Advances in diagnostics and management of inflammatory rheumatic conditions.
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Synchronized measurements to visualize spinal motion during gait by means of 4D MotionLab

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Goal of the presentation

I. Introduction

- Who we are, where we are
- Rasterstereography, how it works

II. Towards visualization of spinal motion relative to phases of gait

- MotionLab until 2015
- Further development of the system (DICAM) and software tools (SAS, SPSS)

III. Some of our scientific findings using this new methodology

- All-cycles-in-one representations
- AI-based gender classification
- Individual movement patterns / AI identification of the individual
- Moving point of intersection
- Physiologic asymmetry of the spinal alignment
- Seat wedge influence on scoliosis
- Influence of knee arthrosis on spinal motion
- Using explainable AI for pathology independent classification

IV. Summary and conclusion

I. Introduction

Who we are

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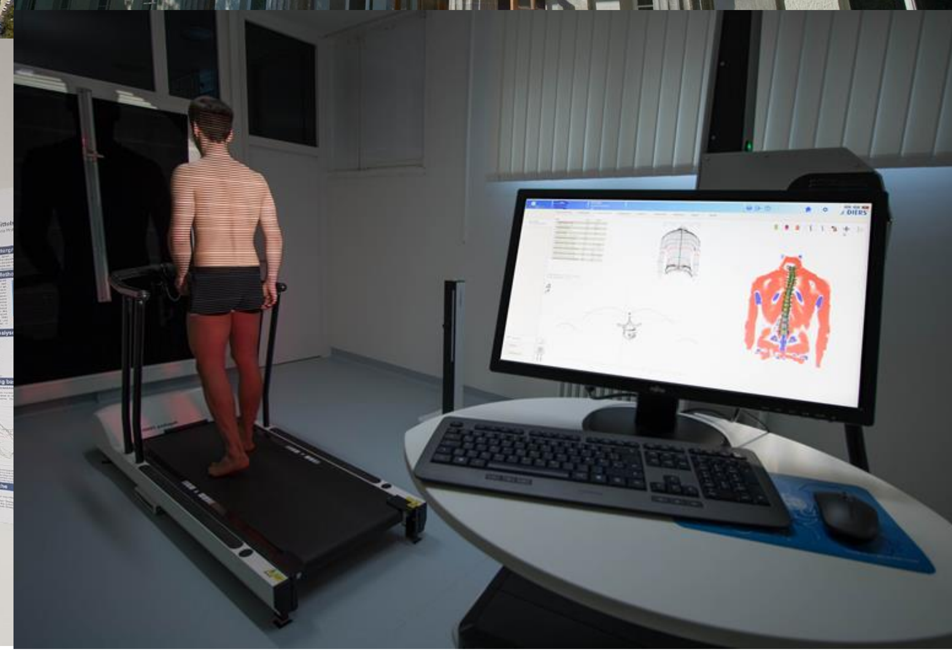
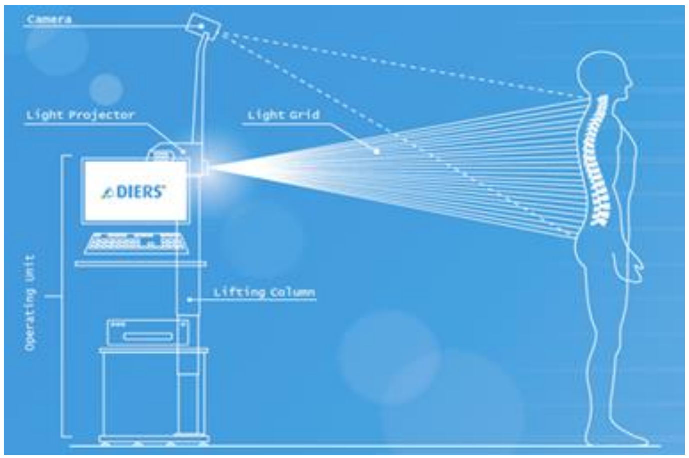
Therapist)

