




Reply: “Human Pose Estimation Is Approximate: Limitations and Considerations for its Use in Clinical Trials”

Carlo Alberto Artusi, MD, PhD,^{1,2,*}  Christian Geroin, PhD,³  Serena Camozzi, PT,⁴ Stefano Aldegheri, PhD,⁵  and Nicola Bombieri, PhD⁵

We thank Dr. Kondo for the comments reported in his letter regarding our study on AutoPosturePD.^{1,2} We appreciate his perspective and acknowledge that the gold standard for identifying anatomical landmarks of spinal levels is instrumental, involving imaging methods such as X-ray, magnetic resonance imaging, or computed tomography. To date, direct measurement on the patient’s back by palpation-based identification of anatomical landmarks, even when performed by trained medical professionals, is practical but has demonstrated limited accuracy.³ Therefore, while the spinal level can be identified using one or more of these modalities, the major advantage of AutoPosturePD, based on the Human Pose Estimation (HPE), lies in its ability to automatically detect the angles of axial postural abnormalities according to the recently proposed measurement methods and diagnostic criteria.⁴

In our previous study,⁵ we validated AutoPosturePD against the “gold standard” (manual measurement), demonstrating low margins of error, with intraclass correlation coefficients above 0.9 and a mean difference compared to the anatomical landmark assessment of $0.6 \pm 3.1^\circ$ for lateral trunk flexion, $0.3 \pm 2.5^\circ$ for anterior trunk flexion with thoracic fulcrum, and $1.3 \pm 1.8^\circ$ for anterior trunk flexion with lumbar fulcrum.⁵ Because such validation confirms the high accuracy of AutoPosturePD relative to the gold standard (assuming in-person anatomical landmark assessment is considered the gold standard for this type of evaluation), we see no reason why it should not be considered a viable outcome measure in future clinical trials. Of course, this should ideally be preceded by further validation in a larger PD population, as well as external validation by independent groups using different datasets.

In fact, while it is true that AutoPosturePD measurements are derived from computational models,⁶ this is also the case for many

widely accepted clinical tools. Many commonly used “derived” measures, such as gait analysis with wearable inertial sensors, are now being incorporated into clinical trials after validation against gold-standard counterparts (eg, infrared motion capture).

AutoPosturePD’s primary advantage in assessing axial postural abnormalities in PD lies in its ability to provide a time-efficient, automated measurement that can be performed remotely. This is particularly relevant in clinical and research settings where in-person evaluations may not always be feasible.

Over the past decade, technological advancements in Deep Learning applications for video analysis have significantly improved the accuracy of human keypoint prediction, leading to the widespread adoption of HPE software for human motion analysis. Beyond traditional application domains such as sports performance analysis, human-robot interaction, and gesture recognition, numerous research studies have implemented this computer vision technology for clinical applications. A common perspective across these studies is that motion analysis using HPE software represents a very near future in trials and clinical practice.

In conclusion, we appreciate the discussion on this topic and believe that, as technology evolves, automated tools like AutoPosturePD can complement traditional assessments, ultimately enhancing accessibility and efficiency in both clinical practice and research settings.

Author Roles

All authors have participated in the article preparation. All authors have approved the final submitted article. This article

¹Department of Neuroscience “Rita Levi Montalcini”, University of Turin, Turin, Italy; ²Neurology 2 Unit, A.O.U. Città della Salute e della Scienza di Torino, Torino, Italy; ³Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy; ⁴Neurology Unit, Movement Disorders Division, Department of Neurosciences Biomedicine and Movement Sciences, University of Verona, Verona, Italy; ⁵Department of Computer Science, University of Verona, Verona, Italy

*Correspondence to: Dr. Carlo Alberto Artusi, Department of Neuroscience “Rita Levi Montalcini”, University of Turin, Turin, Italy; E-mail: carloalberto.artusi@unito.it

Keywords: postural abnormalities, pisa syndrome, camptocormia, Parkinson’s disease, quantitative assessment.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Received 20 March 2025; accepted 18 February 2025.

Published online 00 Month 2025 in Wiley Online Library ([wileyonlinelibrary.com](https://www.wileyonlinelibrary.com)). DOI: 10.1002/mdc3.70075

represents original work by the authors, has not been published elsewhere, and is not under consideration for publication elsewhere. (1) Research Project: A. Conception, B. Organization, C. Execution; (2) Statistical Analysis: A. Design, B. Execution, C. Review and Critique; (3) Manuscript Preparation: A. Writing of the first draft, B. Review and Critique.

C.A.A.: 1A, 1C, 3A, 3B

C.G.: 1B, 1C, 3A, 3B

S.C.: SA: 1C, 3B

S.A.: 1C, 3B

N.B.: 1A, 1B, 3B

Disclosures

Ethical Compliance Statement: The authors confirm that the approval of an institutional review board was not required for this work. Informed consent was not obtained as no patients were involved. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this work is consistent with those guidelines.

Funding Sources and Conflict of Interest: None.

Financial Disclosures for the Previous 12 Months: CAA received speaker honoraria from Abbvie, Bial, Zambon, Lusofarmaco. CG reports no financial disclosures. SC reports no

financial disclosures. SA reports no financial disclosures. NB reports no financial disclosures. The authors declare that there are no additional disclosures to report.

Data Availability Statement

No data to be shared. ■

References

1. Kondo Y. Human pose estimation is approximate: limitations and considerations for its use in clinical trials. *Mov Disord Clin Pract* 2025.
2. Artusi CA, Geroin C, Pandino C, et al. Dynamic video assessment of axial postural abnormalities in Parkinson's disease: a pilot study. *Mov Disord Clin Pract* 2025.
3. Robinson R, Robinson HS, Bjorke G, Kvale A. Reliability and validity of a palpation technique for identifying the spinous processes of C7 and L5. *Man Ther* 2009;14:409–414.
4. Tinazzi M, Geroin C, Bhidayasiri R, et al. Task force consensus on nosology and cut-off values for axial postural abnormalities in parkinsonism. *Mov Disord Clin Pract* 2022;9:594–603.
5. Artusi CA, Geroin C, Imbalzano G, et al. Assessment of axial postural abnormalities in parkinsonism: automatic picture analysis software. *Mov Disord Clin Pract* 2023;10:636–645.
6. Aldegheri S, Artusi CA, Camozzi S, et al. Camera- and viewpoint-agnostic evaluation of axial postural abnormalities in people with Parkinson's disease through augmented human pose estimation. *Sensors* 2023;23:3193.