Verification of the measurement accuracy of marker-less motion analysis in evaluating single-leg squat movements after anterior cruciate ligament (ACL) reconstruction

Ayaka Tanaka[1], Tomoki Ohori[1], Akira Tsujii[2], Shuto Yamashita[1],

Toshitaka Tsunematsu[1], Shunya Otani[3], Seira Sato[4], Ken Nakata[5], Seiji Okada[1]

1) Department of Orthopaedic Surgery, The University of Osaka Graduate School of Medicine, Osaka, Japan
2) Sports Medical Biomechanics, The University of Osaka Graduate School of Medicine, Osaka, Japan
3) Department of Orthopaedic Surgery, Tokyo Women’s Medical University, Tokyo, Japan
4) Sports Medical Science, The University of Osaka Graduate School of Medicine, Osaka, Japan
5) Medicine for Sports and Performing Arts, The University of Osaka Graduate School of Medicine, Osaka, Japan

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COI Disclosure

Authors：◎A Tanaka, T Ohori, A Tsujii, S Yamashita, T Tsunematsu,

S Otani, S Sato, K Nakata, S Okada

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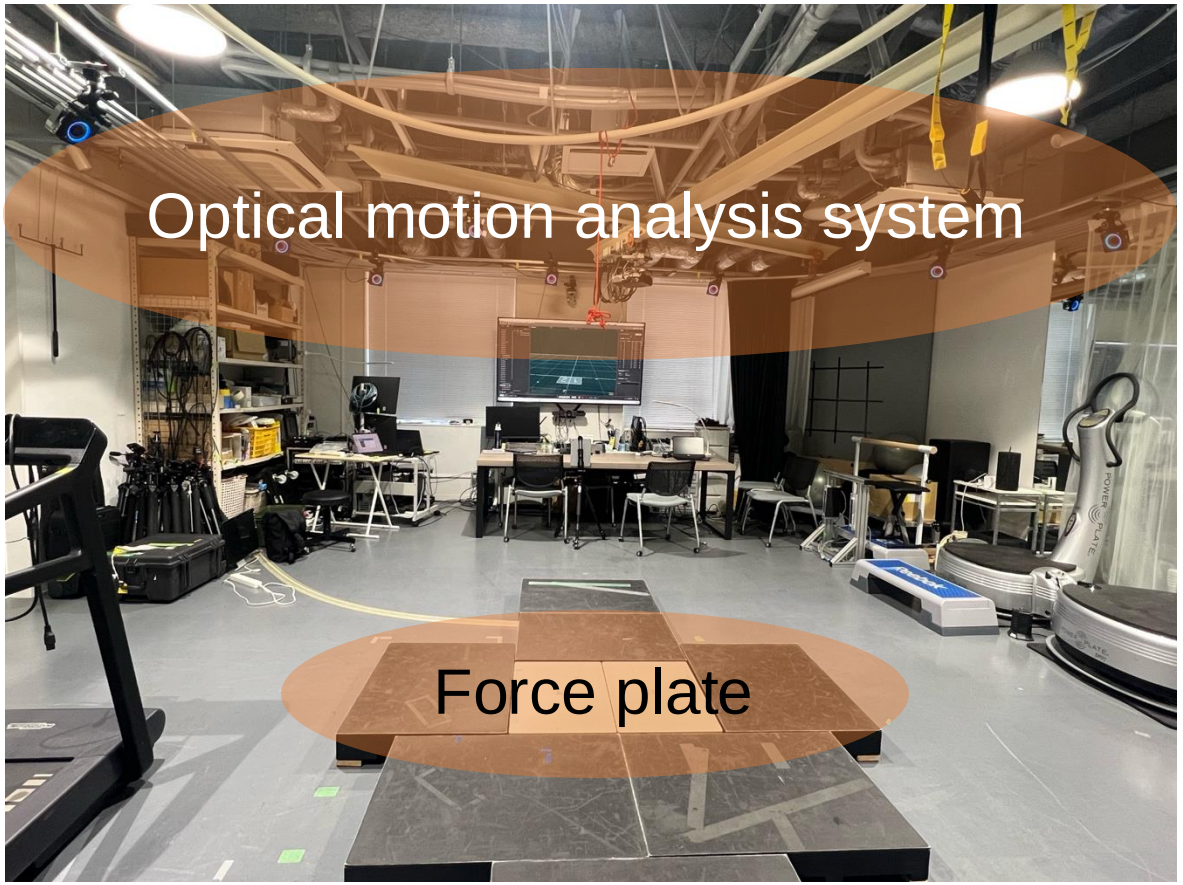
Marker-based motion analysis after ACLR

