Quantitative Fall Risk Assessment with an Enhanced Timed Up and Go Test: A Machine Learning and Markerless Motion Capture Approach

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Summary

This study enhances fall risk assessment by integrating markerless motion capture and machine learning with the TUG test. Seventy participants performed TUG movements, and spatiotemporal and kinematic features were used to predict BBS scores. Random Forest and GBDT models achieved the highest accuracy, while markerless Mocap closely matched marker-based methods, offering an efficient, scalable approach for fall prevention in older adults.

Introduction

Falls among older adults pose a significant global health challenge, affecting one in three individuals aged 65 and above annually, leading to substantial injuries and healthcare costs [1]. Effective fall risk assessment is crucial for guiding preventive strategies. Traditionally, the BBS and the TUG test are standard methods for assessment, but they are time-intensive and require specialized clinicians. Our objective is to develop an enhanced fall risk assessment for older adults by integrating a markerless Mocap system and machine learning with the TUG test. This framework aims to accurately predict fall risk (BBS scores) while providing detailed gait analysis, including spatiotemporal parameters and joint kinematics.

Methods

Seventy participants (age: 52.3 ± 18.7 years, sex: 46F/24M) were involved in the study. They were asked to perform TUG movements within the capture range of a markerless Mocap system, with BBS assessments conducted by professional physical therapists. TUG features were extracted using an auto-segmentation approach (115 features) and then served as inputs for machine learning models to predict BBS scores. Regression models, including LR, Lasso, RF, GBDT, XGBoost, KNN, and SVR, were employed for this prediction. Additionally, a comparison of lower limb joint kinematics between marker-based and markerless Mocap systems during the gait phase of the TUG motion was performed.

Results and Discussion

All regression models demonstrated high prediction accuracy (RMSE$\leqslant$1.62, MAE$\leqslant$1.38, $R^2 \geqslant$0.82, Fig. 1). RF, GBDT, and KNN exhibited low prediction error and high explanatory power, while LR and XGBoost had higher prediction errors and lower explanatory power. RF had the lowest RMSE, with GBDT showing similar performance, whereas XGBoost had higher prediction errors possibly due to hyperparameter complexities. These findings align with Lin et al. (2022) [2], who also found RF to have the lowest RMSE among models predicting BBS scores.

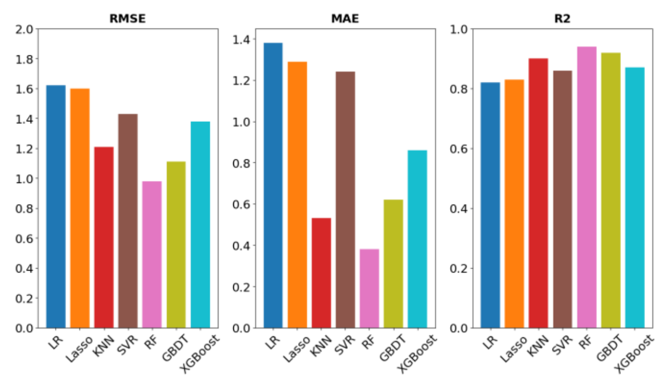

Figure 1: Root mean square error (RMSE), absolute mean error (MAE), and R-squared (R2) between predicted by machine learning models and actual BBS scores.

The lower limb joint kinematics captured by our markerless Mocap system exhibited similar patterns and ranges of motion to marker-based systems, with an average RMSE $\leqslant$9.14°. Our system showed better accuracy for ankle D/P (3.03°), and achieving accuracy comparable to state-of-the-art technologies like Theia 3D (RMSE $\leqslant$ 13.2°) in a recent study [3].

Conclusions

Our enhanced TUG test combines markerless motion capture and machine learning to accurately predict BBS scores and analyze gait. High-fall-risk individuals exhibited slower performance and reduced joint motion. The RF model excelled in predicting BBS scores, and our markerless system matched state-of-the-art accuracy without requiring markers or sensors. This study innovates fall risk assessment with a quantitative approach for better prevention in older adults.

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