Phase-Level Analytical Validation of a Bring-Your-Own-Device Smartphone Timed Up and Go Assessment in Multiple Sclerosis

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What is the Methodological Issue Being Addressed? Smartphone-based mobility assessments offer a scalable approach for decentralized clinical trials and real-world monitoring. However, analytical validation of derived mobility endpoints remains challenging. For the Timed Up and Go (TUG), total duration is the primary outcome and accurate estimation of this measure from smartphone sensors is an important benchmark for broader use in clinical studies while also enabling evaluation of more granular movement features.
Establishing agreement between smartphone-derived movement states and observable functional mobility behaviors requires structured reference methods capable of linking sensor outputs to real-world movement events. This work presents a framework for phase-level analytical validation of a smartphone-based TUG, anchored in accurate estimation of total test duration, and extended to phase-level characterization using synchronized video annotation.

Introduction The TUG is a widely used assessment of functional mobility across neurological populations. While smartphone-based implementations may enable remote and bring-your-own-device (BYOD) assessment, validation efforts have largely focused on overall test duration. Less attention has been given to validating discrete movement phases such as turning and transitional movements, which may provide clinically relevant information regarding balance and functional performance. We evaluated a structured video-based approach to validate total TUG duration and phase-level smartphone-derived metrics in individuals with multiple sclerosis (MS).

Methods Nine individuals with MS were recruited through the Portuguese Multiple Sclerosis Society (mean age 44±10 years; 60% female) and completed smartphone-based TUG assessments using a standard smartphone in a clinic setting. Participants represented a heterogeneous mobility cohort, including individuals using walking aids (n=3). Synchronized video recordings were independently annotated by three raters using a literature-informed framework defining key TUG phases (sit-to-stand, walking, turning) and step count. Inter-rater reliability was assessed for annotated TUG phases using the intra-class correlation coefficient (ICC). Agreement between smartphone-derived and video-derived measurements was evaluated using mean absolute error (MAE), correlation, and Bland-Altman analyses.

Results High inter-rater reliability was observed for total TUG duration (ICC=0.99), walking duration (ICC=0.95), and sit-to-stand duration (ICC=0.80), supporting the annotation framework as a reference method.
Smartphone-derived total TUG duration demonstrated close agreement with video measurements

(MAE=0.41 seconds; bias=-0.40 seconds; Spearman ρ=1.00). Walking duration similarly showed strong agreement (bias=-0.16 seconds; Spearman ρ=1.00), with all observations within Bland-Altman limits of agreement.
Sit-to-stand duration showed a MAE of 0.36 seconds and minimal bias (0.05 seconds), although with greater variability due to the short duration of this phase. Step count correlated strongly with video reference (Spearman ρ=0.89, p=0.001). Turn detection identified 16 of 18 turns, including complete detection in 8 of 9 assessments.

Conclusion This pilot study demonstrates the feasibility of a structured framework for phase-level analytical validation of smartphone-derived TUG outcomes using ground-truth video annotation. The approach supports robust estimation of the primary endpoint (TUG duration) while enabling evaluation of additional mobility features, including turning and transitional movements, under BYOD conditions. Findings are based on a heterogeneous patient cohort, including patients using walking aids, and support the feasibility of smartphone-based mobility assessments for decentralized and hybrid CNS clinical trials. Further validation in larger samples and longitudinal studies is warranted.

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Guidelines I have read and understand the Poster Guidelines

Disclosures Jacqueline Lutz serves as a fractional Chief Scientific Officer and consultant to Beats Medical (I would like to add that affiliation, in addition to my BU academic position to the poster). Co-authors Mariana Abreu, PhD is employee and Ciara Clancy, PhD is CEO of Beats Medical.

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