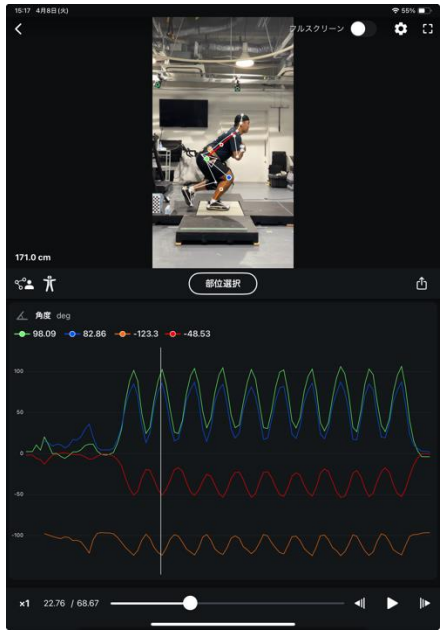


Advantage
-accuracy
-precision

Disadvantage
-laboratory environment
-expensive & special equipment
-time-consuming (set up, data analysis)

This is not suitable for analysis in clinical settings or sports fields.

Marker-less motion analysis system



- ✓ SPLYZA Motion: A marker-less motion analysis app. utilizing deep learning technology for image processing with artificial intelligence
- ✓ More accessible in clinical settings and on sports fields
- ✓ <u>The accuracy of this system has not been sufficiently validated.</u>

Purpose

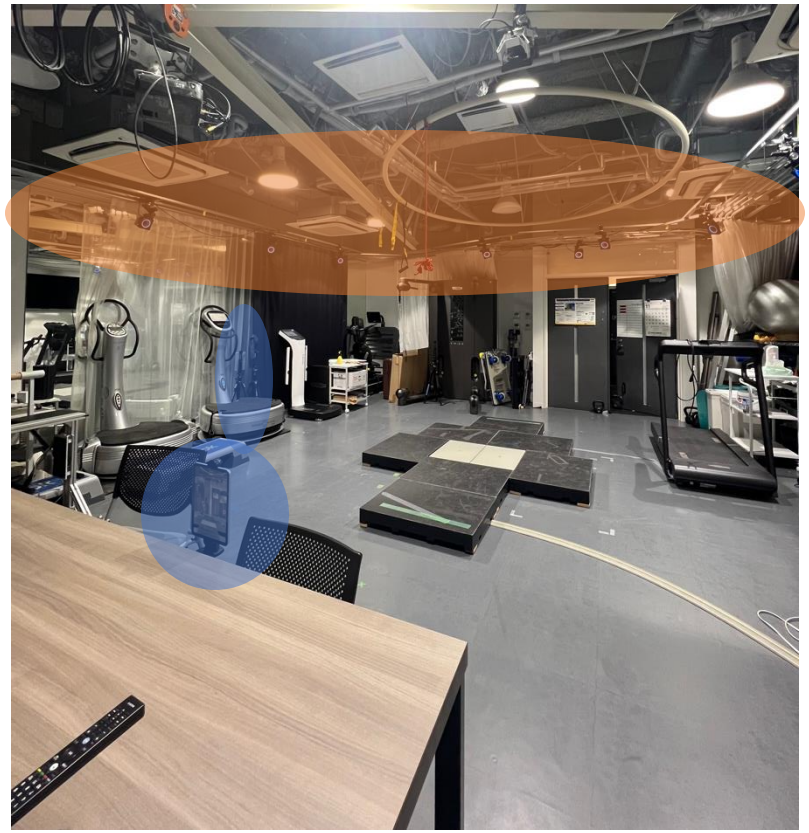
To verify the measurement accuracy of marker-less motion analysis system using SPLYZA app. compared with optical (marker-based) motion analysis system as a reference

Participants

7 patients who had undergone ACL reconstruction between October 2023 and July 2024 were involved.

