OrthoLoad Club
Science for Orthopaedics

OrthoLoad Lab

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Report: Validation Study – Re.flex

Aim of the Study

The aim of this study is a validation of the sensor-based mobile physiotherapy system Re.flex with the gold standard of accuracy for movement analyses.

Methods

Several optical motion capture systems are used worldwide in numerous fields and are the gold standard systems in biomechanical and sport kinematic studies. In this study, we compared the accuracy of the Re.Flex system, using the state of the art Vicon-Nexus system of the OrthoLoadLab. With this optoelectronic motion capture system we are able to collect the placements of the used optical markers within an accuracy of up to 0.3mm. Afterward the collected three dimensional positions of the optical markers were used to calculate the movement angles of the upper and lower leg.

Figure 1: OrthoLoadClub Vicon-Nexus System

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Description of the Re.Flex System

Re.Flex develops digital care programs, for people that need physical therapy for knee arthrosis pain, post-op knee ligaments, post-op total/partial knee replacement, and lower back pain. The system is based on two motion tracking sensors, connecting via Bluetooth to a mobile device.

The mobile app offers patients motion sensor assisted 3D real-time visualization of their injured leg, and guidance to complete their personalized recovery protocol, which is based on a database of 300+ detectable exercises.

The motion sensing devices can be placed randomly above and below the patient's affected joint. The patient doesn't have to fix them in a certain position; the calibration algorithm detects the actual positioning and ensures that the orientations of the sensors are related to the actual physical axis of rotation of the join. During the training a muscle compensation algorithm corrects for the sensors movement on the body due to muscle tissue.

The metrics that the Re.Flex solution uses to evaluate the overall performance of the patient while exercising are:

- Knee flexion/extension, hip flexion/extension and abduction/adduction angles
- Speed and timing of the repetition
- Time spent in an isometric position
- Training time and rest times
- Progress of flexion before and after training
- Body rotation detection

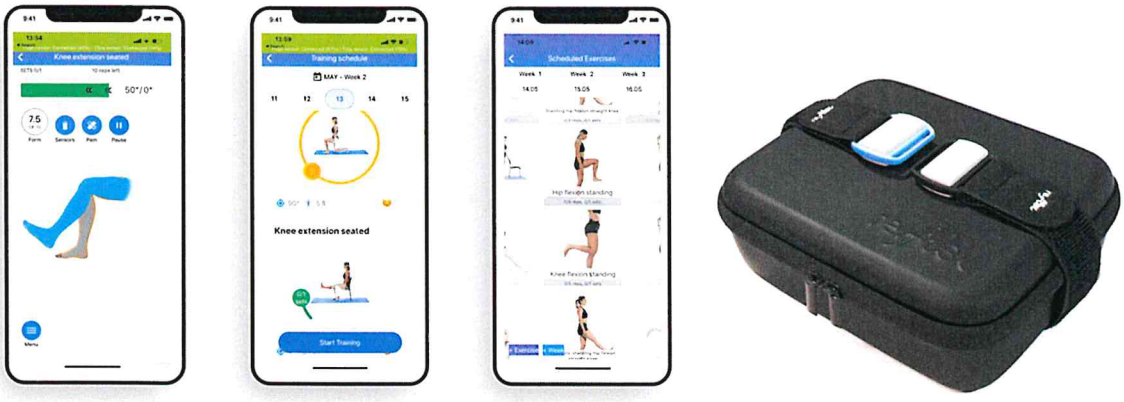

Fig 2 Re.Flex system consists in a set of two motion tracking sensors, a mobile application for patients and one for physical therapists and exercise protocol scheduling

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Calculation of the Movement Angles based on optoelectronic markers

The hip flexion and the hip abduction angle are both calculated between the z-axis of the laboratory and the femur vector. Hereby, the z-axis of the laboratory corresponds to the gravity vector. The knee flexion angle is calculated between the femur and tibia vector.

The femur vector in the Vicon System is based on the Markers LTHI and LKNEE or the RTHI and RKNE respectively and is positive in the proximal direction.

The tibia vector in the Vicon System is based on the markers LANK and LKNE or respectively the RANK and RKNE and is positive in proximal direction.

