



HAL
open science

Evaluation of the Margin of Stability during Gait Initiation in Young Healthy Adults, Elderly Healthy Adults, and Patients with Parkinson's Disease: A Comparison of Force-Plate and Markerless Motion Capture Systems

Arnaud Simonet, Arnaud Delafontaine, Paul Fourcade, Florent Loete, Eric Yiou

► To cite this version:

Arnaud Simonet, Arnaud Delafontaine, Paul Fourcade, Florent Loete, Eric Yiou. Evaluation of the Margin of Stability during Gait Initiation in Young Healthy Adults, Elderly Healthy Adults, and Patients with Parkinson's Disease: A Comparison of Force-Plate and Markerless Motion Capture Systems. *Multidisciplinary Biomechanics Journal*, 2025, 49th congress of the Société de Biomécanique, <10.46298/mbj.14578>. <hal-04738071v2>

HAL Id: hal-04738071

<https://hal.science/hal-04738071v2>

Submitted on 31 Jan 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

Evaluation of the Margin of Stability during Gait Initiation in Young Healthy Adults, Elderly Healthy Adults, and Patients with Parkinson's Disease: A Comparison of Force-Plate and Markerless Motion Capture Systems

Arnaud Simonet^{*a}, Arnaud Delafontaine^b, Paul Fourcade^c,
Florent Loete^d, Eric Yiou^c

Received date: 03/04/2024
Accepted date: 28/06/2024
Publication date: 31/01/2025

a LADAPT Loiret, Centre de soins de suite et de réadaptation, Amilly, France
b Laboratoire d'anatomie fonctionnelle, Faculté des Sciences de la Motricité ; Laboratoire d'anatomie, de biomécanique et d'organogénèse, Faculté de Médecine, Université Libre de Bruxelles, Bruxelles, Belgique
c CIAMS, Université Paris-Saclay, Orsay, France
d Laboratoire GeePS-CENTRALESUPELEC, Gif-sur-Yvette, France
* Corresponding author: simonet.arnaud@ladapt.net

Keywords: gait initiation, stability, markerless motion capture, force plate

© 2025 The Authors
Licence CC-BY 4.0
Published by Société de Biomécanique

1. Introduction

Postural stability is a prerequisite to the performance of most of our daily motor tasks. Gait initiation, the transient period between quiet standing and steady-state walking, is a functional task classically used in the literature to evaluate the capacity of healthy individuals and neurological patients to maintain stability under dynamic conditions (Yiou *et al.* 2017). Postural stability during gait initiation is commonly evaluated through the “margin-of-stability”, a quantity which takes into account both the position and velocity of the centre-of-mass within the base-of-support (Hof *et al.* 2005). This quantity is often computed from force plate system recordings (e.g. Yiou *et al.*, 2016). This study tested the agreement between the force plate system (considered here as the “gold standard”) and markerless motion capture system, an innovative and easy-to-use technology, to estimate the MoS during gait initiation in young and elderly healthy adults as well as in patients with Parkinson's disease. Markerless motion capture system uses standard video and deep learning-based software to detect body segment landmarks directly from digital images (Kanko *et al.* 2021). In the present study, the focus was put on the margin-of-stability along the mediolateral direction, because controlling stability along this direction is known to be particularly challenging during locomotor tasks.

2. Methods

2.1 Population

Thirty-three participants divided into three groups (young healthy, elderly healthy, and patients with Parkinson's disease) took part in the experiment which was conducted in accordance with the Declaration of Helsinki.

2.2 Experimental Set-up and procedure

Participants initiated gait from the standing posture and continued walking to the end of a six-meter track. Gait was initiated at a spontaneous velocity (“spontaneous velocity condition”) and at a maximum velocity (“maximum velocity condition”). The force plate system was composed of two force plates (400x600mm, AMTI, USA) placed in series and embedded at the beginning of the walking track. The markerless motion capture system was composed of twelve Qualisys Hybrid cameras (Qualisys, Göteborg, Sweden) which recorded the body motion during the entire gait initiation process and the subsequent steps.

2.3 Margin of stability

The margin-of-stability was computed as the difference between the mediolateral base of support boundary (BoSymax) and the mediolateral position of the “extrapolated centre-of-mass” at the time of foot-contact ($yCoM_{FC}$), i.e. $MoS = BoSymax - yCoM_{FC}$. $yCoM_{FC}$ was calculated as follows: $yCoM_{FC} = yCoM_{FC} + y'CoM_{FC}/$

ω_0 , where $y_{CoM_{FC}}$ and $y'_{CoM_{FC}}$ are respectively the mediolateral centre-of-mass position and the velocity at foot-contact; ω_0 is the eigenfrequency of the body modelled as an inverted pendulum, calculated as:

$\omega_0 = \sqrt{\frac{g}{l}}$, where g is the gravitational acceleration and l is the length of the inverted pendulum (57.5% of body height (Winter, 2009)).

2.4 Statistics

For each trial, the margin-of-stability was computed with both systems. To investigate the agreement between force plate system and markerless motion capture system, a Bland-Altman analysis was performed. Bland-Altman plots were generated for each velocity condition and group, with the horizontal axis representing the average MoS obtained using the two systems, and the vertical axis representing the difference between the two systems. The lack of agreement between the two systems was summarised by calculating the bias, estimated by the mean difference (d) and the standard deviation of the differences (SD). Repeated-measures (RM) ANOVA with the Velocity (spontaneous velocity condition vs. maximum velocity condition) and System (force plate system vs. markerless motion capture system) as within-subject factors, and the Group (young healthy, elderly healthy adults, patients with Parkinson's disease) as between-subject factor were also carried out.

