WHITEPAPER

MARKERLESS MOTION ANALYSIS WITH AI-BASED IMAGE RECOGNITION-TECHNOLOGY

First results of the clinical validation

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STATUS QUO AND PERSPECTIVES THE MOVEMENT ANALYSIS

Manual angle measurement with the goniometer is still considered the clinical gold standard for testing the function of joints, for example in sports and rehabilitation medicine. This simple and inexpensive method achieves a measurement accuracy of ± 5° to 10°. However, only static, two-dimensional measurements are possible with the goniometer. In addition, the reliability is strongly dependent on the examiner (inter-rater reliability). In contrast, marker-based motion capture systems can be used for dynamic, three-dimensional motion analysis.[1] However, in addition to high acquisition costs, their use is complex. Furthermore, the markers also limit the application possibilities.[2]

This is where the latest development comes in: Markerless video analysis artificial intelligence (AI) - such as Orthelligent® VISION - allows for simple, cost-efficient and automated motion measurements with precise results, as this white paper shows.

PROFILE ORTHELLIGENT® VISION

Markerless motion analysis with Orthelligent® VISION

The AI-based, markerless image recognition technology of Orthelligent® VISION makes it possible to analyse and precisely assess movements based on videos.

Technical equipment

To use Orthelligent® VISION, you need a commercially available tablet with an integrated video camera and the Orthelligent® VISION app.

The measuring principle

The movement analysis with Orthelligent® VISION proceeds in the following three steps:

1. **Video/photo recording:** First, the movement sequence of a person is recorded as a video with the tablet camera (on device camera) - without attaching optical markers. A single video recording is often sufficient.
2. **Image recognition with AI:** Based on deep learning algorithms, a neural network and extensive annotated image data sets, Orthelligent® VISION uses the video recording to calculate 33 coordinate points, which indicate specific positions on the human body (pose estimation).
3. **Motion analysis:** On the basis of the determined coordinate points, Orthelligent® VISION analyses the movement and automatically supplies precise measurement results, for example on the functionality of joints or in the context of a gait analysis.

The advantages

Orthelligent® VISION offers these five advantages:

- Simple, fast and flexible application without markers and additional special cameras
- Precise, objective and robust measurements thanks to the latest AI-based image recognition technology
- Time advantages due to minimisation of patient preparation as well as fast, automated analysis - without manual evaluation
- Can be used without specially trained personnel
- Cost savings, as no additional equipment (markers, cameras) and specialist staff are required