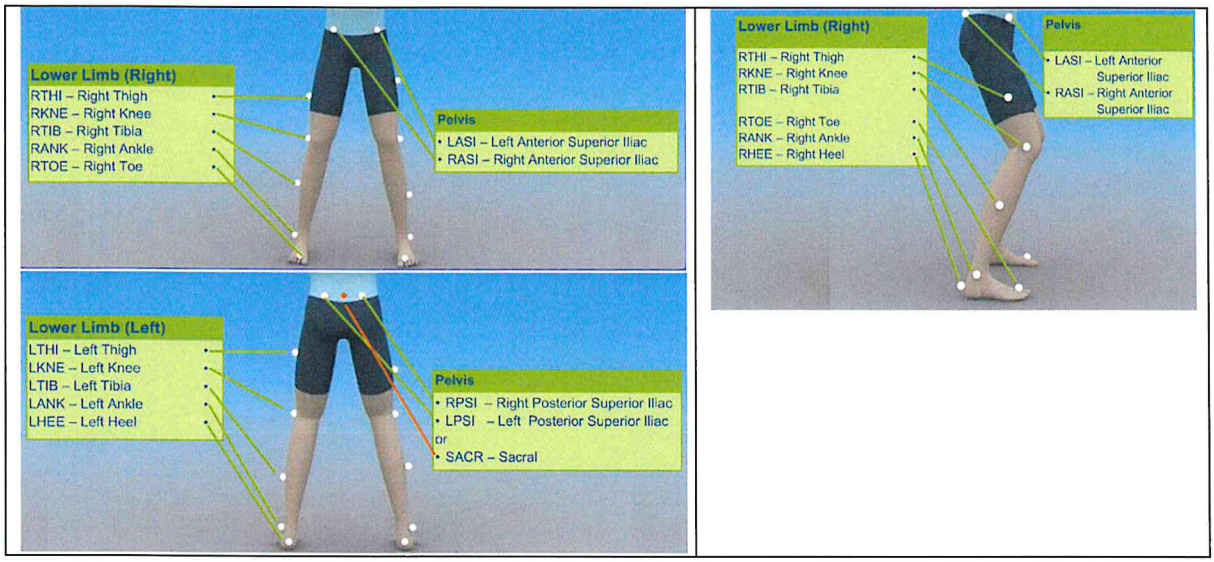

Figure 3: used Vicon Marker Setup

The origin of the Pelvic Coordinate System is located in the pelvic center (defined by the markers: LASI, RASI, RPSI, LPSI). The gravity vector is used as a normal vector for the horizontal plane also called transversal plane. The sagittal plane is normal to the vector from RASI and LASI. The third vector of this system is given by the cross product of both vectors. The angles of movement measured with the Vicon System will be given relative to these planes.

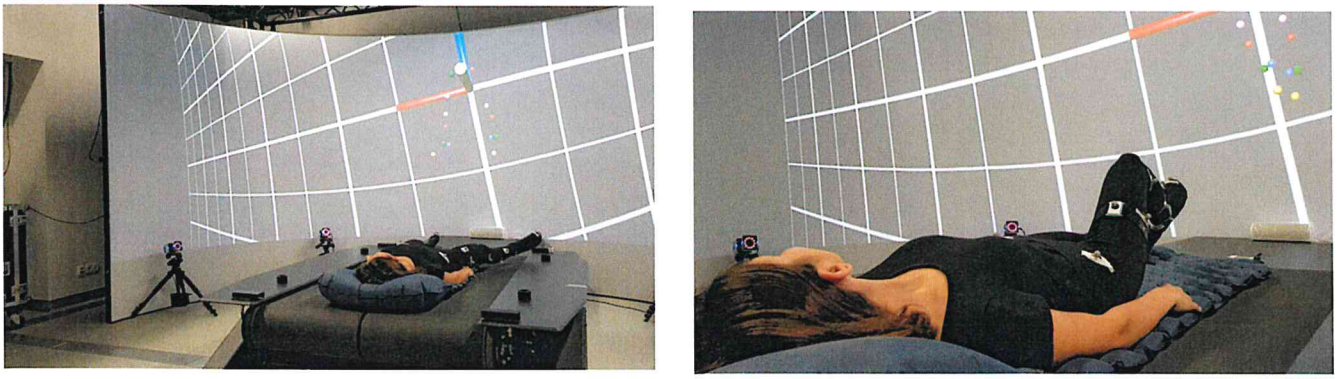

Figure 4: supine exercise with Re.Flex sensors and Vicon Markers placed on the affected joint

