Comparison of Ground Reaction Forces and Knee Joint Moments between Parkinson's Disease and Healthy Older Adults using a Kinect-Driven Musculoskeletal Gait Analysis Model

Oh, Jeonghoon ; Eltoukhy, Moataz ; Kuenze, Christopher ; Andersen, Michael Skipper; Signorile, Joseph F.

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Comparison of Ground Reaction Forces and Knee Joint Moments between Parkinson's Disease and Healthy Older Adults using a Kinect-Driven Musculoskeletal Gait Analysis Model

[1] Jeonghoon Oh, [1] Moataz Eltoukhy, [2] Christopher Kuenze, [3] Michael S. Andersen, and [1] Joseph Signorile

[1] University of Miami, Coral Gables, FL, USA
[2] Michigan State University, East Lansing, MI, USA
[3] Aalborg University, Fibigerstraede, Denmark

email: jxo130@miami.edu

INTRODUCTION

The gait impairment is commonly observed in people with Parkinson's disease (PD). It is caused by the progressive loss of dopamine-producing cells of the central nervous system. Clinically, it is characterized by rigidity and freezing of the gait, which causes significant loss of independence and increased incidences of falls [1].

Despite the large increase in the number of PD patients in the US, clinicians are still using subjective measures to assess the level of the disease. But, these methods often produce inconsistent diagnoses. At the same time, gait analysis using a laboratory-based motion capture system provides a quantitative assessment of the rate of the disease progress. Yet, due to its high cost, technical difficulty, lack of portability, need for larger spaces, and the large requirements for setup time, it is very difficult to adopt this technology in clinical settings.

According to the literature, measurement of kinetics, such as the vertical ground reaction forces (vGRF) pattern during gait in PD patients is often used to monitor the stage of the disease. In addition, many researchers used GRF in order to develop ways to automatically classify gait patterns in PD patients. Other studies have also indicated that an abnormality in the pattern of the kinetics was more pronounced than in the kinematics in PD patients during gait.

Therefore, the purpose of this study was to compare the GRFs and knee joint flexion moments during gait between PD and healthy individuals using a full-body musculoskeletal model driven by the Microsoft Kinect v2.

METHODS

Nine elderly patients diagnosed with PD (71.0±5.6 yrs) and eleven healthy age-matched control participants (71.1±7.5 yrs) were recruited for this study. We recruited PD patients who were impaired with mild to moderate (H&Y stages I-III) and had a score of 24 or above on the Folstein Mini-Mental State Examination.

The Kinect v2 was located at 2.5 m from the subject, at a height of 0.75 m from the ground. This location was determined by formerly published research which involved measuring gait parameters using the Kinect sensor. The subjects performed three walking trials at their normal walking speeds without wearing any type of footwear. The Kinect's depth data was analyzed by subtracting the background depth information and tracking the subjects' movement using anthropometric models in order to extract 26 joint trajectories using a customized MATLAB code [2].

The musculoskeletal GaitFullBody model (AnyBody Technology, Aalborg, Denmark), generated the gait GRFs and knee joint flexion moment using a modified version of the method proposed by Fluit et al. and Skals et al. [2-3]. This is attained by 25 artificial muscle-like actuators which are connect to under each foot.

We used an unpaired Student *t*-test analysis to compare the mean kinetic data between PD patients and control healthy subjects. The ensemble curves and associated 90% confidence intervals (CI_{90}) of the vGRF were compared between both groups.

RESULTS AND DISCUSSION

Table 1 shows the kinetic data of the PD and control groups. A significantly lower vGRF (*P*<.05) and $_{AP}$GRF (*P*<.05) was found in both the braking and propulsion phases of the PD group. At the knee joint, however, the maximum flexion moment generation in the stance phase did not significantly differ from that of the controls.

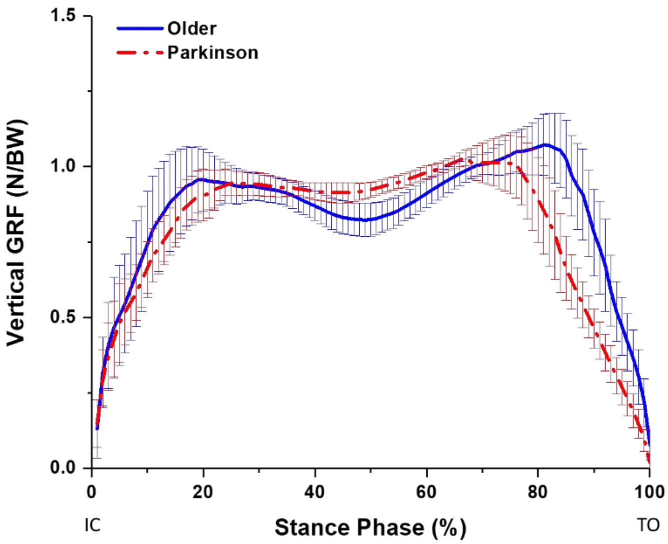

Figure 1: The ensemble curve of estimated vGRF from Kinect-driven musculoskeletal gait model for the Parkinson's group (red) and healthy control group (blue).

In the PD group, subjects appear to walk flat-footed, with minimal push-off with plantar flexion, so the two peaks of vGRF is lower than the control groups'. Also, the vGRF curve in the PD did not show the two distinct peaks and showed a more pronounced valley which then became more of a plateau. It indicates that the PD subjects utilized more load at the mid-foot when compared with the healthy subjects. The vGRF pattern of the PD group is similar to the findings reported by Nieuwboer et al [4]. Additionally, patients with PD showed less $_{AP}$GRF braking and propulsion impulse, due to their inability to generate sufficient braking impulse followed by a decline in the propulsion impulse, than those generated by the healthy control group.

This was the first study to compare the differences in the vGRF and knee joint moment between PD and healthy subjects using a Kinect-driven musculoskeletal modeling. The ability of the model to effectively estimate gait kinetics was apparent in its ability to effectively assess PD gait abnormalities characterized by a reduction in the vGRF second peak.

CONCLUSIONS

The findings of this study confirm that both vGRF and $_{AP}$GRF generated by the PD patients are significantly different than the healthy group. On the other hand, statistically no significant difference was found in the maximum knee flexion moment. In addition, the gait-related kinetic outcomes obtained using our Kinect-driven musculoskeletal model, proves that Kinect has the potential to be an effective, accurate gait analysis tool for the PD population.

REFERENCES

1. Halliday et al. *Gait & Posture.* 8(1):8-14, 1998.
2. Skals et al. *Multibody System Dynamics.* 41(4):297-316, 2017
3. Fluit et al. *Journal of Biomechanics*. 47(10):2321-2329, 2014
4. Nieuwboer et al. *Scandinavian journal of rehabilitation medicine*, 31(3):185, 1999

Table 1: Comparison between Parkinson's and older groups kinetics variables during the stance phase.

	Max vertical GRF (N/BW)		Max horizontal GRF (N/BW)		Max knee flexion moment (Nm/BW)
	Braking	Propulsion	Braking	Propulsion	
Parkinson's group	1.02±0.03	1.10±0.04	-0.13±0.03	0.16±0.04	0.75±0.15
Older group	1.09±0.11	1.18±0.12	-0.16±0.05	0.19±0.06	0.77±0.14
***P*-value**	.009*	.041*	.042*	.037*	.716