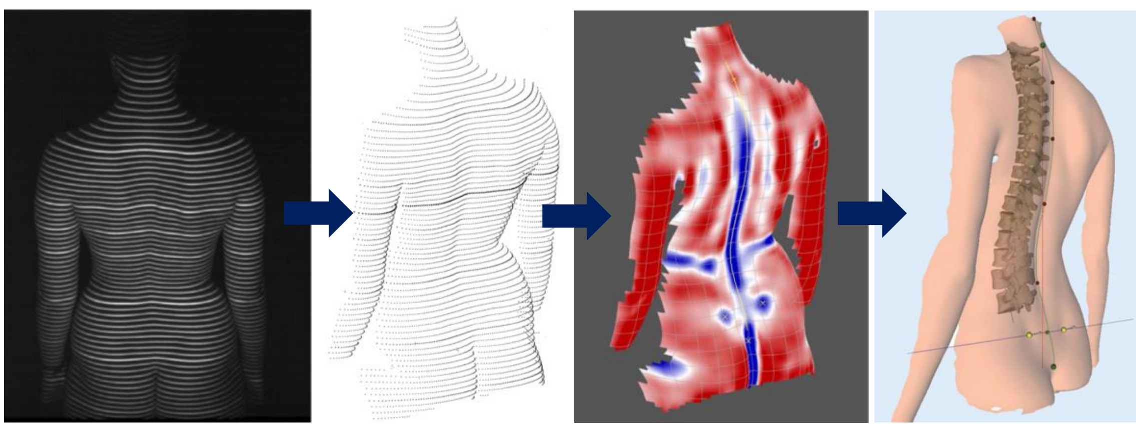
ClarCert
Zertifiziertes Qualitätsmanagement
ISO 9001:2015