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Hip: Flexion/Extension angle between the femur vector and the gravity vector projected to the sagittal plane

Ab/Adduction angle between the femur vector and the gravity vector projected to the frontal plane

Knee: Flexion/Extension angle between the femur vector and the tibia vector projected to the sagittal plane

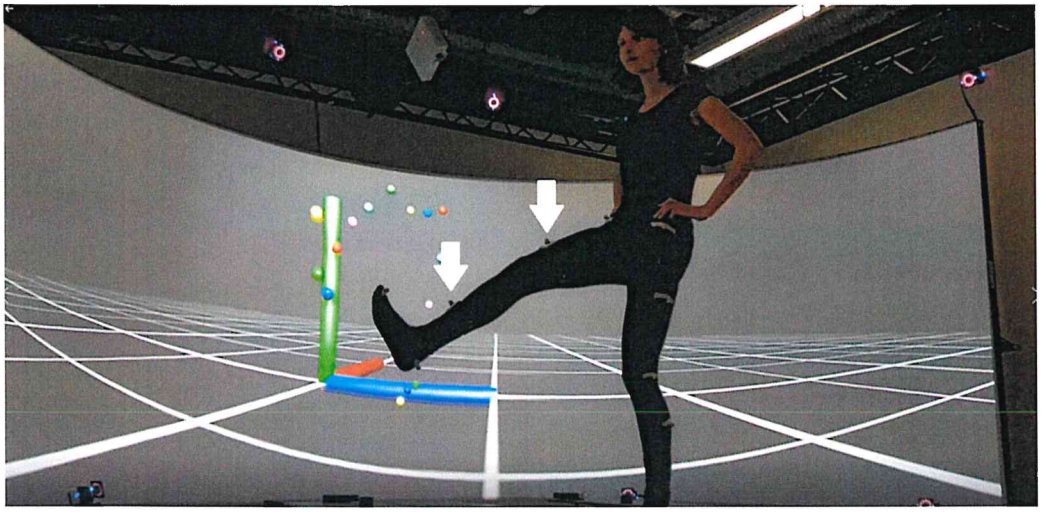

Figure 5: Re.Flex sensors placed randomly above and below the affected joint. The patient doesn't have to fix them in a certain position.

Investigated activities

I. Standing Position (One Legged Stance) – Activities were performed with unloaded leg

- Straight Hip: Knee Flexion/Extension
- Flexed Hip (~90°): Knee Flexion/Extension
- Flexed Hip (~60°): Knee Flexion/Extension
- Flexed Hip (~30°): Knee Flexion/Extension
- Straight Knee: Hip Flexion/Extension (~45°)
- Straight Knee: Hip Ab/Adduction (~30°)

II. Supine Position:

- Straight Knee: Hip Flexion/Extension (~45°)
- Straight Knee: Hip Ab/Adduction (~30°)
- Flexed Hip (~45°): Knee Flexion/Extension

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All trials were synchronized via a synchronization signal stored in the Vicon system and the length of the Vicon trial was cut to the length of the Re.Flex Trial. Gaps in the Re.Flex Trials were interpolated linearly. Each trial of both systems has been set to zero in the beginning to allow a better comparison of both systems.

Results

It could be shown that the differences between the angle of movement measured with the Vicon and synchronously measured with the Re.Flex system are less, especially for the hip joint.

For some of the values, where peak values are very low, there's little relevance on the percentage of error from the peak value (having 1 - 3 degrees difference translated to 17%-45% error in the table to the right when the peak value was 6-7 degrees) but the relevant value is how well the Re.Flex angle follows the Vicon one and what absolute difference there is on consistent variations between adjacent peaks.

