Single IMU assessment of postural sway and falls risk in older adults

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***Abstract*—Ageing incurs a natural decline of balance and postural control which has been linked to falls risk. Objective, accurate and reliable assessment of balance is important in identifying postural instability and informing exercise interventions. Precise measures of balance can be derived from a single inertial sensor (IMU), and offer massive potential given the ubiquity of IMU sensors in smartphones. This study aims to (1) establish the intra-session reliability of 21 different measures of postural sway derived from a single lumbar-mounted IMU, (2) report the development of two new aggregated measures of balance, namely the Balance Score (BS) and the Weighted Balance Score (WBS), and (3) compare the ability of these two novel balance scores, with that of the Berg Balance Scale (BBS), in classifying fallers in an older adult cohort. 283 community dwelling older adult participants performed repeated static balance assessments under two conditions while wearing a lumbar-mounted IMU. Results show that most of the sensor-derived measures displayed good to excellent intra-session reliability across both conditions. Results obtained using logistic regression classifier models suggest that both the BS and the WBS are similarly, if not more accurate (58.8% and 61.7%) than the BBS (56.1%) at classifying fallers.**

I. Introduction

Deficits in balance and postural control are well-established risk factors for falls. A person's balance is often assessed clinically using costly and cumbersome equipment. However, the emergence of inertial sensor (IMU) technology has provided a low-cost alternative for the measurement of postural stability. The ubiquity of smartphone-embedded IMUs mean that the scalability of single IMU algorithms is greatly increased. A single-sensor balance assessment algorithm could allow older adults to assess their balance unsupervised at home and could be of clinical benefit.

II. Data

283 (178 female, age 74.47±6.68 yrs) participants performed 3 repetitions of a 30 second static balance test under two conditions (eyes open (EO) and eyes closed (EC)) while wearing a lumbar-mounted IMU. All participants were also assessed using a Berg Balance Scale (BBS). 39 of the participants also performed the balance tests while standing on a foam mat. Falls status was determined via a history of falls in the past 5 years and a Comprehensive Geriatric Assessment.

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III. Methods

Twenty-one features were derived from the IMU using a previously reported method [1]. The sensitivity of each feature to the foam mat-induced balance deficit was analyzed in the 39 participants using a Mann-Whitney U-test. The U test statistic values for each feature are used in the calculation of the Weighted Balance Score (WBS). The intra-session reliability of each feature was evaluated using intraclass correlation coefficients (ICC(2,k)). Logistic regression classifier models were used to establish the ability of the Balance Score (BS), WBS and BBS in classifying fallers in the remaining 244 participants. The classifier performance for each model was estimated using 5 reps of 10-fold cross-validation. In the calculation of the BS and WBS, for a given participant, a percentile was calculated for each IMU feature with reference to population values. The BS is calculated as the mean of the percentiles of the root-mean square (RMS) IMU features. The WBS is calculated as a *weighted mean* of the percentiles for *all IMU features*. The weights for each IMU feature percentile are taken as the U-test statistic values from the analysis performed above.

IV. Results

Intra-session reliability results showed that most features displayed good or excellent reliability (16/21 for EO, and 20/21 for EC, ICC>0.75) across conditions, only one had poor reliability (ICC<0.5). Furthermore, falls classification results suggest that the BS (52.7% (EO), 58.8% (EC)) and the WBS (57.2% (EO), 61.7% (EC)) are more accurate than the BBS (56.1%) at classifying falls risk.

V. Discussion

The reliability results demonstrate the potential of a single IMU in producing repeatable measures of postural sway. The reported results for classifying falls status are lower that the usually reported accuracies for classifier models, however, this is to be expected; Balance deficits are just one factor contributing to fall risk. The analysis shows that the BS and WBS can identify fallers at similar accuracy levels to a clinical balance assessment. As such, these simple and interpretable scores are sufficient to encapsulate the physical function deficits that contribute to the person's fall risk. The results show the scores may have clinical utility in screening older adults for falls prevention interventions.

VI. References

[1] E. P. Doheny, B. R. Greene, T. Foran, C. Cunningham, C. W. Fan, and R. A. Kenny, "Diurnal variations in the outcomes of instrumented gait and quiet standing balance assessments and their association with falls history," *Physiol Meas*, vol. 33, no. 3, pp. 361–373, Mar. 2012, doi: 10.1088/0967-3334/33/3/361.