87%
accuracy
specificity 89%
sensitivity 86%

7.5 degree
Mean Absolute Error
cobb angle prediction

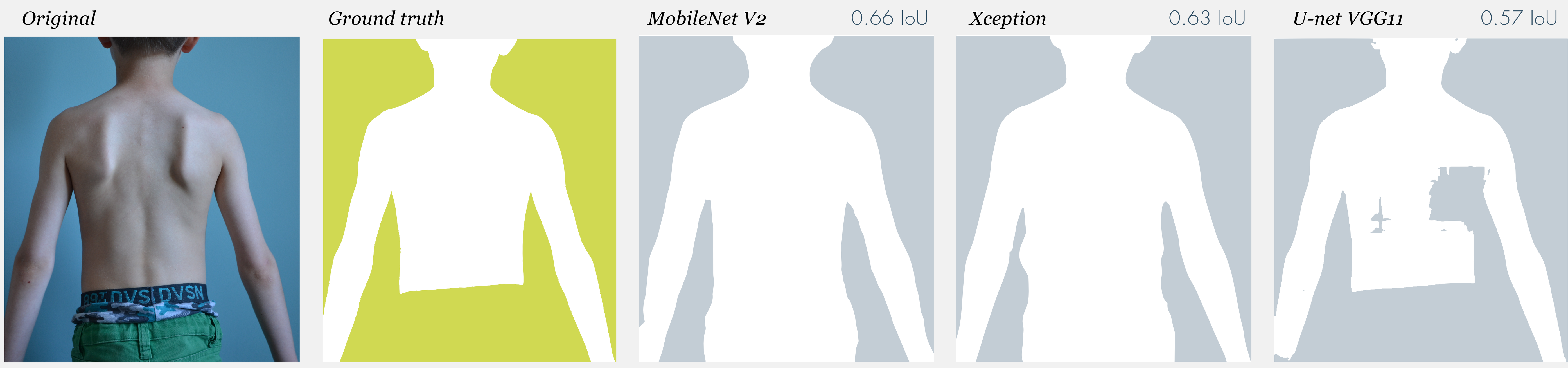
Scoliosis detection in ordinary pictures: an explainable approach

Claartje Barkhof, Victoria Foing, Kenneth Goei & Osman Ulger

Master Artificial Intelligence
University of Amsterdam
June, 2019

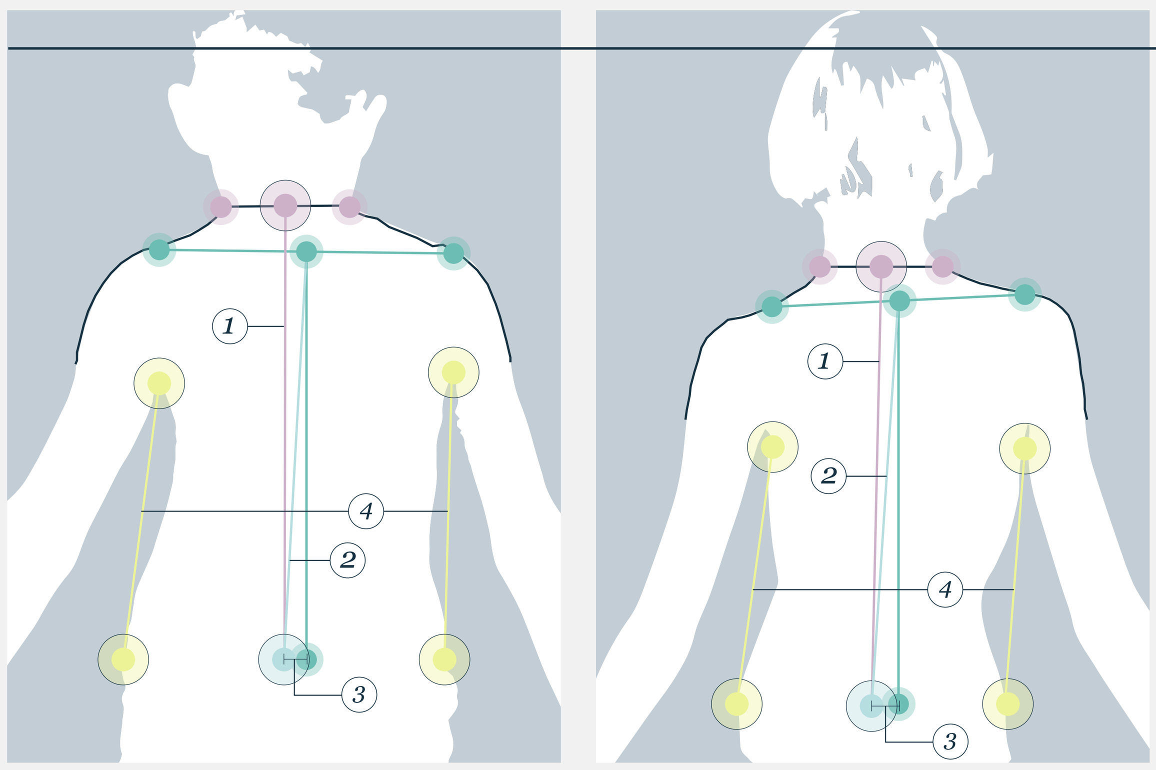
This work is aimed at detecting the presence of scoliosis as well as the degree of severity, while preserving the privacy of the client and yielding an explainable prediction. To this end, different models were experimented with, of which a Random Forest model outperformed other tree-based and neural approaches, with a final binary classification accuracy of 0.87 (± 0.03). The final model uses hand-crafted features, which enable a certain prediction to be explainable in terms of measurements used by orthopedic specialists themselves.