PROFILE ORTHELLIGENT® VISION

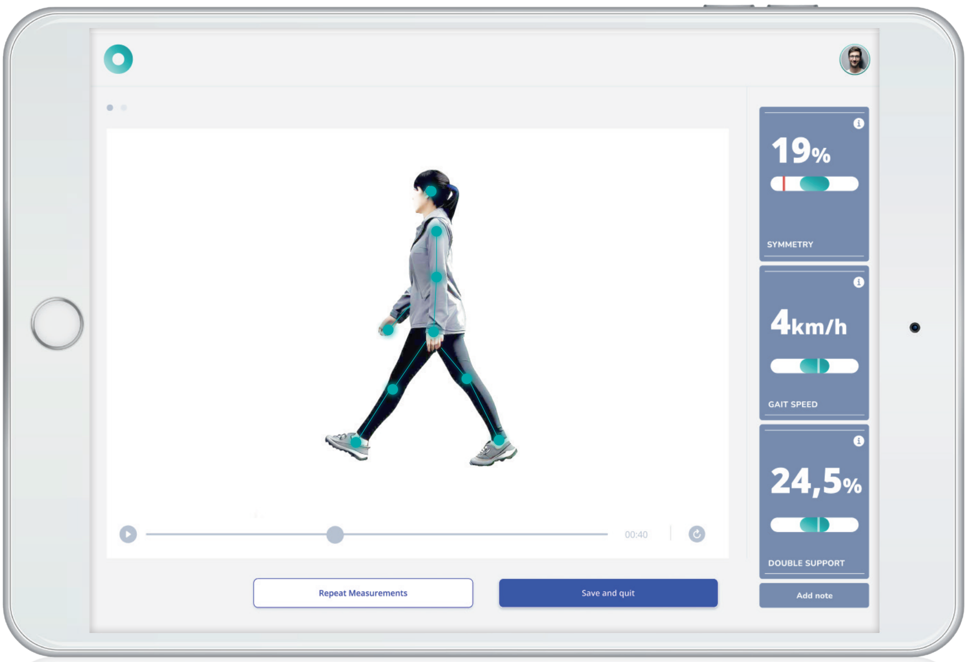
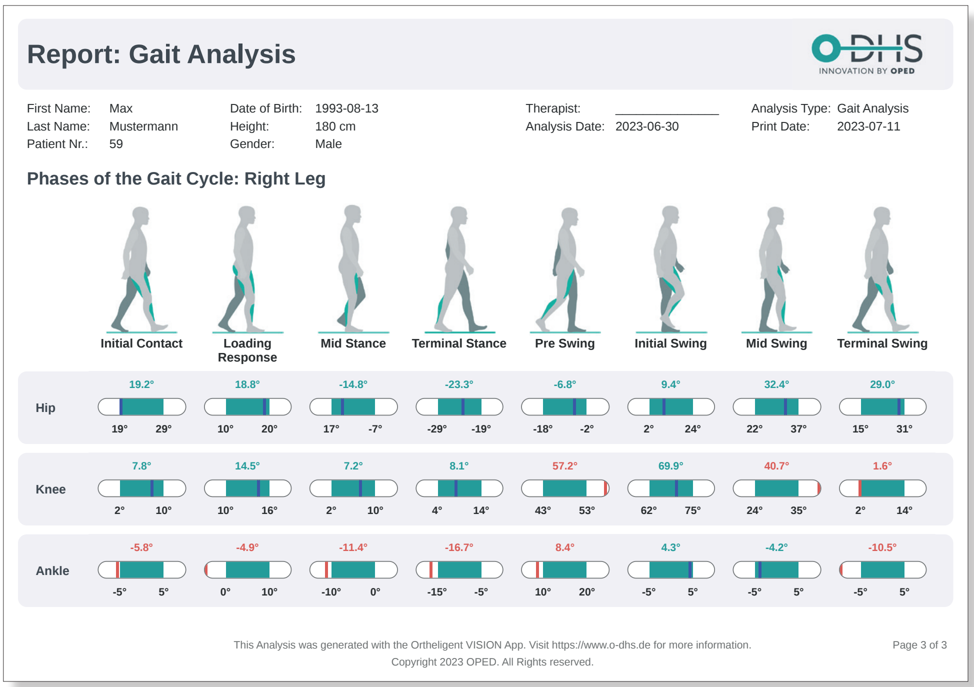


Fig. 1: Video recording with superimposition of the coordinate points within Orthelligent® VISION.



Report: Gait Analysis

O-DHS INNOVATION BY OPED

First Name: Max
Last Name: Mustermann
Patient Nr.: 59

Date of Birth: 1993-08-13
Height: 180 cm
Gender: Male

Therapist:
Analysis Date: 2023-06-30

Analysis Type: Gait Analysis
Print Date: 2023-07-11

Phases of the Gait Cycle: Right Leg

	Initial Contact	Loading Response	Mid Stance	Terminal Stance	Pre Swing	Initial Swing	Mid Swing	Terminal Swing
Hip	19.2° (19° – 29°)	18.8° (10° – 20°)	-14.8° (17° – -7°)	-23.3° (-29° – -19°)	-6.8° (-18° – -2°)	9.4° (2° – 24°)	32.4° (22° – 37°)	29.0° (15° – 31°)
Knee	7.8° (2° – 10°)	14.5° (10° – 16°)	7.2° (2° – 10°)	8.1° (4° – 14°)	57.2° (43° – 53°)	69.9° (62° – 75°)	40.7° (24° – 35°)	1.6° (2° – 14°)
Ankle	-5.8° (-5° – 5°)	-4.9° (0° – 10°)	-11.4° (-10° – 0°)	-16.7° (-15° – -5°)	8.4° (10° – 20°)	4.3° (-5° – 5°)	-4.2° (-5° – 5°)	-10.5° (-5° – 5°)

