Associations between Foot Accelerations and Ground Reaction Forces during Walking in Patients with End-Stage Knee Osteoarthritis

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Summary

The pattern and magnitude of ground reaction forces (GRFs) during walking can have important implications for musculoskeletal pathology such as osteoarthritis (OA). This study explored whether GRF metrics, traditionally measured with high accuracy in lab environments with force plates, could be represented through lower extremity wearable accelerometry in patients awaiting knee arthroplasty (KA) surgery to treat advanced knee OA. Six patients with knee OA underwent gait analysis using optoelectronic motion capture, in-ground force plates, and wearable inertial measurement units (IMUs). Significant correlations were found between sensor-derived acceleration metrics and GRF metrics, particularly with GRF minima representing midstance unloading, a particular feature of importance to knee OA. This study supported the feasibility of enabling out of lab kinetic analyses for patients with OA.

Introduction

Kinetic outcomes during walking are important measures in understanding patient variability in KA outcomes [1] and implant stability [2]. GRF is the most critical component to calculating accurate joint level kinetic outcomes through inverse dynamics techniques. Traditionally, GRFs are acquired using in-ground force plates in lab environments [1]. GRFs have been estimated with wearable sensors successfully in healthy participants [3], but not in a clinical population. With a long-term goal of accessible clinically relevant kinetic outcome capture in natural environments, this study examined the associations between GRFs and foot accelerometry using IMUs placed on varied parts of the distal lower extremity anatomy in a cohort of patients awaiting KA surgery.

Methods

Six Patients (4F, 2M, age: 64±11 years, BMI: 33±6 kg/m^2) with end-stage knee OA awaiting KA surgery underwent instrumented three-dimensional kinematic and kinetic gait analysis in Dalhousie University's Dynamics of Human Motion (DOHM) Lab using a synchronized optoelectronic camera system (Motion Analysis Inc.) and inground force platforms (AMTI). IMUs (APDM Opal) were placed on the lateral distal fibula, the dorsal foot (laces) and heel (calcaneus) of the affected leg, aligned to each segment [4], and data was parsed for gait strides [5]. Midstance minimums, stance maximums and first peak to midstance ranges were extracted from vGRF data and sensor acceleration data.

Pearson's correlation analyses were used to examine associations between the indicated vertical acceleration and vertical GRF outcomes (α=0.05).

Results and Discussion

Significant and strong correlations were found between the stance phase range and midstance minimum vGRF with the sensor-based metrics ($p<0.05$), but no significant correlations with the vGRF peaks during walking. Strong correlations were found between stance range vGRF and peak distal fibula acceleration during stance (r=0.84, p=0.03). The strongest correlations were found between the midstance minimum of the vGRF with the stance peak and range of dorsal foot and peak heel accelerations (r=-0.82, p=0.04, r=-0.80, p=0.05, r=-0.82, p=0.04). This is a clinically relevant finding as the midstance minimum represents a lack of midstance unloading (i.e. more constant loading) of the lower extremity joints, an indicator of knee OA progression [6]. The acceleration of the dorsal foot and heel sensors were most correlated to the vGRF metrics.

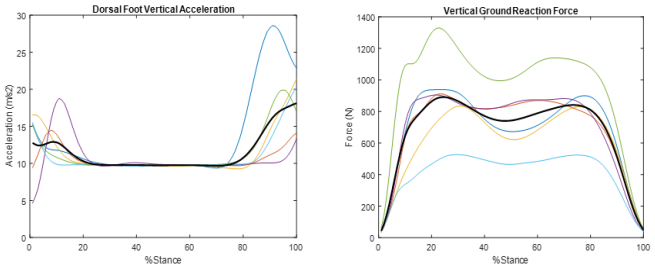

Figure 1: Mean dorsal foot vertical acceleration and mean vertical ground reaction forces for each participant with the total mean plotted in bold.

Conclusions

Correlations were found between IMUs and GRF in a small sample of patients awaiting KA. Preliminary results suggest the feasibility of capturing clinically relevant OA gait metrics through simple foot-worn accelerometry.

References

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