1 Segmentation



For segmentation techniques, three different methods were used, namely a fine-tuned Ternaus U-Net VGG11 encoder/decoder model, a pre-trained DeepLab Xception model, and a pre-trained DeepLab MobileNet2 model. The model with the highest Jaccard similarity (IoU) proved to be model MobileNet2, with a an IoU of 0.66, whereas Xception achieved an IoU of 0.63 and the U-Net 0.57.

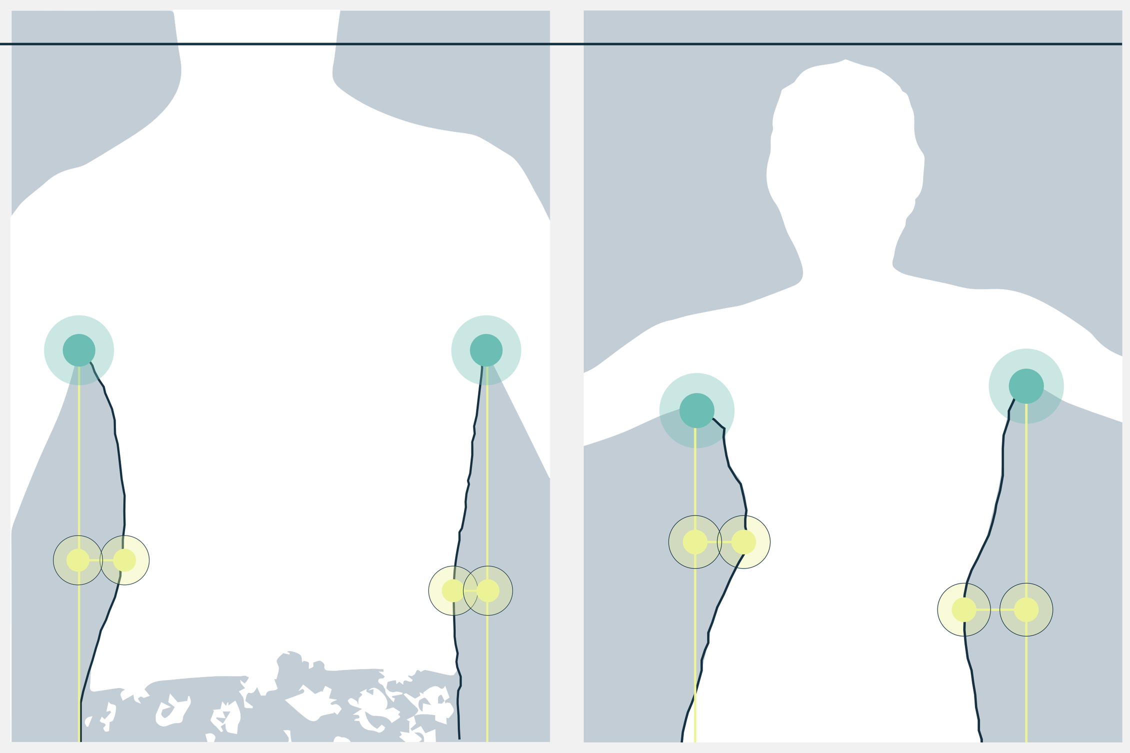
2 Feature engineering (18 in total)