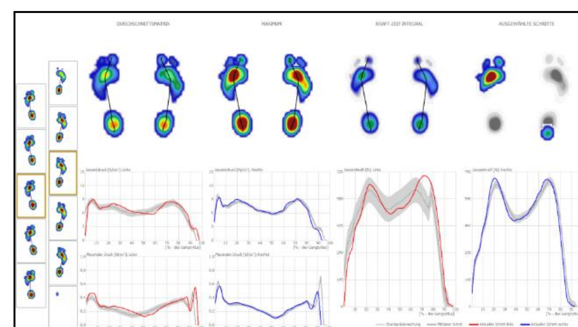
Where we are



Rasterstereography – how it works



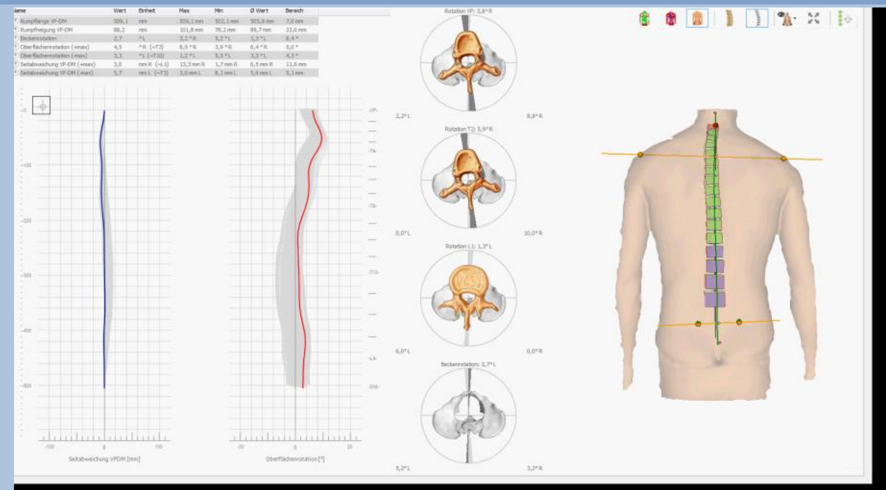




II. Towards visualization of spinal motion relative to phases of gait

MotionLab capabilities until 2015

- Internal visualization of the course

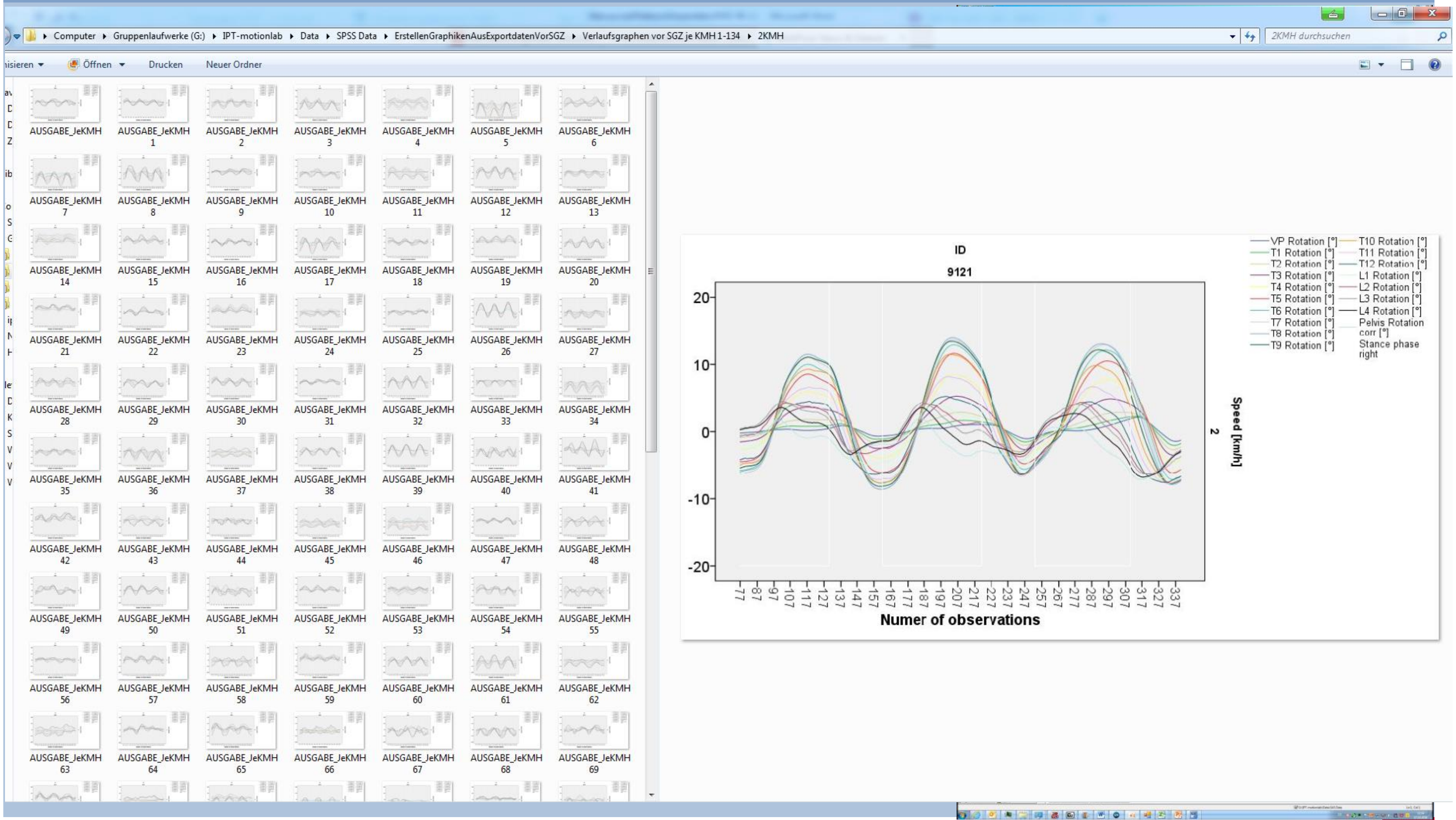


- Separate, aggregated DICAM parameters

Name	Wert	Einheit	Max	Min	Ø Wert	Bereich
Rumpflänge VP-DM	505,7	mm	509,1 mm	502,1 mm	505,8 mm	7,0 mm
Rumpfneigung VP-DM	92,0	mm	101,8 mm	78,2 mm	89,7 mm	23,6 mm
Beckenrotation	0,4	°R	3,2 °R	5,2 °L	1,3 °L	8,4 °
Oberflächenrotation (+max)	6,7	°R (~T2)	8,9 °R	3,9 °R	6,4 °R	5,0 °
Oberflächenrotation (-max)	3,9	°L (~L1)	1,2 °L	5,5 °L	3,3 °L	4,3 °
Seitabweichung VP-DM (+max)	6,4	mm R (~L1)	13,3 mm R	1,7 mm R	6,5 mm R	11,6 mm
Seitabweichung VP-DM (-max)	6,2	mm L (~T3)	3,0 mm L	8,1 mm L	5,6 mm L	5,1 mm

➢ Raw data for continuous measuring and visualization of the course existed, but were not exportable