Male/Female	4/3
Age [yrs., mean (range)]	21.6 (17–26)
Height [cm, mean (range)]	168.6 (155.5–187.0)
Weight [kg, mean (range)]	68.3 (51.3–95.0)
Tegner AS [mean (range)]	6.9 (3–10)

Measurement environment



marker-based

OptiTrack：360Hz

-14 cameras

-42 reflective markers

Data processing software：Motive

marker-less

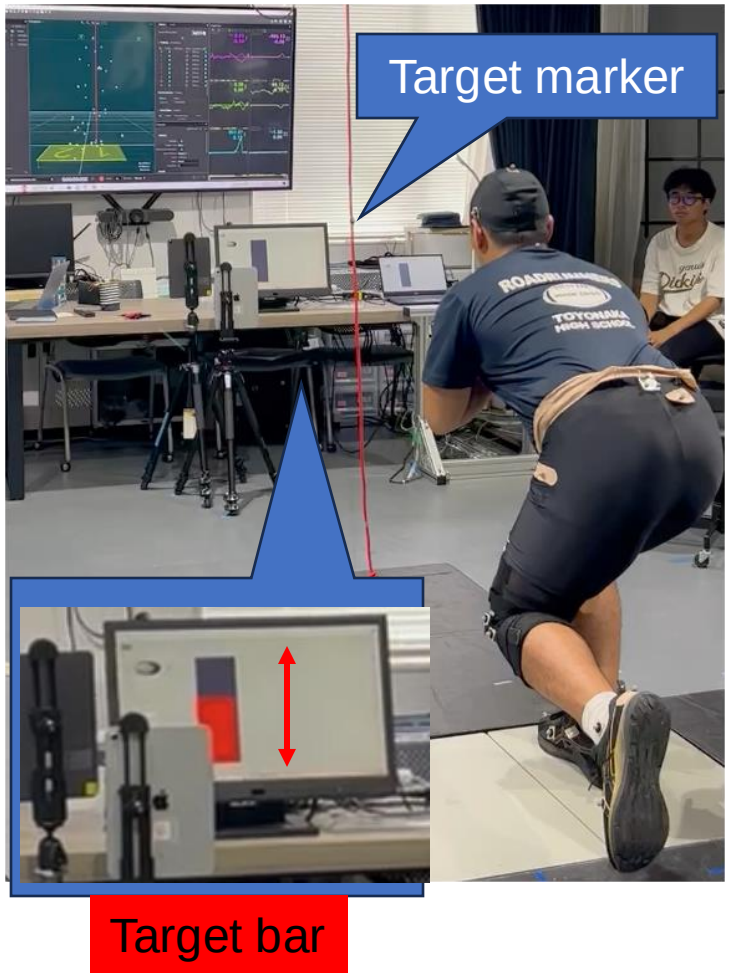
2 iPads (front, right side)：30Hz

-Height: 1 meter above the ground

-Distance: 3 meters from the subject

Data analysis：SPLYZA Motion app.

Movement: single-leg squat with target tracking



Repetitions	10 times
Range	From a standing position until the eye height drops to the level of the target marker which was positioned at 70% of the subject's height.
Speed	Single-leg squatting by following the up-down movement of the target bar on the front monitor -Slow (0.2Hz) -Fast (0.3Hz)

Data analysis

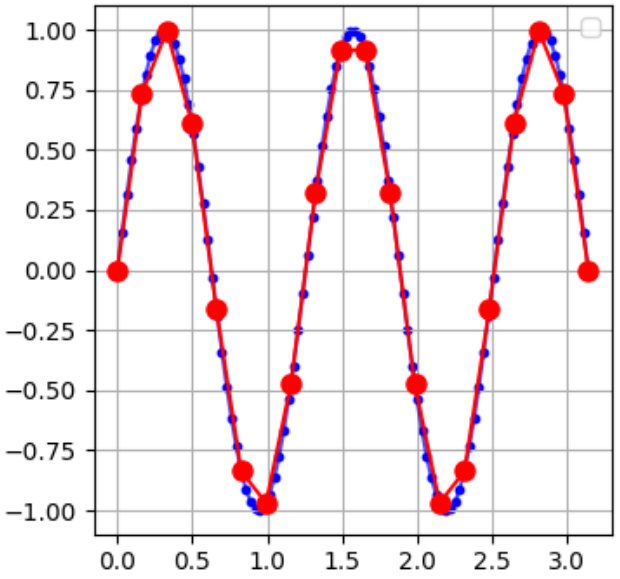
1) Hip flexion, 2) knee flexion, and 3) ankle dorsiflexion angle waveforms were calculated from 3D positional coordinates of optical motion analysis system via Motive, and automatically extracted by marker-less motion analysis app. (SPLYZA).