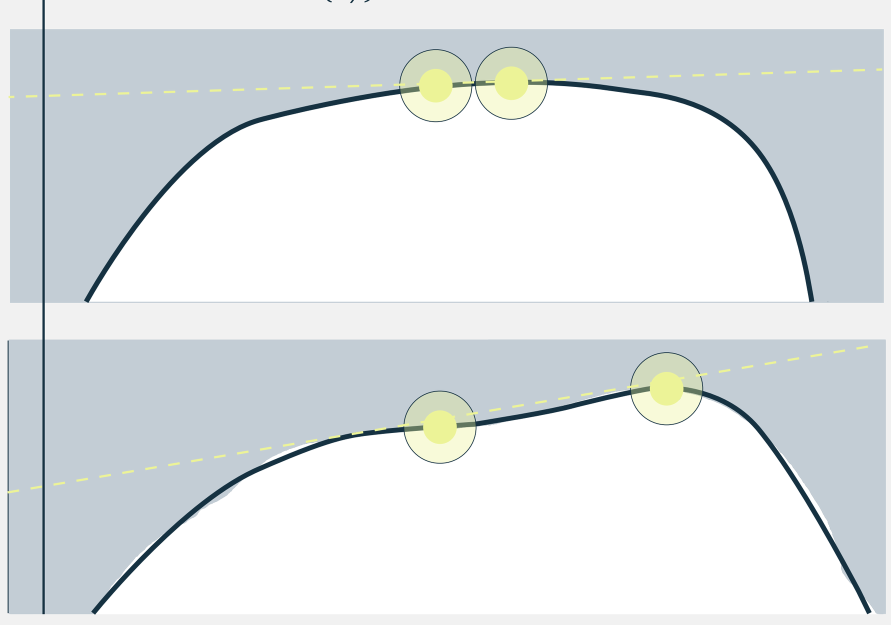
Off-balance. *Measures to which extent the upper body of the person is off-balance. 1. The angle between the center of the neck and the center of the waist. 2. The angle between the center of the shoulders and the center of the waist. 3. A perpendicular line from the center of the shoulder points is drawn towards the waist and it is measured how much this position differs from the true center of the waist. 4. Two lines are drawn from armpits to the sides of the waist and the ratio between the length of those lines is added as a feature as well. 5. The slope between the shoulders is measured.*

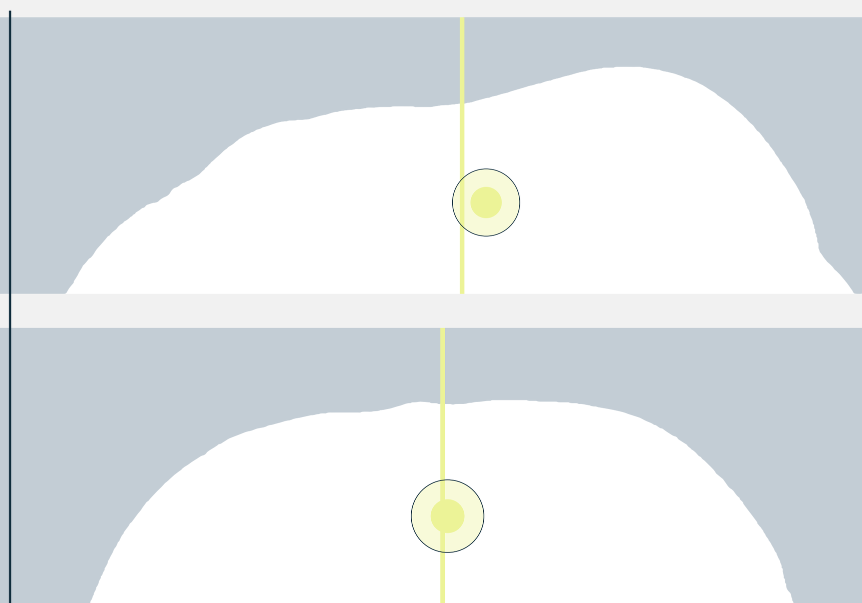
Triangular waist area. *This feature focuses on the triangular area between the line from the armpit downwards and the side of the person. This feature is looking for asymmetry between the two areas, which could be an indicator for scoliosis. Multiple approaches have been used to approximate this area.*

