TOWARDS OBJECTIVE TOOLS TO INFORM AMPUTEE CLINICAL CARE: PELVIC ACCELERATION AS A MEANS OF QUANTIFYING GAIT ASYMMETRY

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INTRODUCTION

Over 1 million Americans are living with lower limb loss, and this number could double by 2050. Lower limb amputees (LLAs) often exhibit gait deviations and asymmetries, which can lead to secondary disabilities (e.g., back pain, osteoarthritis) if unaddressed [1]. Poorly-fitting prosthetic sockets and misaligned prosthetic limbs can exacerbate walking asymmetries, causing LLAs to favor their sound limb. Overloading of the sound limb with repetitive impulsive forces due to asymmetry can then contribute to joint degeneration, further restricting LLA mobility [2]. To mitigate these health risks, there is a need for frequent clinical reassessment. However, there are two key problems. First, the quality of prosthetic fitting and alignment can vary greatly between practitioners, leading to variable quality of care. Second, fitting or alignment may degrade between appointments, during which LLAs may adopt a detrimental gait asymmetry that goes unnoticed until the next clinic visit.

There is a pressing need for tools or sensors that can monitor the gait of LLAs to better inform clinical interventions. Observational gait analysis is most commonly used in the clinical setting, but it relies on the subjective visual assessment of a single practitioner. This assessment can have low inter-observer reliability, and fails to provide objective gait performance records, which are critical for future evaluations and long-term mobility trend tracking. Clinical gait analysis using motion capture cameras and force plates is the gold standard for quantitative assessment, but it is too time consuming and costly for global use in the outpatient setting. Inertial measurement units (IMUs) may offer an intermediate solution, as they are portable, inexpensive, and can provide some objective movement data. We propose that tracking pelvic movement may be useful for assessing amputee gait asymmetry, since it reflects the combined biomechanical performance of both lower limbs.

CLINICAL SIGNIFICANCE

We lack objective tools/metrics to monitor LLA gait, guide prosthetic fitting or intervention.

METHODS

A comparative instrumented analysis was performed to investigate the potential of using a pelvis-mounted IMU to estimate sound vs. residual limb force asymmetries experienced by LLAs during walking. We tested 1 able-bodied control, 1 unilateral transtibial amputee, and 1 unilateral transfemoral amputee while they walked on a split-belt force-treadmill (Bertec). An IMU (BTS G-Walk) was affixed at the top of the pelvis, near L5. Force and acceleration data were collected simultaneously, filtered, and stride-averaged. We computed a Pearson correlation between the fore-aft ground reaction forces (left + right limb) and pelvic acceleration, to assess the degree to which pelvic motion tracked center-of-mass motion. We also estimated fore-aft asymmetries in right vs. left leg loading behavior, by quantifying braking/deceleration. The amount of deceleration was quantified by computing the negative area under the acceleration curve immediately following each foot contact (roughly 5-25%

and 55-75% of the stride cycle, Fig. 1). A similar calculation was applied to individual limb ground reaction force curves to quantify the braking impulse. We then calculated asymmetry indexes by dividing sound (control's left) by prosthetic (control's right) limb braking.

DEMONSTRATION

We observed a strong correlation (R>0.6) between pelvic acceleration and net ground reaction force waveforms for each of the 3 subjects (Fig. 1), suggesting that pelvic motion may be a useful surrogate for assessing net limb loading when force plate use is infeasible. Force braking asymmetry ratios were >2 for the LLAs, indicating greater loading on the sound limb. However, LLA braking asymmetry ratios derived from pelvic accelerometer data were 0.6 and 1.7, showing poor correspondence with the force asymmetry ratios. This could be due to IMU sensing limitations (e.g., sampling rate), or IMU-pelvis affixation methods. Alternatively, this may reflect methodological limitations in estimating individual limb braking with a single IMU, due to challenges in parsing leading vs. trailing limb contributions during double support. Further study is ongoing to determine if and under what conditions force asymmetries could be reliably assessed using a pelvis-mounted IMU.

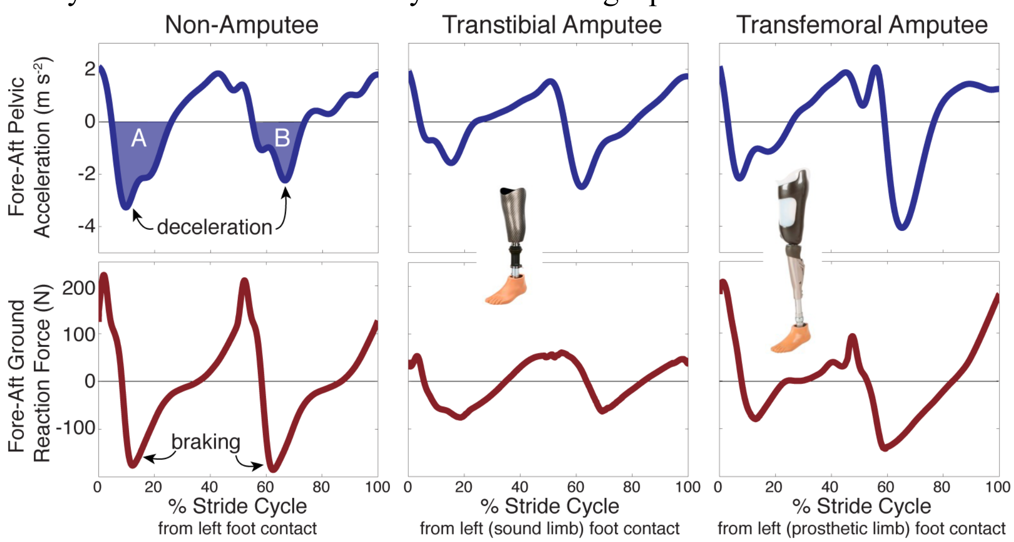

Figure 1. Fore-aft pelvic acceleration (top) and ground reaction force (bottom) for 3 subjects. Shaded areas, representing deceleration after left (A) and right (B) foot contacts, were used to assess gait asymmetry.

SUMMARY

We posit that an inexpensive, portable measure of walking performance would facilitate clinical decision-making by alerting clinical practitioners to unhealthy gait deviations and enabling timely intervention. The observed similarity in waveforms between pelvic acceleration and ground reaction force highlights the potential utility of IMUs. Efforts are ongoing to identify what information can be reliably gleaned from these sensors.

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