3. Results and discussion

In spontaneous velocity condition (Figure 1), Bland-Altman analysis showed that 95% of the absolute differences between the two measurement systems ranged between -0.01 and 0.02 m for young healthy (which corresponded to a [-17 and 20%] range of relative difference), -0.02 and 0.02 m for elderly healthy adults ([-23 and 26%]) and -0.02 and 0.03 m for patients with Parkinson's disease ([-28 and 30%]). In maximum velocity condition (Figure 1), 95% of the absolute differences between the two systems ranged between -0.02 and 0.03 m for young healthy ([-21 and 25%]), -0.02 and 0.03 m for elderly healthy adults ([-27 and 36%]) and -0.04 and 0.04 m for patients with Parkinson's disease ([-41 and 37%]). Absolute bias was very close to zero and the deviation was considered neglectable for each velocity condition and group, indicating that the accuracy of the markerless motion capture system was good. RM ANOVA further showed that there was a significant main effect of the Group ($F[2,476]=5.7$,

$p<0.001$) and the Velocity ($F[1,476]=28.1$, $p<0.001$) on the margin-of-stability. In contrast, there was no significant main effect of the System, nor any significant interaction between factors. In other words, although relatively high differences in the margin-of-stability do occur between markerless motion capture system and force plate system on a trial-by-trial basis, these two systems are similarly effective in detecting an effect of the group and velocity on the margin-of-stability.

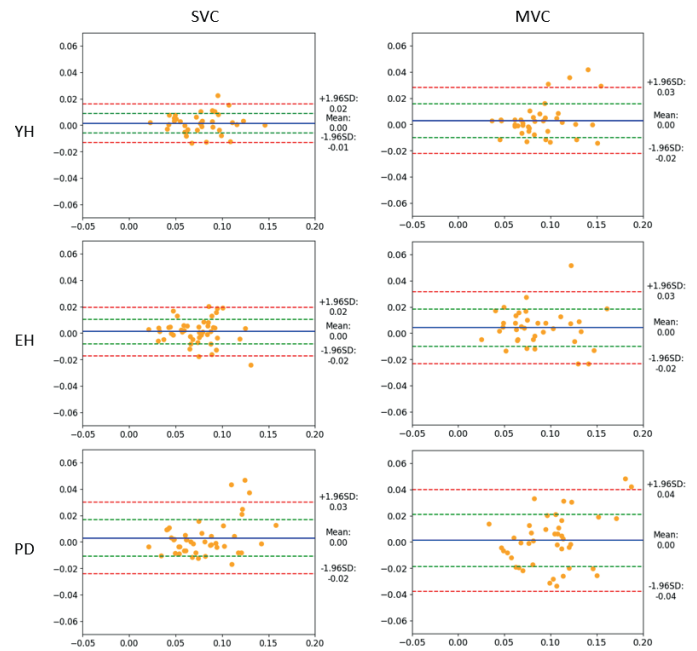


Figure 1. Bland-Altman plots showing the margin-of-stability

Legend: Obtained with the two systems (mean values, in abscissa), against the difference between these two systems (in ordinate), for the young healthy adults (YH), elderly healthy adults (EH) and PD groups. Each point represents one trial for one participant. Reported are the absolute values obtained in the spontaneous (left) and maximum (right) velocity conditions (SVC and MVC, respectively). For each plot, the 95% limits of agreement (red dotted lines), standard deviation (green dotted line) and bias (blue full line) are shown.

4. Conclusions

Results of the present study add to the growing body of evidence in the literature that markerless motion capture system is a sufficiently reliable tool to investigate gait initiation biomechanical features in healthy participants and patients with Parkinson's disease patients (Simonet *et al.* 2024). This statement may have important

implications in both clinical and laboratory settings due to the ease of use of markerless motion capture system compared to force plate system.

Conflicts of Interest

All authors state that they have no financial or personal relationships with other people or organizations that could inappropriately influence (bias) their work.

References

- Hof, A. L., Gazendam, M. G. J., & Sinke, W. E. (2005). The condition for dynamic stability. *Journal of Biomechanics*, 38(1), 1–8. <https://doi.org/10.1016/j.jbiomech.2004.03.025>
- Kanko, R. M., Laende, E. K., Davis, E. M., Selbie, W. S., & Deluzio, K. J. (2021). Concurrent assessment of gait kinematics using marker-based and markerless motion capture. *Journal of Biomechanics*, 127, 110665. <https://doi.org/10.1016/j.jbiomech.2021.110665>
- Simonet, A., Delafontaine, A., Fourcade, P., & Yiou, E. (2024). Vertical Center-of-Mass Braking and Motor Performance during Gait Initiation in Young Healthy Adults, Elderly Healthy Adults, and Patients with Parkinson's Disease: A Comparison of Force-Plate and Markerless Motion Capture Systems. *Sensors* (Basel, Switzerland), 24(4), 1302. <https://doi.org/10.3390/s24041302>
- Winter, D. A. (2009). *Biomechanics and Motor Control of Human Movement*. John Wiley & Sons.
- Yiou, E., Artico, R., Teyssedre, C. A., Labaune, O., & Fourcade, P. (2016). Anticipatory Postural Control of Stability during Gait Initiation Over Obstacles of Different Height and Distance Made Under Reaction-Time and Self-Initiated Instructions. *Frontiers in Human Neuroscience*, 10, 449. <https://doi.org/10.3389/fnhum.2016.00449>
- Yiou, E., Caderby, T., Delafontaine, A., Fourcade, P., & Honeine, J.-L. (2017). Balance control during gait initiation: State-of-the-art and research perspectives. *World Journal of Orthopedics*, 8(11), 815–828. <https://doi.org/10.5312/wjo.v8.i11.815>