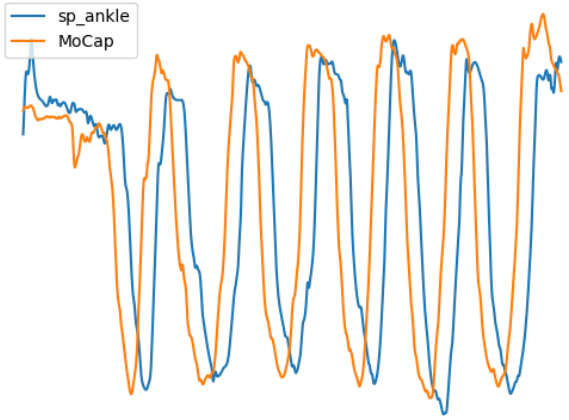
↓

Down-sampling of Motive data
（360Hz→30Hz）

↓

Correction for time offset





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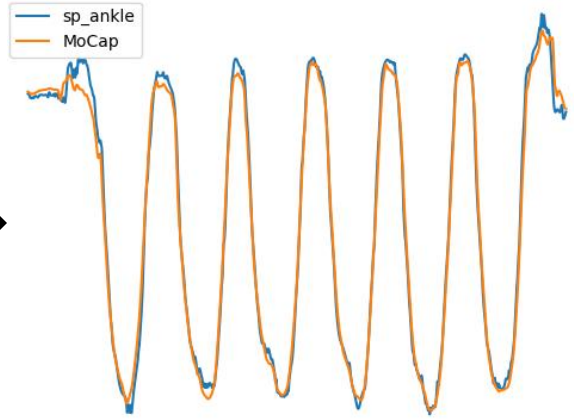
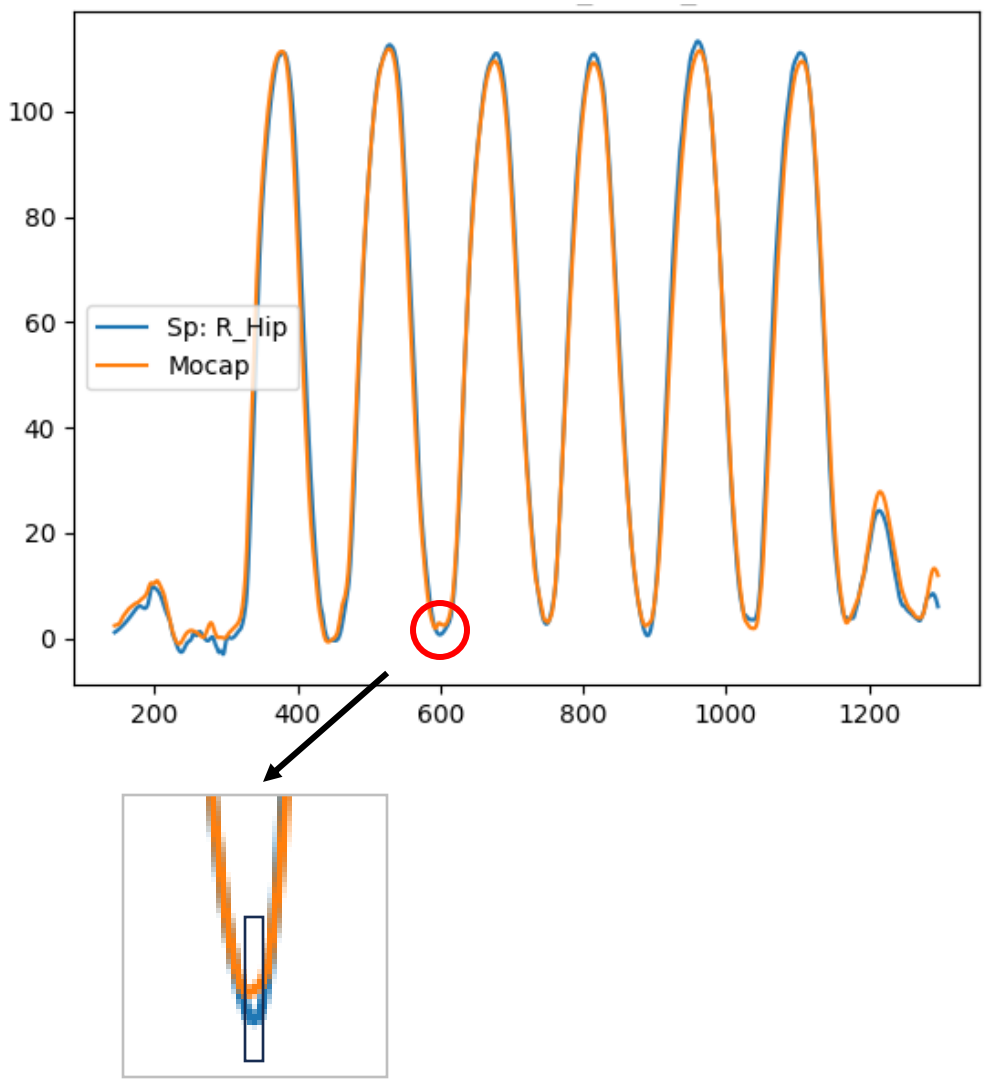


