Markerless Gait Analysis Using Single-Camera: Validation of a Novel System Against 3D Motion Capture

Omid Safarzadeh[1], Mahsa Tajik[1], Reza Rezaeian[1], Hossein Bodaghi[1], Ali Alirezazadeh[1], Mohammadreza Zarei[1], Ali Kiapour[2], Santiago A. Lozano Calderon[2]

[1]FlexiTrace Research Team, [2]Massachusetts General Hospital, Harvard

1. Abstract

The study validates the FlexiGait-P1 system, a single-camera, computer vision-based gait analysis tool, against the gold-standard 3D motion capture system, Vicon, by evaluating its accuracy in extracting spatiotemporal parameters. More information is available at: https://www.flexitrace.com/

2. Highlights

Challenge: Traditional gait analysis requires expensive 3D motion capture labs with complex setup and operation, limiting widespread clinical application.

Motivation: Leveraging AI technology and 3D computer vision to develop an accessible, affordable gait analysis solution using a single camera, such as a smartphone.

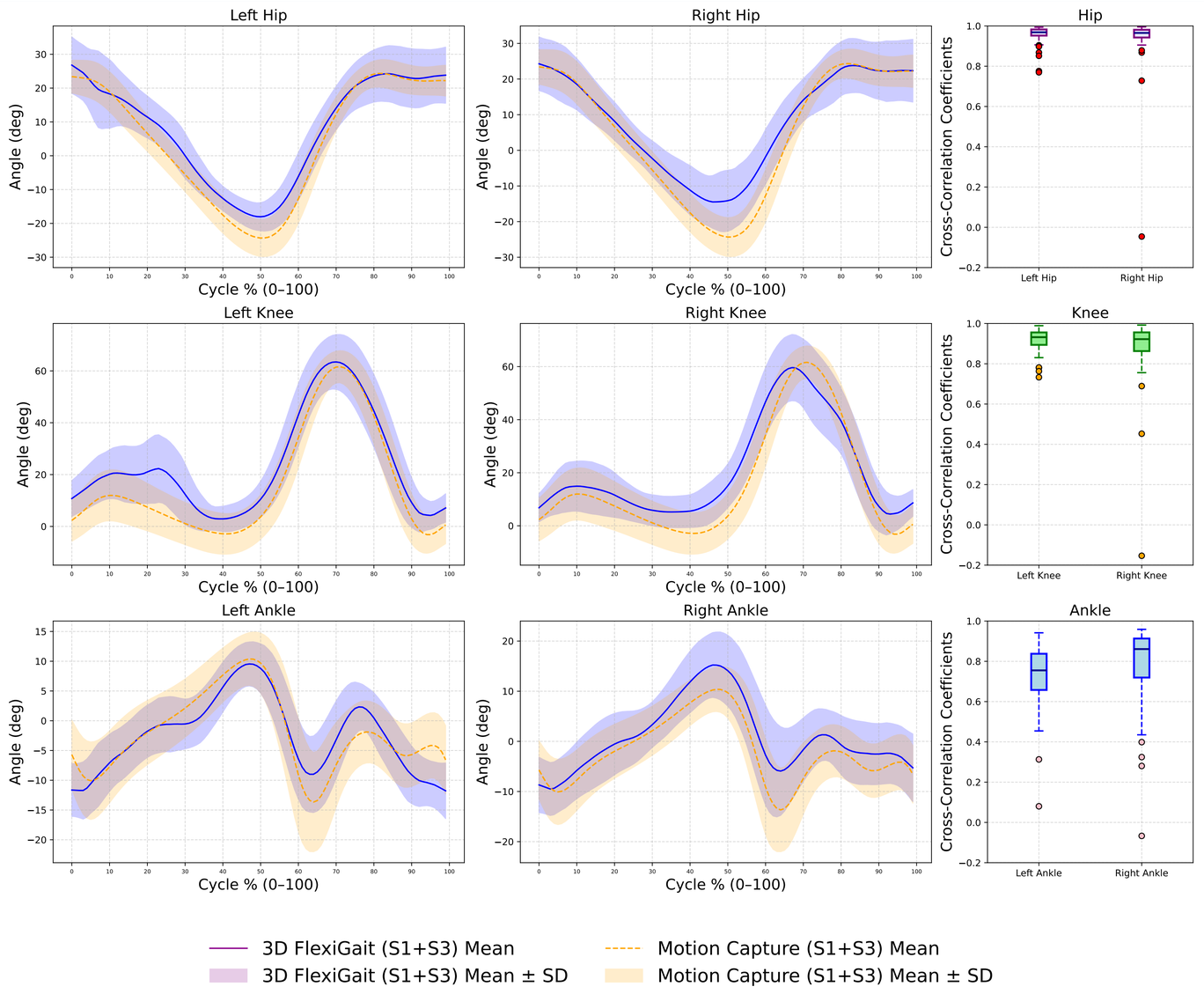
Key Contributions:

