

Quantifying Tip-Toe Support During Upright Stance Using OpenPose: A Pilot Study on Individuals with Autism and intellectual disability

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BACKGROUND

Toe walking (TW), also referred to as tip-toe behavior (TTB)¹, affects approximately 20% of individuals with Autism Spectrum Disorder² (ASD). TTB in ASD can be observed in a spectrum of clinical manifestations: in some individuals, TTB can completely disappear over time without any intervention, while in others it can frequently persist during the day. It was found that those who manifest TTB during standing, walking and running present an Achilles’ tendon shortening³. Thus, TTB quantification during standing can provide insights into the TTB trajectory, helping in guiding interventions. However, individuals with ASD and intellectual disability often poorly tolerate optoelectronic and wearable motion-capture systems. Moreover, although video-based coding protocols allow TTB assessment in natural settings, they require time-consuming manual analysis¹. Markerless gait analysis systems (MGAS) offer a feasible solution for automated TTB detection with minimal patient burden.

OBJECTIVES

This study aimed to quantify the percentage of time spent in a toe-toe upright posture using the OpenPose module.

METHODS

This exploratory study involved five individuals (mean age: 9.05 ± 2.58 years; all male) diagnosed with ASD according to DSM-5 criteria, as confirmed by the Childhood Autism Rating Scale (CARS-2). Intellectual disability was assessed through the Vineland-2.

All participants were administered a validated video-based coding protocol based on standardized video recordings to quantify tip-toe support during a standing test¹. The task consisted of playing in front of a table (e.g., puzzle) for two minutes. All trials were conducted without shoes.

Using the MGAS “OpenPose”, the skeletons were extracted in the sagittal plane, and kinematics were computed⁴. These outcomes were then used to automatically identify the time spent standing on tiptoes. MGAS-derived results were compared with the manual reference using the Coefficient of Determination (R-squared, r^2), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE).

RESULTS

Participants presented mean scores of 51 ± 9.62 on CARS-2 and 27.2 ± 11.34 on Vineland-2. Three participants out of five exhibited TTB. The comparison between the traditional and automated approaches demonstrated an r^2 value of 0.895. Furthermore, this approach shows an MAE = 0.77% and an RMSE 2.54%.

CONCLUSION

The proposed method offers the potential for automated quantification of TTB in standardized protocols and settings. This approach also provides detailed kinematic data using a fully non-invasive method that does not require the patient's instrumentation. The following research steps will focus on a larger cohort of subjects to further validate the findings of this preliminary study.

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