARS-2 score was 41.25 ± 9.10 . In the clinical sample, Naïve Bayes showed the best agreement with manual assessment. The classifier effectively distinguished TW from non-TW participants, with a significant difference between groups (Mann–Whitney U test $Z = -4.099$, $p < 0.001$) in automatically extracted gait parameters (Figure 2).

Conclusions: The MGAS, combined with a machine learning framework, provides a reliable, automated approach for detecting TW in autistic individuals. The Naïve Bayes classifier consistently outperformed other models and successfully discriminated between TW and normal gait, supporting its potential clinical application for objective gait assessment.



408.456 Alexithymia and Interoceptive Confusion Uniquely and Jointly Explain Sensory Symptoms in Autism

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