6-11 Triangle features



Back curvature & slope
First, a function is fitted on the outline of the back, after which:
i) it is compared to a ground truth 2-dimensional polynomial (i.e. perfect back) & similarity is computed (12)
ii) its skew, excess kurtosis, mean and variance is measured (13-16)
iii) a peak is found in each half, and the slope is computed between the two (17)





Center of mass offset *18. In this feature, the normalized offset between the x-position of the middle of the back and the x-position of the center of mass of the entire back is computed. In case of scoliosis, the center of mass tends to be more towards the side where the back is higher, resulting in a higher offset.*

3 Feature selection & models

After extracting features from the images, it is important to explore whether they are a strong basis for a model to make predictions. First, we looked into the correlation of the features with the binary target variable (if someone has scoliosis or not) and with the cobb angle: measure of the curvature of the spine (Figure 1). We also performed the dimensionality reduction technique Principal Component Analysis and found that this had a negative effect on the performance even if we used the number of components corresponding to the number of original features. After perfoming this Exploratory Data Analysis, we tested different types of models, of which tree-based models performed best (XGBoost, Random Forest & Decision Tree). Neural approaches seemed hard to train with this dataset (small in size and noisy in quality). Tree-based models also are better suited for explainability purposes. In Figures 2 and 3 the performance of the models with an increasing number of features is shown. Figure 2 shows the performance for the regression task in Mean Absolute Error (MAE) and Figure 3 the performance for binary classification (sensitivity and specificity).