	Delta [%]	
	Hip	Knee
Standing		
Knee Flexion	7.5	6.6
Hip Flexion	3.4	-17.2
Hip Abduction	-5.5	29.4
Hip (30°) - Knee Flexion	-10.7	8.0
Hip (60°) - Knee Flexion	-6.3	0.0
Hip (90°) - Knee Flexion	0.7	5.0
Lying		
Hip Flexion	-1.3	-14.1
Hip Abduction	-1.4	45.9
Hip and Knee Flexion	-3.4	-1.0

Joint flexion

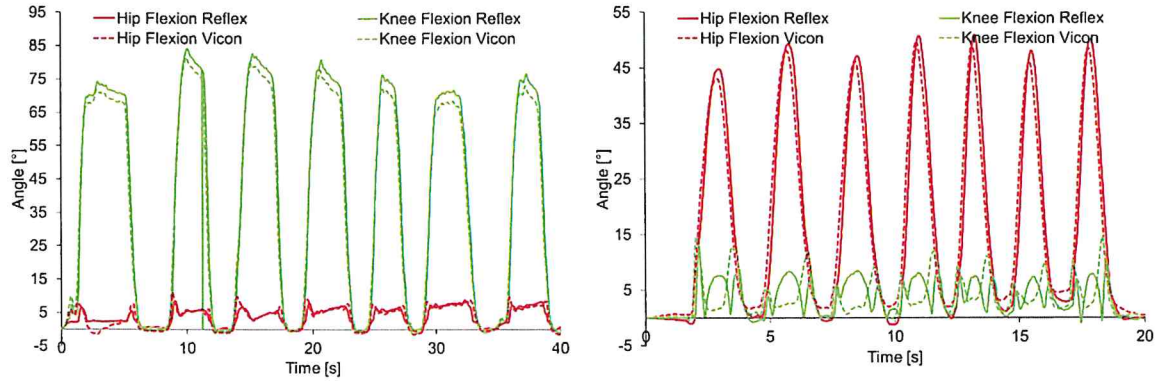

Figure 6: Knee flexion (left) and hip flexion (right) during standing

Knee flexion (Fig. 6 left)

- flex angle average delta on peaks, between 3.3 and 7.1 degrees (4.2% and 10.1%.). hip angle average delta between 0.9 and 2.3 degrees.

Hip flexion (Fig. 6 right)

- flex angle average delta on peaks, between 1.4 and 2.9 degrees. The hip angle average deltas vary between 1.3 and 2.2 degrees (0.7% to 1.2%).

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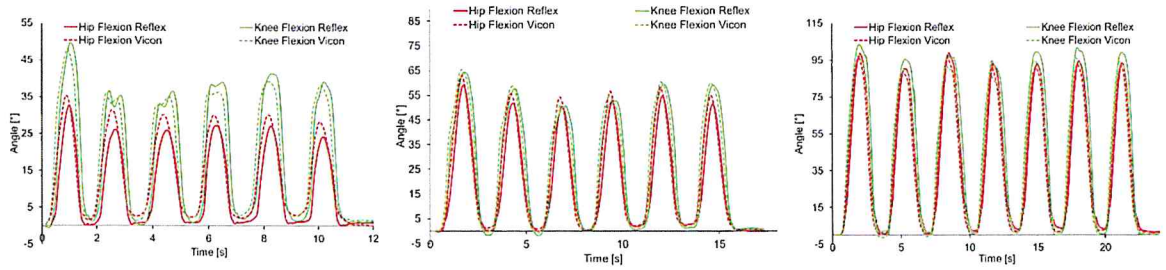

Figure 7: Hip and knee flexion during standing with 30deg (left), 60deg (middle) and 90deg hip flexion (right)

Hip and knee flexion 30 degrees (Fig. 7 left)

- flex angle average delta on peaks, between 1.6 and 5.6 degrees (4% and 16.5%).
- hip angle average delta between 2.8 and 3.9 degrees.