Assessment indicator



RMSE（Root Mean Squared Error）

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

- ✓ Mean difference between measured values and reference values
- ✓ Smaller values indicate higher accuracy.
- ✓ If the error is within 5˚, the system is considered applicable in practical settings.

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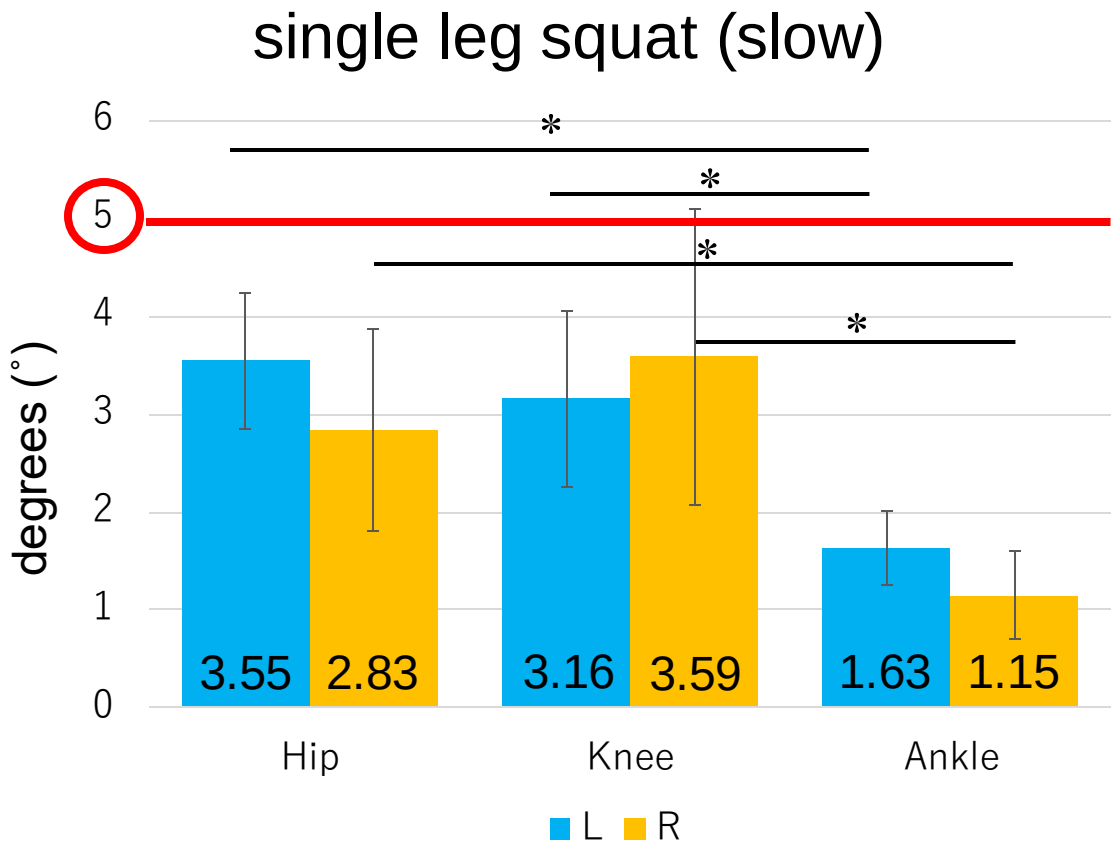
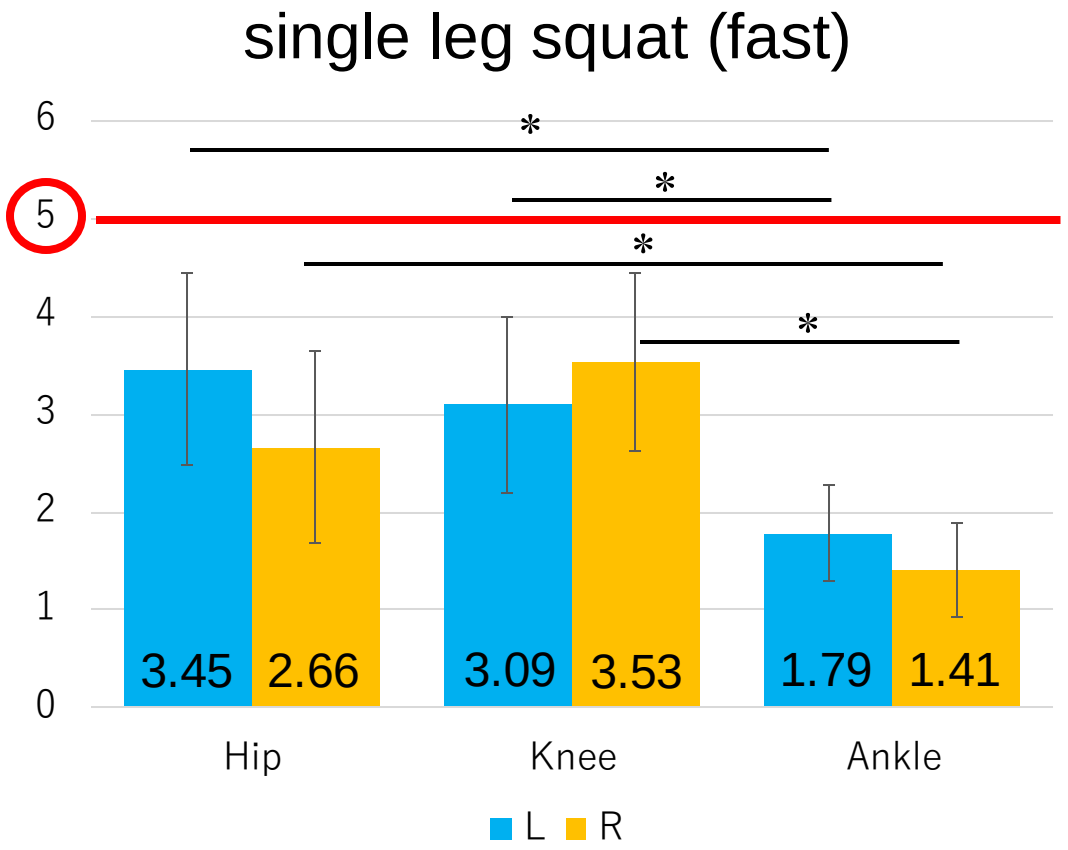
Results：RMSE





