Robustness of a Support Vector Machine Model to Walking Speed in Young and Older Adult Gait Classification

Rodrigo Quintero[1,2], Brett Speedy[1], Karansinh Padhiar[1], Ashirbad Pradhan, Victoria Chester[1]
[1]Andrew & Marjorie McCain Human Performance Laboratory, Kinesiology, University of New Brunswick, Fredericton, Canada
[2]Dept. of Translational Bioengineering, Universidad de Guadalajara, Guadalajara, Mexico
Email: vchester@unb.ca

Summary

Research has shown that gait patterns change as a function of speed and age [1,2]. As older adults tend to walk slower, variations in walking speed pose a significant challenge to examining age-related differences in gait kinematics. The purpose of this study was to classify gait patterns in young and older adults independent of walking speed and identify optimal kinematic features for classification. Gait patterns were compared using radial basis function (RBF) support vector machine (SVM) models based on temporal-spatial (TS) and joint angle (JA) data. Top contributing features were then determined. The model resulted in a classification accuracy of 92% demonstrating the model's robustness to walking speed variation. SHAP analysis highlighted age-related differences in postural and pelvic features that may increase our understanding of balance, mobility, and physical function.

Introduction

The interrelationship between age-related changes in gait kinematics and physical function is unclear. Recently, machine learning (ML) models have been used for classification of young and older adult gait patterns to increase our understanding of age-related changes in kinematics [3]. As walking speed declines with age, classification models that isolate age-related differences from speed-mediated effects are needed. Such analyses can lead to improved models of classification and an increased understanding of the relationship between physical function and age-related declines in mobility and gait.

Methods

A total of 78 adults: 40 young adults (age=23.70±3.50 yrs; height:1.72±0.13 m; weight: 68.44±16.5 kg) and 38 older adults (age=72.70±5.71 yrs; height: 1.68±0.1 m; weight: 80.47±15.18 kg) participated in the study. A 12-camera Vicon T160 motion capture system (Oxford Metrics Group Ltd., UK) was used to track 36 retro-reflective markers placed on the skin. Six force plates (Kistler Instruments, Winterthur, Switzerland) sampling at 1000 Hz, were used to identify key gait events. Participants walked at various self-selected speeds (very slow to very fast). Joint angle (n=99) and temporal-spatial (n=15) features for each participant's left and right gait cycle were computed. Features extracted from the gait waveforms included max/min values, time to max/min values, and range of motion, which served as input to SVM classifier with RBF kernel. Forward feature selection was used to select the feature subset with the most accurate classification of young vs older adult gait patterns irrespective of walking speed. Leave-one-out-cross-validation was performed and the mean classification accuracy was reported. SHAP scores were used to assess the feature importance.

Results and Discussion

Gait patterns in young and older adults were classified with high accuracy, specificity, and sensitivity (92%, 98%, 88%, respectively) irrespective of walking speed. The most contributing speed-invariant features included ankle DF/PF angle at heelstrike (HS), pelvic obliquity ROM, anterior/posterior trunk tilt angle at opposite toe-off (OTO), time to minimum pelvic obliquity during swing phase, and anterior/posterior pelvic tilt at OHS. Global feature importance using SHAP scores (Fig, 1), demonstrated age-related differences in postural control and pelvic motion independent of variations in walking speed. These results also demonstrate the robustness of the SVM model in classifying young vs older gait patterns in the presence of speed variations.

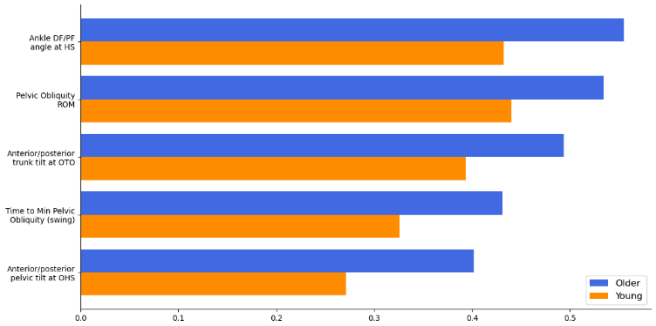

Figure 1: Feature importance ranking based on SHAP values.

Conclusions

This work highlights SVM model robustness in classifying young and older gait patterns independent of walking speed. Improved classification accuracy may be possible with speed-variant SVM models. Further, age-related changes in gait patterns may be further understood using EMG data in future studies.

Acknowledgments

Thank you to NSERC and NBIF for their support of this research.

References

[1] Jerome GJ et al. (2015). *Arch Gerontol Geriatr*, **60(2):** 243.
[2] Rezaei A. (2024). *PLoS ONE*, **19(10):** e0310764.
[3] Begg R et al. (2005). *J Biomech*, **38(3):** 401-408.