Figure 1

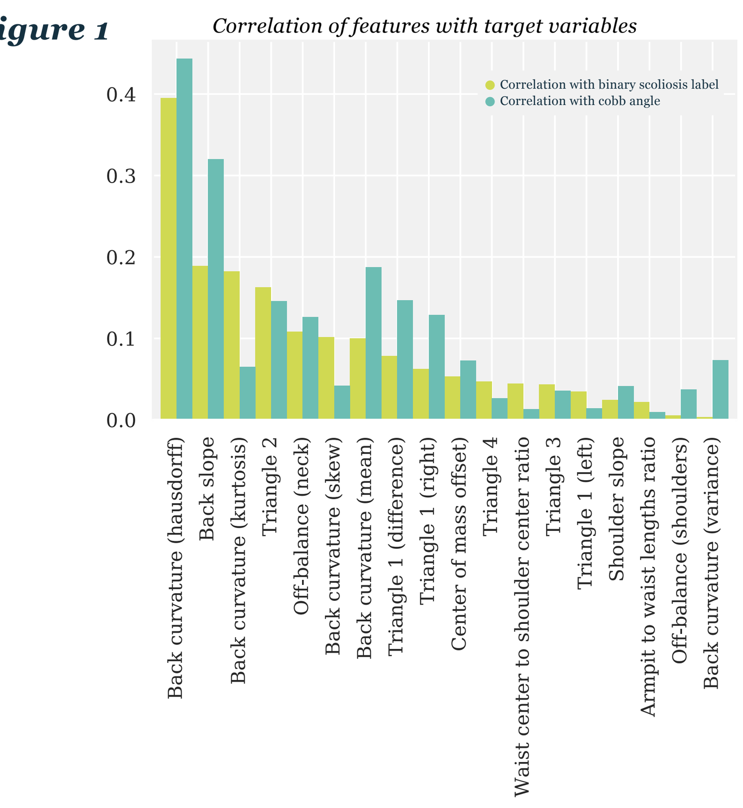


Figure 2 *Regression: degree of scoliosis*

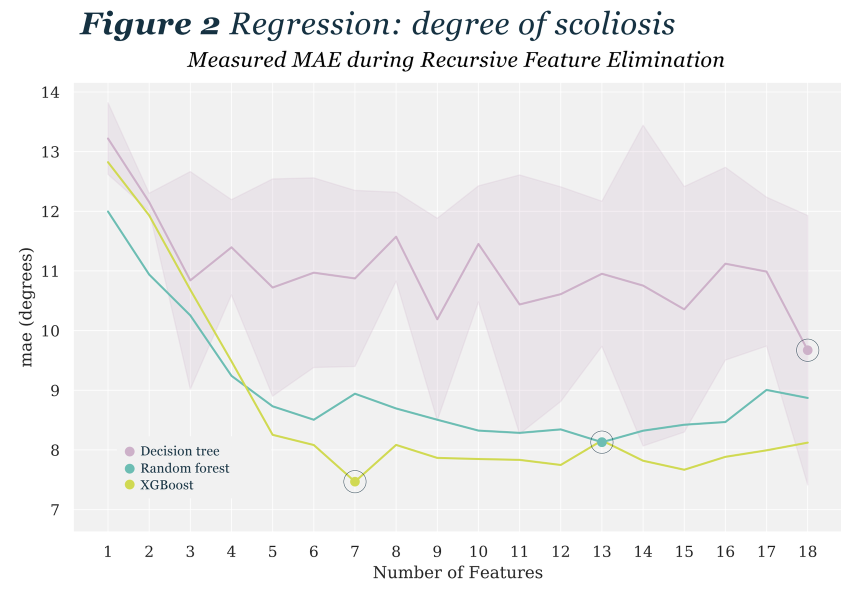
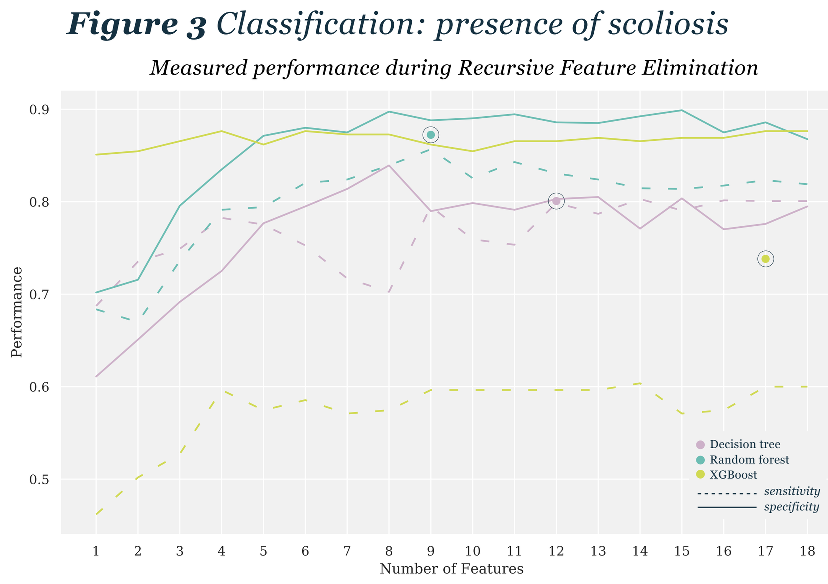