Software adjustments



* All tools are available in repositories to enable open science

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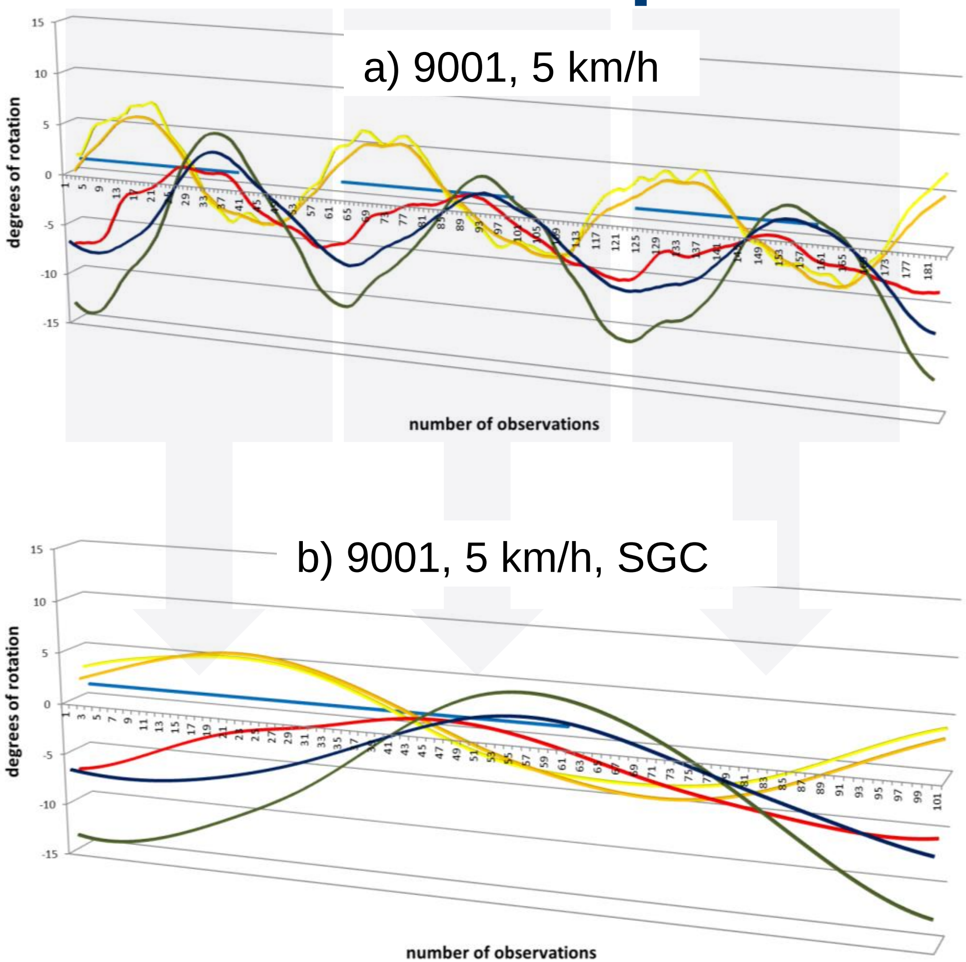
Visualization of transversal plane rotation and results of spline interpolation

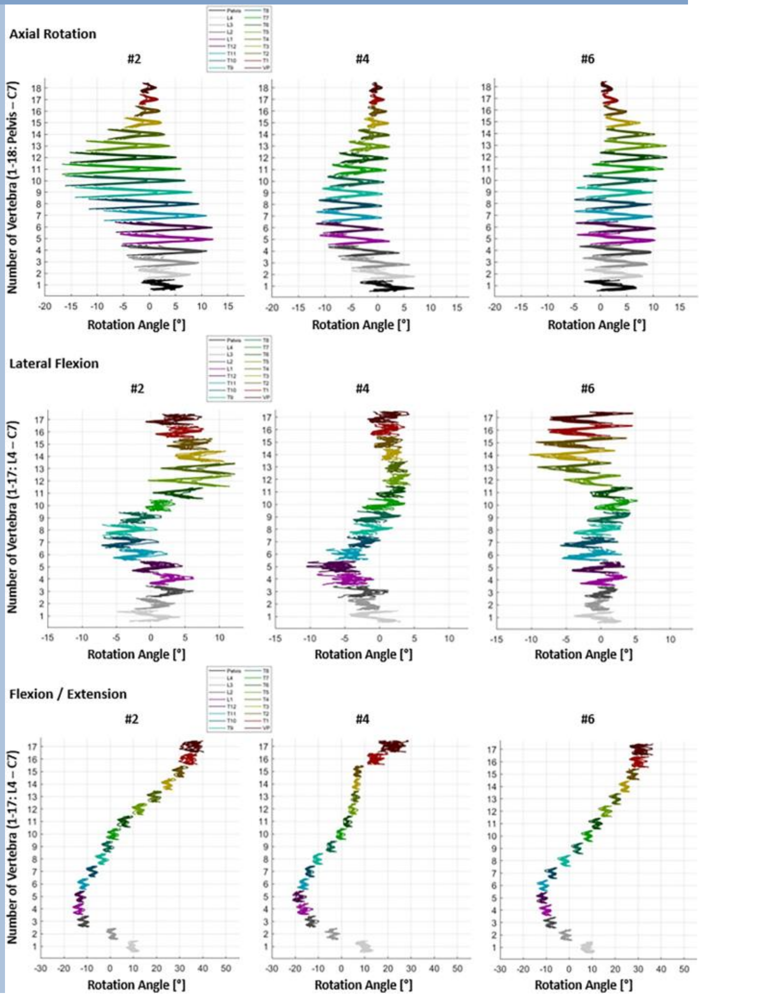


- T4 rotation [°]
- T8 rotation [°]
- T12 rotation [°]
- L4 rotation [°]
- Pelvic rotation [°]
- Stance phase: right foot

