Towards Equitable Biomechanics:
Rethinking Vision-Based Biomechanics for Resource-Limited Settings with Resourceful Design Strategies

Rune Chi Zhao[1,2]; Xiuyuan Yuan[1,2]
[1]Student Conference Access Network [2]Equal Contribution

SCAN Student Conference Access Network

CVPR JUNE 3-7, 2026 DENVER COLORADO

Introduction

Advances in computer vision (CV) and machine learning (ML) have significantly furthered the field of biomechanics, enabling the design of valuable clinical applications such as rehabilitation monitoring, gait assessment, and musculoskeletal evaluation.

However, the benefits brought by these advances have not been equitably distributed. Many current systems are designed and validated in well-resourced, and high-income healthcare environments, often assuming access to stable connectivity, specialised equipment, controlled conditions, and technical expertise.

Resource-limited settings (RLS) need different design priorities. RLS include low- and middle-income countries (LMIC), as well as rural, remote, underserved, and marginalized communities in high-income countries where healthcare access is constrained by infrastructure, workforce shortages, geography, poverty, or exclusion. Thus, these are also the settings that that possess the greatest burden of disease and the most urgent need for improvements in quality of healthcare.

If the field continues to optimise for benchmark performance in ideal settings, vision-based biomechanics may improve care only where resources are already abundant, leading to the risk of disparity amplification. We argue for a shift toward more resource-aware, implementation-focused, and equitable design.

Challenges and Limitations for Resource-Limited Settings

Infrastructure Assumptions

Many systems are reliant upon and therefore assume access to multiple cameras, specialist equipment, cloud processing, high compute, and reliable internet. These assumptions are difficult to meet in many rural, remote, and under-resourced environments.[1]

Complex Operational Requirements

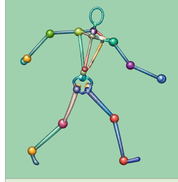
Systems often require careful setup, calibration, lighting and technical quality control, and trained users. This makes them hard to use in community clinics, home rehabilitation settings, or by non-specialist health workers.[2]

Bias and Limited Representation

Models trained on narrow datasets may not generalise to the diverse bodies, clothing, environments, movement patterns, and clinical needs in RLS.[3] In RLS, there is a severe lack of local data, as well as limited validation capacity and specialist oversight, so biased performance can more likely lead to unreliable outputs.

Therefore, the challenge is not only to build more accurate models, but to design systems that can work under real constraints. The design strategies on the right explore how vision-based biomechanics can become more accessible, robust, and deployable in RLS.

Resourceful Design Strategies



Pose-First Biomechanics Pipelines

Convert video into skeletal keypoints for downstream analysis.

- Reduces storage and bandwidth by avoiding continuous raw video use
- Better suited to intermittent connectivity and limited device storage
- Could avoid long-term storage of identifiable video data
- May reduce privacy risks, but still requires explicit governance for data protection, privacy regulations

Smartphone-First Biomechanics

Use phones as the primary sensing platform.

- Builds on existing mobile access instead of requiring new lab systems, reducing cost
- Combines camera, sensors, and local processing into a device that most are familiar with
- Enables lower-cost assessment in clinics, homes, and field settings
- Current studies demonstrate the potential of smartphone-first biomechanics, e.g. OpenCap[4]

Low-Frame-Rate and Imperfect-Video Biomechanics

Design for lower-quality real-world video.

- Design systems that still work on lower quality videos, such as those produced by lower-cost devices or due to suboptimal conditions
- Exploring alternative such as frame interpolation to compensate for reduced resolution[5]
- Imperfect but robust systems could still support screening, triage, follow-up, and rehabilitation monitoring, but must be transparent about uncertainty

Low-Bandwidth & Local-First Processing

Run analysis on-device where possible.

- Adopt local-first processing architectures (for example BlazePose[6]), in which pose estimation and biomechanical feature extraction occur directly on-device
- Only transfer compact skeletal trajectories or derived features when connectivity is available
- Reduces dependence on cloud upload and stable internet connections

Community-Based Deployment

Design for those who will actually use it

- Simplify workflows for non-specialists such as community health workers and carers
- Successful deployment depends heavily on usability, training burn, workflow fit, and community acceptance
- For a technology to be successful, it cannot just be deployed, instead it must be trusted, accepted, and then used

Future Directions

1. **Design and validate applications for RLS**
   Build context-specific and limitation-aware applications for RLS, and test in the real settings where possible
2. **Benchmark robustness, not just accuracy**
   Evaluate performance under conditions like low frame rates, poor lighting, occlusion, low-resolution video, and intermittent connectivity.
3. **Evaluate fairness and representation**
   Test whether systems work across different populations and produce more varied and unbiased datasets that reflect RLS groups.
4. **Co-design with local users and communities**
   Work together with local clinicians, community health workers, patients, families, and health institutions
5. **Strengthen governance and privacy**
   Prioritise and protect local data ownership, informed consent, minimal data transmission, and transparent use of movement data.

Key Message

Rather than waiting for technologies to gradually diffuse into lower-resource contexts, we should rethink how biomechanical systems are designed and deployed and as a field, more actively explore more creative and resourceful design strategies.

In many cases, a slightly less precise system that is affordable, usable, and locally deployable may deliver far greater real-world impact than a technically superior system that remains inaccessible.

Ultimately, progress in vision-based biomechanics should be judged not only by benchmark performance, but by whether systems can be implemented responsibly and sustainably in the contexts they are intended to serve.

If vision-based biomechanics is to realize its full societal potential, it must be designed not only to perform well in ideal conditions, but to function effectively where it matters most.

Contact

Rune Chi Zhao
Email: runechizhao@gmail.com

References

Images created using Canva.com (Canva, 2026) or ChatGPT (OpenAI, 2026)
1.International Telecommunication Union. Facts and figures 2023
2.Borges do Nascimento IJ, et al. Barriers and facilitators to utilizing digital health technologies by healthcare professionals. NPJ Digit Med. 2023
3.Leo Anthony Celi, et al., Sources of bias in artificial intelligence that perpetuate healthcare disparities - A global review, PLOS Digital Health, 2022
4. Sean D. Uhlrich, et al. Opencap: Human movement dynamics from smartphone videos. PLOS Computational Biology, 2023.
5. Marcus Dunn, et al. Application of video frame interpolation to markerless, single-camera gait analysis. Sports Engineering, 2023.
6. Valentin Bazarevsky, et al. Blazepose: On-device real-time body pose tracking. arXiv preprint arXiv:2006.10204, 2020.