Hip and knee flexion 60 degrees (Fig. 7 middle)

- flex angle average delta on peaks, between 0.1 and 1 degrees (0.1% and 1.6%)
- hip angle average delta between 3.3 and 3.8 degrees (5.9% to 6.7%)

Hip and knee flexion 90 degrees (Fig. 7 right)

- flex angle average delta on peaks, between 3.4 and 5.7 degrees (3.6% and 5.6%)
- hip angle average delta between 0.7 and 2.2 (0.4% to 2.8% difference)

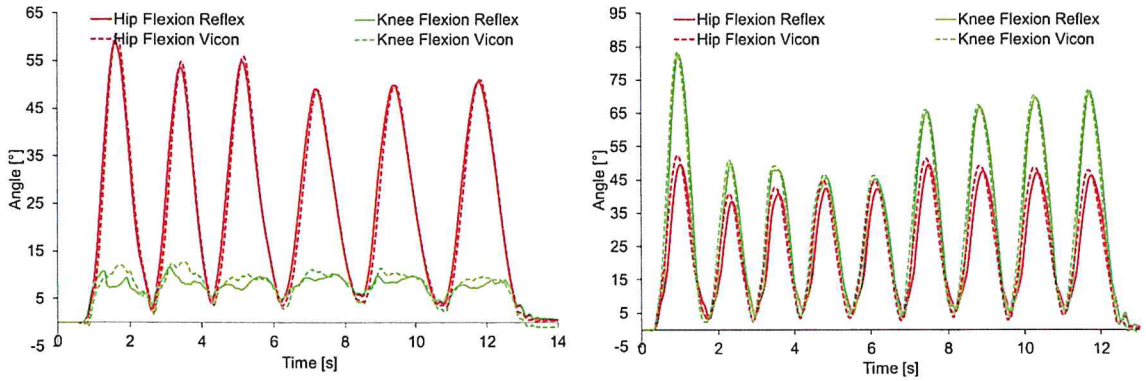

Figure 8: Hip flexion (left) and hip + knee flexion during supine (right)

Hip flexion supine (Fig. 8 left)

- flex angle average delta on peaks, between 1 and 2.9 degrees.
- hip angle average delta between 0.7 and 1.5 degrees which translates to 0.2% to 2.7% difference.

Hip and knee flexion supine (Fig. 8 right)

- flex angle average delta on peaks, between 0.2 and 1 degrees which translates to 0.3% to 1.5% difference
- hip angle average delta between 1 and 2.1 degrees which translates to 1.9% to 4.6% difference

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Joint abduction

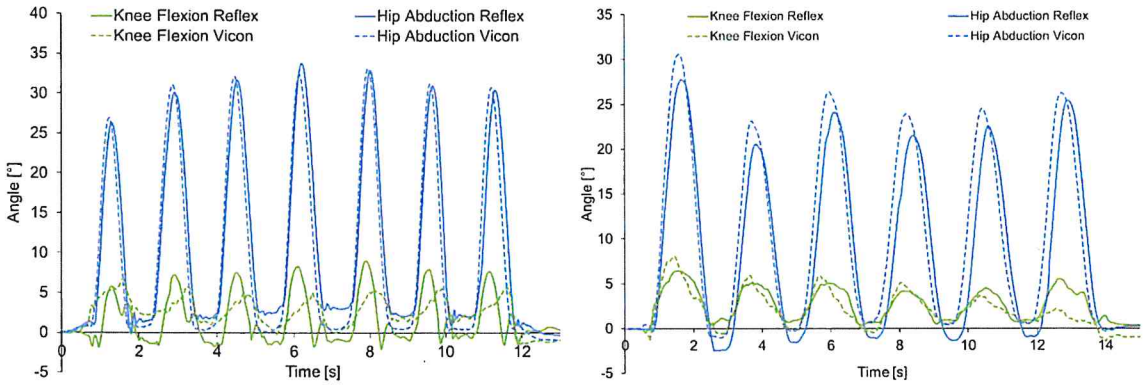

Figure 9: Hip abduction during standing (left) and during supine (right)

Hip abduction standing (Fig 9 left)

- flex angle average delta on peaks, between 1.3 and 2.9 degrees.

Hip abduction supine (Fig. 9 right)

- flex angle average delta on peaks, between 0.2 and 2.7 degrees

Conclusion

In summary the differences between the kinematic data collected with the Vicon System as a gold standard and the data of the Re.flex System are quite comparable for the activities of interest (table). However for some activities, where the joint related movements are low, the relative of error between Vicon and the Re.flex data increased drastically. Because in most of the cases these increase are happen only for the joint with less interest the error has a less influence to the results of interest. However, these data should be filtered within the Re.flex software.

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