III. Some of our scientific findings using this new methodology

All-cycles-in-one (ACIO) representations*

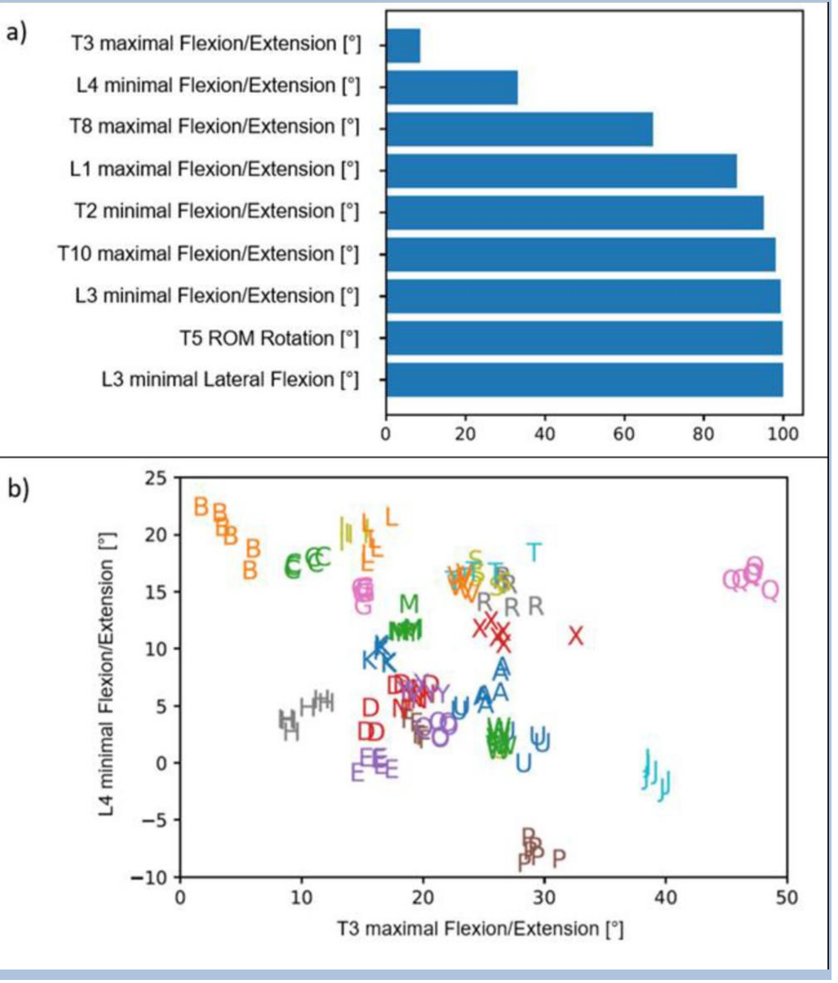
- ACIO comparison of 3 healthy individuals
- 10 gait cycles, 3 speeds, **all planes**
- ➢ visualization tools are helpful to compare different motion sequences
- ➢ High intra-individual consistency, large inter-individual variation



* Haimerl et al. (2022)

AI identification of individuals*

- Spinal motion data of 25 healthy subjects were hidden in motion data of 201
- Siamese neural network was able to detect up to 100%!
- Dimension reduction (2D) of most relevant features make the spinal fingerprint visible



* Dindorf & Konradi et al. (2021)

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AI-based gender classification*

- Spinal stance and motion data of 201 were used to train an AI for a classification task to differenciate between male/female
- Up to 0.96 (MCC) correct classifications were obtained for gait data by a Support Vector Machine

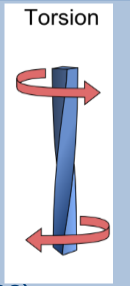
Table 1. Results for stance and gait.

	Stance						Gait					
Threshold	n_{feat}	M_{MCC}	M_{F1}	M_{AUC}	CM		n_{feat}	M_{MCC}	M_{F1}	M_{AUC}	CM	
5 %	10.00 ± 0	0.48 ± 0.13	0.66 ± 0.09	0.73 ± 0.11	99	36	62.20 ± 0.84	0.92 ± 0.03	0.95 ± 0.02	0.98 ± 0.02	132	3
					17	53					4	66
10 %	20.00 ± 0	0.58 ± 0.09	0.71 ± 0.09	0.83 ± 0.09	112	23	125.00 ± 2.12	0.95 ± 0.04	0.96 ± 0.03	0.99 ± 0.01	133	2
					18	52					3	67
20 %	40.00 ± 0	0.62 ± 0.07	0.74 ± 0.04	0.82 ± 0.10	117	18	250.80 ± 4.02	0.96 ± 0.04	0.97 ± 0.03	0.99 ± 0.01	133	2
					18	52					2	68
50 %	101.00 ± 0	0.61 ± 0.09	0.73 ± 0.08	0.84 ± 0.05	120	15	627.60 ± 9.89	0.96 ± 0.02	0.97 ± 0.02	0.99 ± 0.01	134	1
					21	49					3	67
100 %	–						1256.00 ± 19.60	0.97 ± 0.03	0.98 ± 0.02	1.00 ± 0.00	134	1
											2	68
All initial	202	0.61 ± 0.06	0.72 ± 0.07	0.84 ± 0.06	122	13	2021	0.96 ± 0.04	0.97 ± 0.03	1.00 ± 0.01	134	1
					23	47					3	67