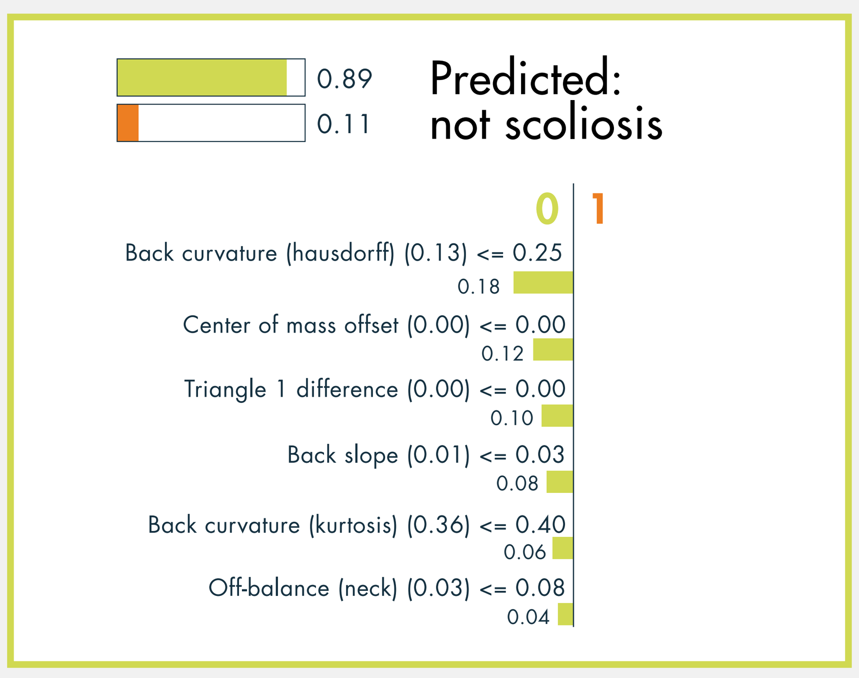
Figure 3 *Classification: presence of scoliosis*

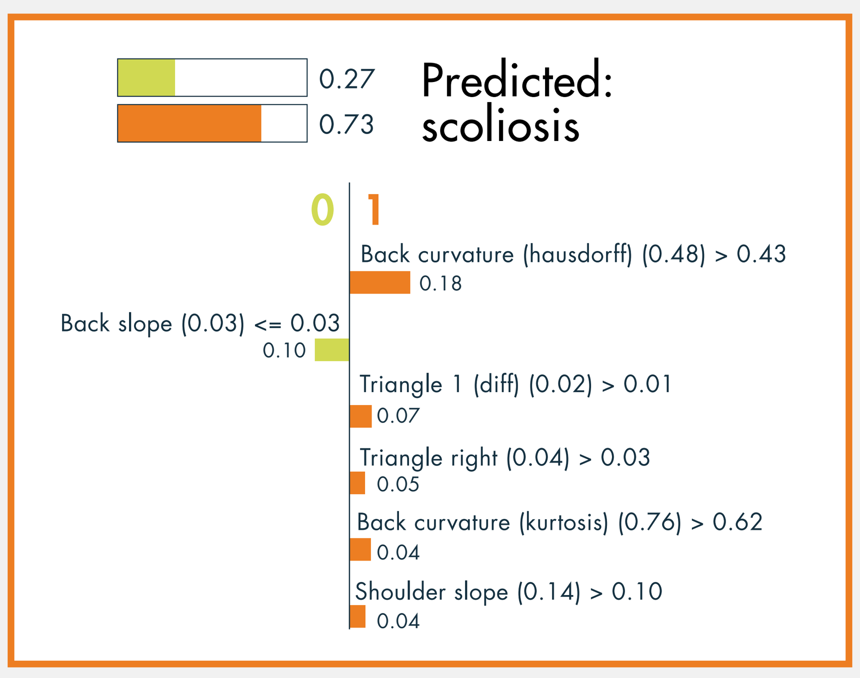


4 Predicting scoliosis

Two types of predictions are made:
1. The binary prediction of whether the patient has scoliosis or not
2. The regression prediction of the cobb angle (measure of curvature of the spine) of the patient

	Binary Classification				Regression		
	# Features	*Accuracy*	*Sensitivity*	*Specificity*	*# Features*	*MAE*	*MSE*
XGBoost	17	0.74 (± 0.04)	0.60 (± 0.11)	0.88 (± 0.05)	7	7.47 (± 0.44)	120.90 (± 10.67)
Random Forest	9	0.87 (± 0.03)	0.86 (± 0.03)	0.89 (± 0.05)	13	8.13 (± 0.42)	117.89 (±10.56)
Decision Tree	12	0.80 (± 0.03)	0.80 (± 0.05)	0.80 (± 0.07)	18	9.67 (± 2.26)	208.14 (± 60.89)





olvg GO DATA DRIVEN