Beyond walking distance: Evaluating propulsion function during the 6-minute walk test with wearable inertial sensors

Dheepak Arumukhom Revi[1,2], Andre M. Alvarez[1], Lillian R. Braga[1], Conor Walsh[2], Stefano M. M. De. Rossi[1] and Louis N. Awad[1,2*]
[1]College of Health and Rehabilitation Sciences, Boston University, Boston, MA
Email: *louawad@bu.edu

Introduction

The 6-minute walk test (6MWT) is commonly used across clinical diagnostic groups to measure functional walking capacity[1,2]. The total distance walked[1,2] and the distance-induced change in walking speed[2] measured during the 6MWT are strong indicators of real world walking activity. Although demonstrably valuable, distance-based measurements (e.g., across 6 minutes or per minute) do not account for differences in gait quality that may underlie the impaired performance observed in heterogeneous populations, such as people post-stroke. Indeed, as a timed walk test, the ability to both achieve and sustain a fast walking speed underlies 6MWT performance. Given the relationship between propulsion function and short- and long-distance walking speed[3], we posit that measurements of propulsion function during the 6MWT may provide crucial diagnostic data that are currently lacking in the distance-based measurements traditionally extracted from the 6MWT, and that can inform targeted gait therapies. In this study, we present the use of a minimal set of wearable inertial measurement units (IMUs) to provide indirect estimates of propulsion function during the 6MWT.

Methods

Seven individuals with chronic post-stroke hemiparesis completed a 6-minute walk test over a 26.6m walking track instrumented with six forceplates while wearing three IMUs securely attached to the pelvis, thigh, and shank. The forceplates provided direct measurements of the anterior-posterior ground reaction force (AP-GRF) generated during steps with a forceplate strike. In addition, subject-specific models driven by IMU-measured thigh and shank angles and an estimate of body acceleration provided by the pelvis IMU were used to provide indirect meaurements of the AP-GRF generated every step[4]. Peak propulsion point metrics were extracted from the direct and indirect estimates of the anterior portion of the AP-GRF and compared. Moreover, the distance walked per minute of the 6MWT was measured using a measuring wheel. Study participants were dichotomized into endurant and non-endurant subgroups, with non-endurant individuals being those who slow down by more than 0.10 m/s between min 1 and min 6[1]. Peak propulsion medians and 95% confidence intervals are reported.

Results and Discussion

In previous work, we showed that indirect measurements of the AP-GRF time series strongly approximated the direct measurements made by forceplates, with low error and high consistency[4]. The average error between indirect and direct measurements of the peak propulsion magnitude (% bodyweight, %bw) was less than 1.2 %bw—which is lower than the Minimal Detectable Change (MDC) of 1.8%bw[4]. In the present study, four out of seven participants were classified as endurant and the other three were non-edurant. The non-endurant subgroup presented with comparable reductions in speed (-14% [-11%, -16%]) and peak paretic propulsion (-16% [-14%, -38%]) (Ps < 0.05). In contrast, the endurant subgroup did not markedly change speed (0% [-16%, 9%]) or peak paretic propulsion (2% [-8%, 8%]).

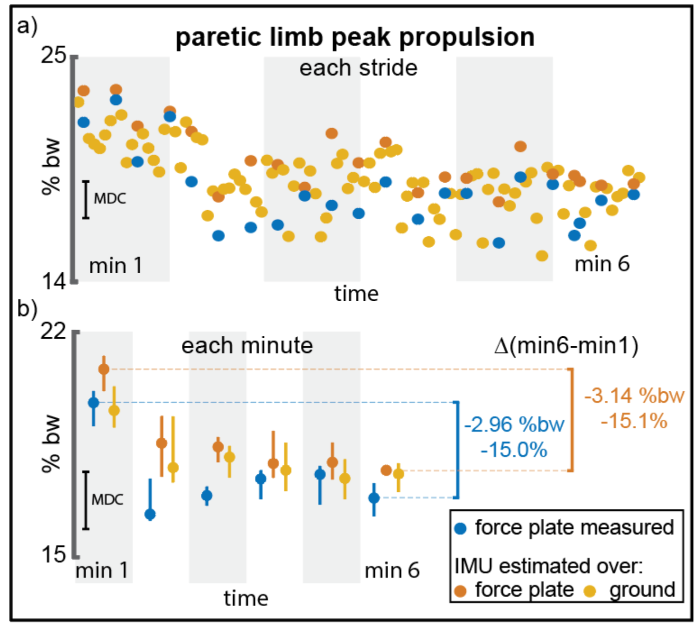

Figure 1: Change in peak paretic propulsion measured by forceplates and estimated by IMUs during the 6-minute walk test for one exemplar, non-endurant participant on a **(a)** step by step basis and **(b)** minute by minute basis. **Minimal Detectable Change (MDC) = 1.8 %bw.*

Significance

Wearable inertial sensors offer a feasible solution to provide clinically-accessible assessments of propulsion function during the 6MWT. We show that individuals post-stroke who reduce their speed over the duration of the 6MWT (i.e., non-endurant individuals) also present with a reduction in paretic limb propulsion (Figure 1). In contrast, individuals who do not reduce their speed (i.e., endurant individuals) do not reduce paretic limb propulsion. This wearable sensor technology has potential to enable clinicians to co-assess changes in propulsion quality with distance-based performance outcomes that are traditionally evaluated, and may thus provide treatment-shaping diagnostic information not currently available in most clinical settings.

Acknowledgment

We thank the Boston University Neuromotor Recovery Lab for assistance with data and our participants for their generous time. Grants: NIH KL2TR001411, AHA 18TPA34170171, AHA 18IPA34170487.

References

[1]Awad, L. N., et al. 2019, *J.N.P.T.* doi: 10.1097/NPT.0000000000000293.
[2]Fulk, D. G., et al. 2017, *Stroke.* doi: 10.1161/STROKEAHA.116.015309.
[3]Awad, L. N., et al. 2015, *N.N.R.* doi: 10.1177/1545968314554625.
[4]Arumukhom Revi, D., et al. 2020, *J.N.E.R* (preprint) https://dx.doi.org/10.21203/rs.2.23757/v1