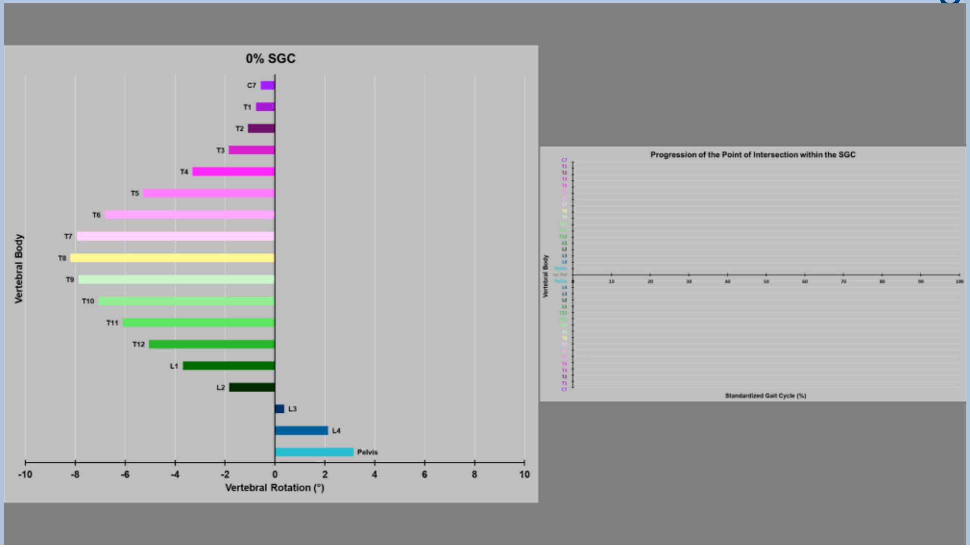
RBF SVC is used for classification. 100% threshold corresponds to all preselected features. Number of features n_{feat}, Mean Matthews correlation coefficient M_{MCC}, M_{F1} mean F1 score, mean Precision-Recall Area Under the Curve M_{AUC}. The true positives and true negatives are highlighted with gray back color in the Confusion Matrix (CM).

* Dindorf & Konradi et al. (2020)

Moving point of intersection*



- During initial contact (right foot) the pelvis is expected to be maximally rotated anti-clockwise (left) and at the end of TSt (right) maximally clockwise (Perry, 1992)
- With increasing speed of movement an opposite direction of rotation between pelvis and the shoulder girdle can be seen (Lamoth et al., 2002)
- But mean vertebral rotation of 201 healthy subjects at 5km/h show no static point of intersection in between but rather a moving one:



* Huthwelker et al. (preparation)

Physiologic asymmetry of the spinal alignment*

- Spine in transversal plane is expected to be straight
- But: 100 asymptomatic females in habitual posture display an average vertebral rotation between T6-L4!