This Analysis was generated with the Ortheligent VISION App. Visit https://www.o-dhs.de for more information.
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Fig. 2: Extract from the final automatically generated report corresponding to the the video recording.

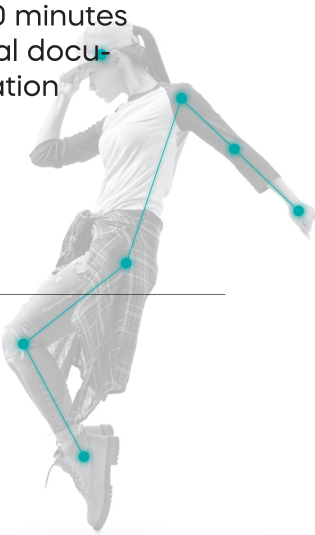
COMPARISON CHART

Movement analysis: Three methods at a glance

AI-based motion analysis differs significantly from other methods such as the goniometer or marker-based video system (Tab. 1).

Tab. 1: Comparison of three methods for movement analysis

	AI-based video analysis with Orthelligent® VISION	**Marker-based Video systems**	**Goniometer**
Technical principle	Movement analysis based on videos with AI-based image recognition techno-logy: determination of coordinate points for specific body positions by matching with extensive, anno-tated image data sets.	Several video cameras track changes in the position of the reflec-tive markers that were previously applied to the body. Based on a biomechanical model, the marker positions movement parame-ters are calculated.	Measurements of the angle of a joint on the body, of a pre-determined move-ment.
Equipement	• Commercially available Tablet with integrated camera, without special technical minimum requirements • Orthelligent® VISION app	• ≥2, better 8 to 16 Special cameras (data quality) • Reflective markers attached to the body are used • System-specific evaluation software	• Goniometer (protractor) • Trained medical personnel
Time required for the measurement and Evaluation effort	• <5 minutes • Automated evaluation	• Preparation: ≥30 minutes per subject plus System calibration and adjustment • Manual evaluation • Total time required approx. 60 minutes	• 5 to 10 minutes • Manual docu-mentation



OVERVIEW/INTRODUCTION VALIDATION

Background: Validation of AI-based motion analysis technology

For several years now, the validity and reliability of AI-based motion analysis have been extensively investigated in studies - among others in comparison to marker-based video systems.[2-6]

The publications already available provide indications that AI-based technology can deliver robust and valid measurement results. In particular, they enable, more consistently and reliably than marker-based video systems.[3,4]

Compared to the goniometer, they show higher accuracy and reproducibility, since the measurement data is obtained without contact and independent of the examiner.[4]

Against this background, three pilot studies were conducted to validate Orthelligent® VISION in preparation for future large-scale studies. In the process Orthelligent® VISION was compared with other motion analysis methods in three different settings:

1. With a marker-based video system - shoulder and knee joint.
2. With the Goniometer - knee joint
3. With the Goniometer - shoulder joint

STUDY 1
COMPARISON WITH SIMI MOTION

Orthelligent® VISION versus marker-based Video analysis - shoulder and knee joint

The setting

Five movement sequences (Tab. 2) with ten repetitions each were analysed in three healthy female subjects. Two methods were compared:

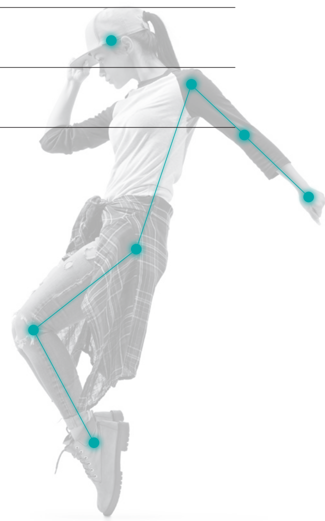
- AI-based video analysis with Orthelligent® VISION
- Marker-based video analysis with Simi Motion® (8 cameras, 16 marker points)

The results

For all five motion sequences, the measurement results of both systems showed a very high level of agreement (Fig. 3). The average Pearson correlation coefficients for all three test persons were - depending on the movement test - between 0.988 and 0.998 (Tab. 2). For classification: A Pearson correlation coefficient of 1.0 means that two variables are in complete agreement.

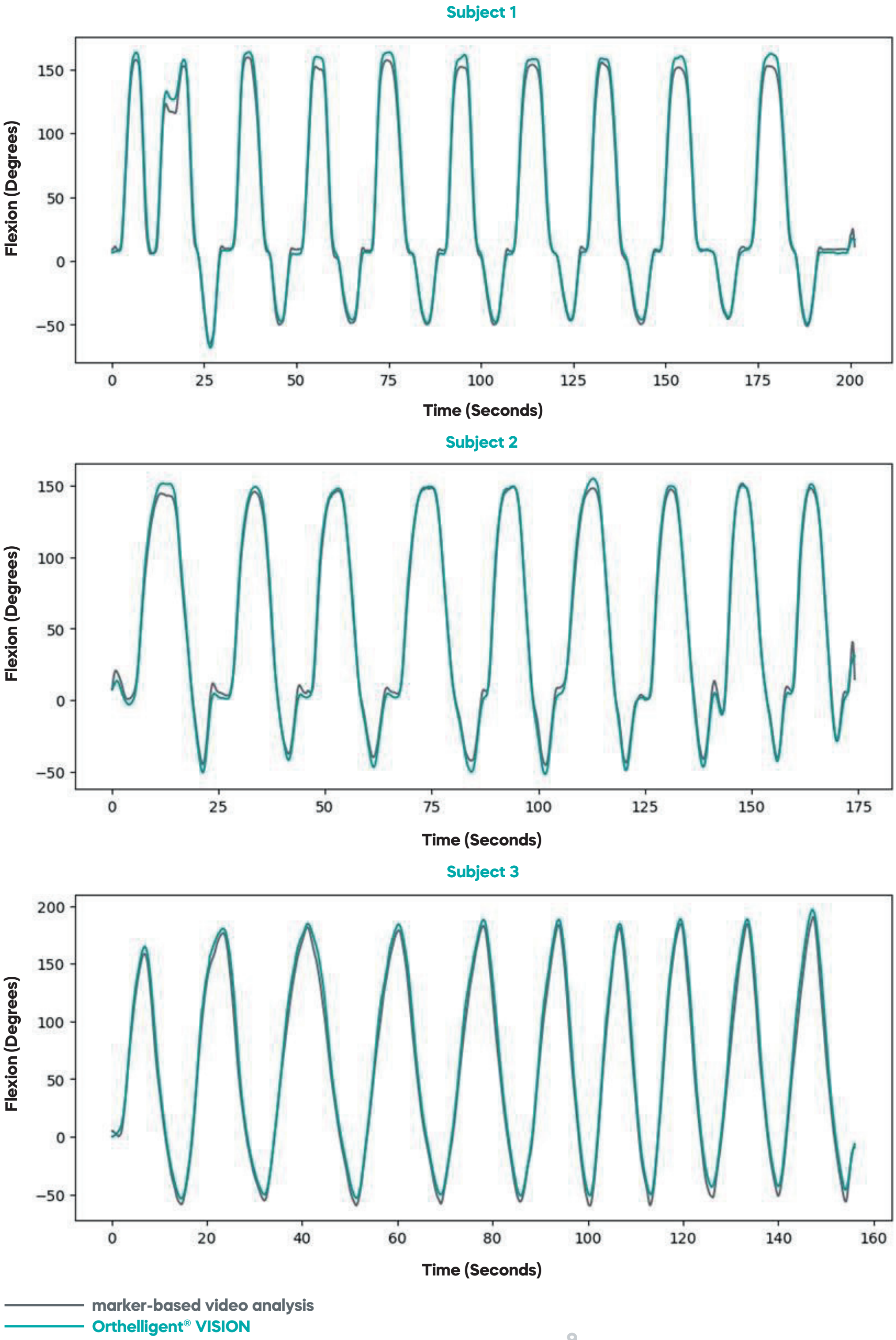
Tab. 2: Pearson correlation coefficients for the comparison of Orthelligent® VISION with a marker-based video analysis for five movement tests.