- FlexiGait-P1 demonstrates that computer vision techniques can reliably extract comprehensive gait parameters from single-camera video
- System accurately extracts joint angles (knee, ankle, hip) and kinematic parameters
- Makes clinical-grade gait analysis accessible outside specialized laboratories

3. Method

We analyzed data from 31 participants in the GPJATK [1] dataset. The FlexiGait-P1 system used video-based pose estimation to calculate key gait parameters, including stance, swing, step, and stride times. These were compared to Vicon outputs using statistical analyses, including mean absolute errors (MAE), intraclass correlation coefficients (ICC), and Bland-Altman plots.

4. Results (Joint Angles)



Comparison of Joint Angle Plots from FlexiGait-P1 and MoCap Systems

5. Results (Kinematic Parameters)

	Leg	N	FlexiGait-P1	Automated Gait	(|Mocap–FlexiGait-P1|)
			Mean ± SD	Mean ± SD	Mean ± SD
Stance time(s)	L	62	0.78 ± 0.08	0.79 ± 0.10	0.05 ± 0.03
	R	62	0.79 ± 0.13	0.76 ± 0.13	0.08 ± 0.08
Swing time(s)	L	62	0.43 ± 0.05	0.41 ± 0.05	0.04 ± 0.02
	R	62	0.42 ± 0.09	0.41 ± 0.04	0.07 ± 0.06
Step time(s)	L	62	0.60 ± 0.09	0.61 ± 0.08	0.04 ± 0.05
	R	62	0.62 ± 0.07	0.59 ± 0.07	0.03 ± 0.03
Stride time(s)	L	62	1.21 ± 0.12	Not Reported	0.04 ± 0.03
	R	62	1.21 ± 0.13	Not Reported	0.03 ± 0.03
Swing phase (%)	L	62	0.35 ± 0.02	Not Reported	0.04 ± 0.02
	R	62	0.35 ± 0.07	Not Reported	0.06 ± 0.06
Stance phase (%)	L	62	0.65 ± 0.02	Not Reported	0.04 ± 0.02
	R	62	0.65 ± 0.07	Not Reported	0.06 ± 0.06

Descriptive statistics of temporal gait parameters measured by the Vicon motion capture system (MoCap), FlexiGait-P1, and Automated Gait [2], including stance time, swing time, step time, and stride time for the left (L) and right (R) legs. The table presents the mean ± standard deviation (SD) for each system, along with the mean differences between MoCap and FlexiGait. N represents the number of videos two times of subjects. Two sessions with the left to right camera were used.

6. Conclusions

- **Accuracy:** FlexiGait-P1 demonstrated excellent agreement with Vicon, particularly for stride time (ICC = 0.98) and cadence (ICC = 0.96).
- **Reliability:** Minimal bias observed for step time (mean difference = 0.01 seconds), indicating strong consistency.
- **Precision:** Joint kinematics captured effectively with deviations below 5°.
- **Versatility:** Suitable for clinics, research labs, and outdoor settings due to low resource requirements and adaptability.

Demo Videos

7. References

[1] Bogdan Kwolek, Agnieszka Michalczuk, Tomasz Krzeszowski, Adam Switonski, Henryk Josinski, and Konrad Wojciechowski. *Multimedia Tools and Applications*, 78(22):32437–32465, 2019.

[2] Chang Soon Tony Hii, Kok Beng Gan, Nasharuddin Zainal, Norlinah Mohamed Ibrahim, Shahrul Azmin, Siti Hajar Mat Desa, Bart van de Warrenburg, and Huay Woon You. *Sensors*, 23(14):6489, 2023.