- ✓ RMSEs of marker-less motion analysis were within 5˚ for all the joint movements.
- ✓ RMSE of ankle dorsiflexion angle was significantly lower compared to those of hip flexion and knee flexion angles.

** statistical significance (Steel-Dwass test, $p<0.05$)*

Discussion

① Accuracy of marker-less motion analysis

✓ RMSEs of analysis using this system were within 5˚, indicating sufficient accuracy.

✓ The results were consistent with those of the previous reports.

Song K, et al. *J Biomech 2023*
Turner JA, et al. *J Biomech 2024*

Further validation should be conducted for high-speed movements such as jumping.

② Differences of accuracy among the 3 joints

✓ The accuracy for ankle dorsiflexion was higher compared to those of hip flexion and knee flexion because the ankle joint might move in almost a single plane.

The accuracy of 3D identification of the joint position in marker-less motion analysis system (SPLYZA app.) needs to be improved.

Conclusions

- ✓ Marker-less motion analysis system via SPLYZA app. could provide sufficient accuracy in evaluating single-leg squat movements after ACL reconstruction, compared with optical (marker-based) optical system as a reference.
- ✓ The marker-less motion analysis system can have the potential to serve as an alternative to the marker-based system in evaluating the joint movements after ACL reconstruction.

References)
Turner JA, Chaaban CR, Padua DA. Validation of OpenCap: A low-cost markerless motion capture system for lower-extremity kinematics during return-to-sport tasks. *J Biomech 2024; 171: 112200.*
Song K, Hullfish TJ, Scattone Silva R, et al. Markerless motion capture estimates of lower extremity kinematics and kinetics are comparable to marker-based across 8 movements. *J Biomech 2023; 157: 111751.*