Movement test	**Average Pearson correlation coefficient (three female subjects)**
Shoulder flexion	0.998
Shoulder abduction	0.996
External rotation of the shoulder; 0° abduction	0.991
External rotation of the shoulder; 90° abduction	0.988
Knee flexion; knee bend on one leg	0.990



STUDY 1
COMPARISON WITH SIMI MOTION

Fig. 3: Exemplary course of the shoulder flexion measurement with Orthelligent® VISION or a marker-based video analysis in three test subjects.



STUDY 2
COMPARISON WITH GONIOMETER - KNEE

Orthelligent® VISION versus Goniometer - knee joint

The setting

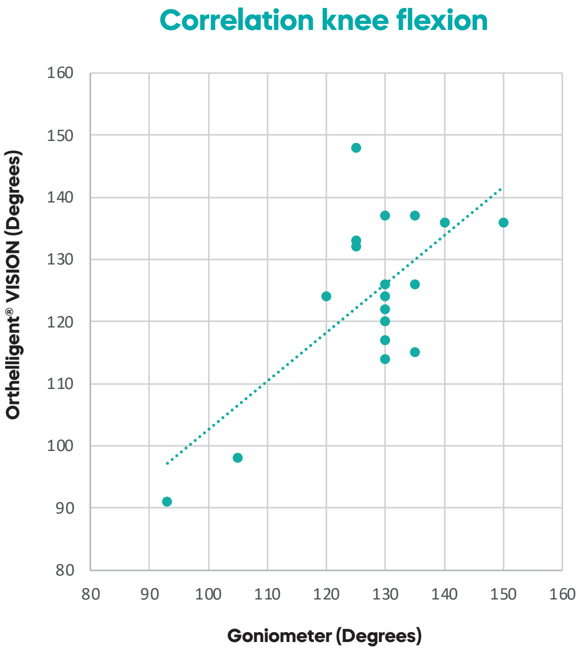
The maximum values of flexion and extension of a knee joint were analysed in 15 subjects using two methods:

- AI-based video analysis with Orthelligent® VISION
- Goniometer

The results

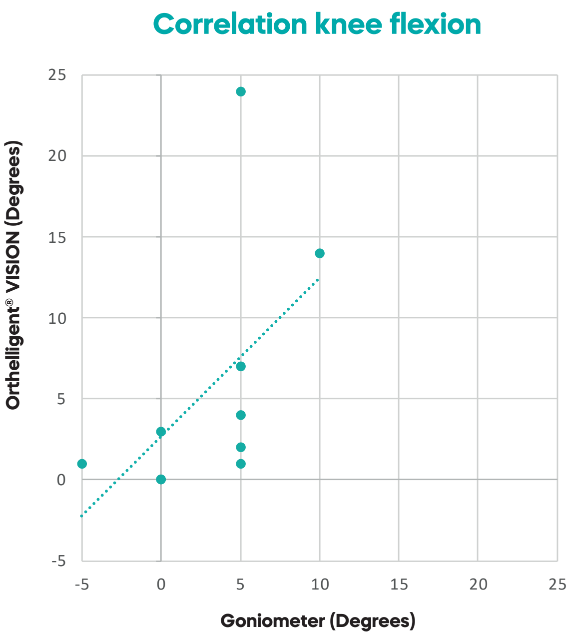
The measurement results for both movement sequences were very similar (Fig. 4 and Fig. 5). The average Pearson correlation coefficient for all 15 subjects and both movements was 0.989 with a mean deviation of 7.35.