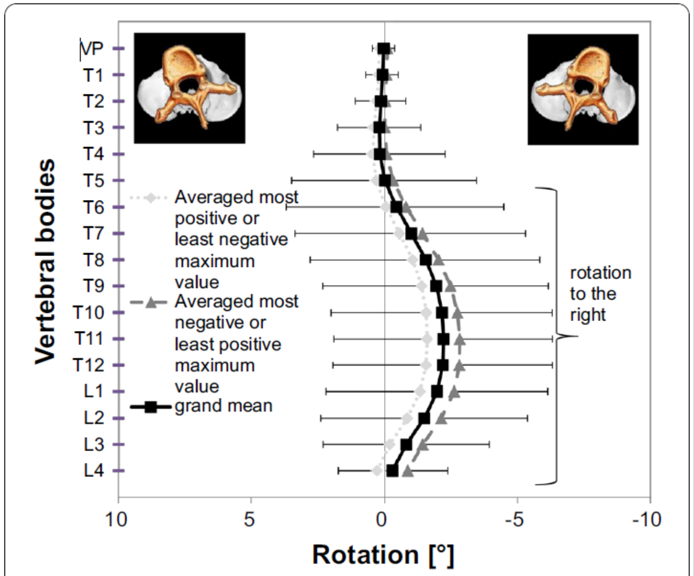
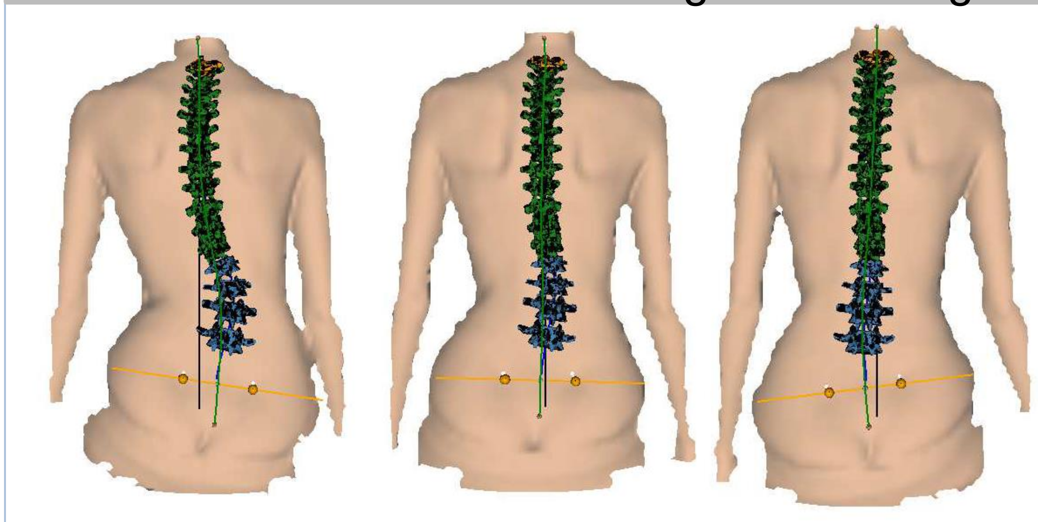


Fig. 4 Vertebral body positions in transversal plane. Positive values mean indicate rotation to the left, negative values to the right. Averaged most positive or least negative maximum value, most negative or least positive with one-sided SDs, and grand means of EG are displayed; area and direction of rotation are marked

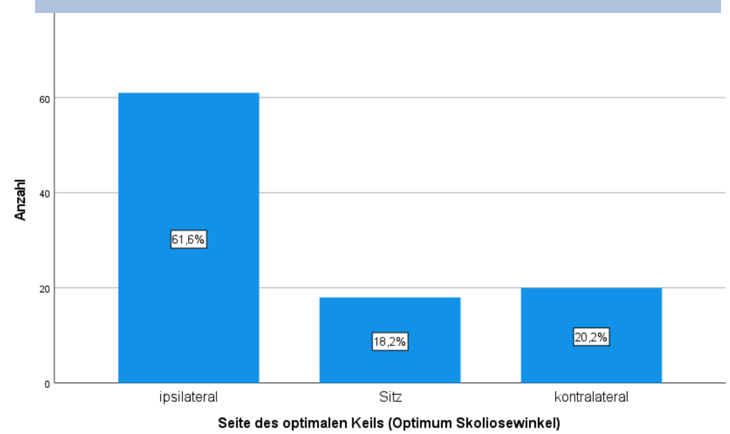
* Wolf et al. (2021)

Seat wedge influence on scoliosis*

10° left | neutral sitting | 10° right



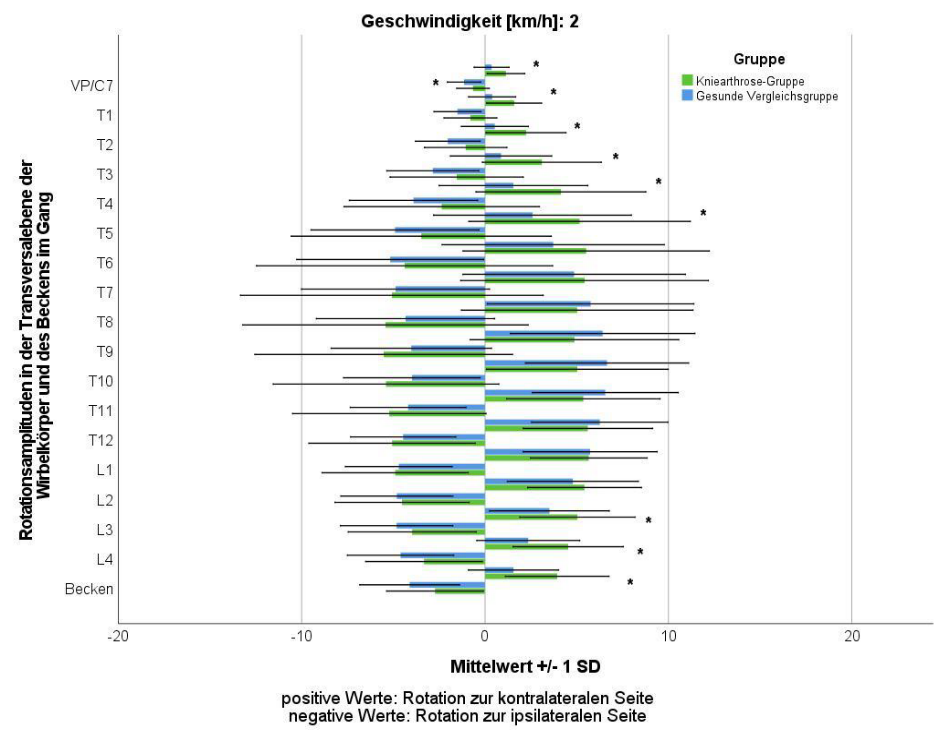
- 99 patients with differnt types and severity of scoliosis show significant reduction of their scoliosis angle when provided with an ipsilateral seat wedge