Fig. 4: Pearson correlation of the knee flexion measurement with Orthelligent® VISION compared to the goniometer. (15 subjects)



STUDY 2
COMPARISON WITH GONIOMETER - KNEE

Fig. 5: Pearson correlation of the knee extension measurement with Orthelligent® VISION compared to the goniometer.



STUDY 2
COMPARISON WITH GONIOMETER - SHOULDER

Orthelligent® VISION versus Goniometer - shoulder joint

The setting

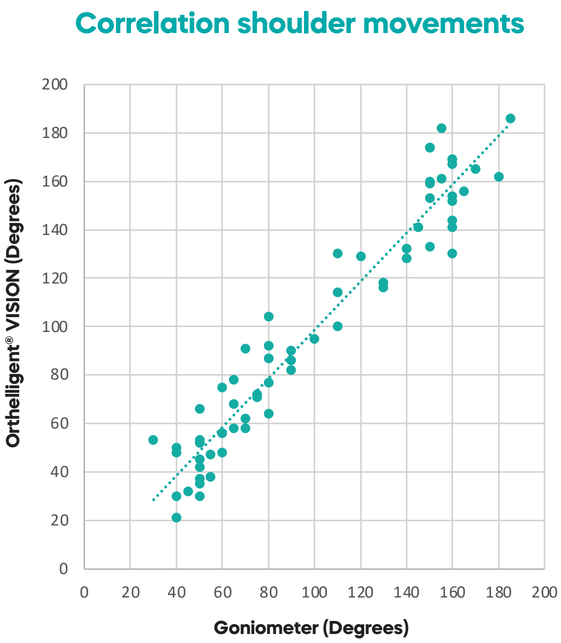
Four shoulder movements were analysed in each of nine test persons: Maximum values of abduction, flexion, extension and external rotation (in 90° abduction). For this purpose two measurement methods were used:

- AI-based video analysis with Orthelligent® VISION
- Goniometer

The results

The measurement results of the two methods show a high degree of agreement for all four movement sequences (Fig. 6). The average Pearson correlation coefficient - related for all nine subjects and four movements - was 0.978 with a mean deviation of 12.65°.

Fig. 6: Pearson correlation of the measurement of a total of four shoulder movements with Orthelligent® VISION in comparison to the goniometer. (9 test persons)



The measurement results for the shoulder movements were checked again with the help of a video analysis software (Kinovea). Once again there was high level of agreement between the Orthelligent® VISION and manual video analysis. The average Pearson correlation coefficient was 0.982 and the mean deviation was 8.15°.

SUMMARY

Discussion and classification of the results

- AI-based, markerless image recognition technology such as Orthelligent® VISION establish a new generation of motion analysis methods in sports and rehabilitation medicine.
- They enable dynamic, three-dimensional and markerless motion measurement and automated evaluation with less time and costs than conventional marker-based video analysis systems.
- In initial pilot studies for validation, Orthelligent® VISION was compared with goniome try or with a marker-based video system. In all measurement series, Orthelligent® VISION showed consistently high validity with Pearson correlation coefficients of >0.98.
- These results support the clinical application of Orthelligent® VISION for reliable and accurate motion analysis.

Further studies with a larger number of subjects are planned to reproduce and verify these initial validation results.

LITERATURE

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