* Feustel et al. (preparation)

Influence of knee arthrosis on spinal motion*

- Comparison of 30 patients with healthy references show that knee arthrosis affects not only adjacent lower parts of the spine but also the upper thoracic spine in transversal plane rotation of the contralateral part
  - ➢ More rotation as a compensation



* Wolf et al. (preparation)

Using explainable AI for pathology independent classification

- AI (One-class SVM) can classify between healthy and back pain, identify relevant areas of the spine, and can provide interpretable information (LIME) about the extent of the deviation from physiology based on stance data.

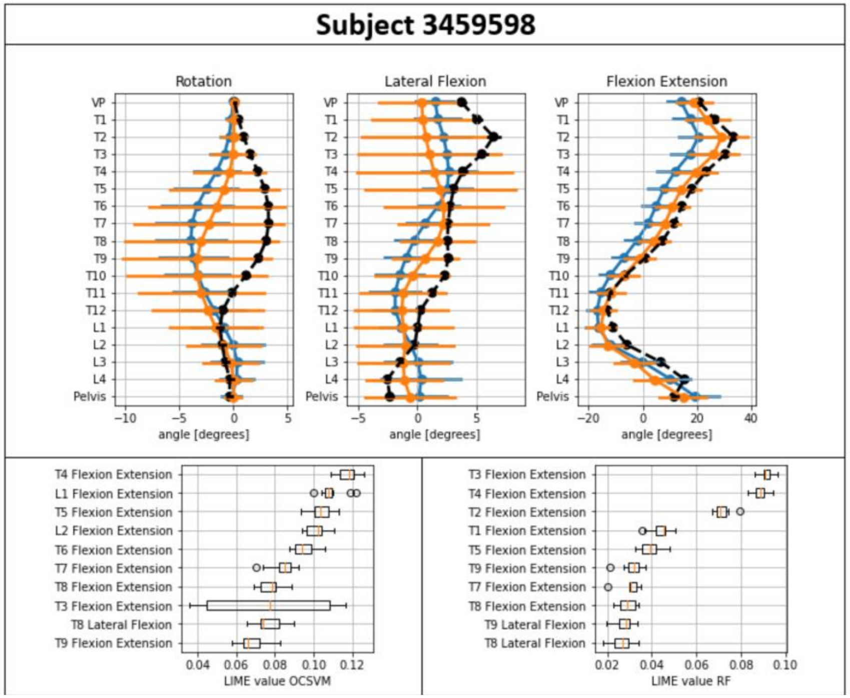


Figure 1. Exemplary posture of one correctly (3459598) and one falsely (8232865) classified subject. Bottom: Displayed LIME values show the effect for the 10 most important features. Negative values represent an effect toward the group of healthy subjects, with positive values indicating an effect that indicates an outlier (patient). Top: Vertebral body positions in the transversal (rotation), coronal (lateral flexion), and sagittal (flexion extension) planes. Positive values indicate a rotation/tilt to the left or ventral (toward flexion), while negative values indicate a rotation/tilt to the right or dorsal (toward extension). Blue = mean and standard deviation (SD) of healthy reference group; orange = mean and SD of group of subjects with the respective pathology; black = mean and SD of the 10 measurements of the subjects of interest.

* Dindorf & Konradi et al. (2021)

IV. Summary and conclusion

Summary and conclusion

- Methodologic advancements of rasterstereography make it possible to visualize 3d spinal motion in direct relation to phases of gait and to transform them into a standardized gait cycle
- This enables analysis of spinal dynamics in direct relation to different phases of gait with the possibility of intra-/ and inter-individual comparisons as well as investigating different types of pathologies
- Spinal movement as well as its orientation during stance are different that previously thought
- AI approaches can be very helpful for classification and interpretation of the complex data

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Thank you for your interest!

Questions?