Form Check

Squat Classification with 3D Convolutional Neural Network

James Nikiforuk

"There is simply no other exercise, and certainly no machine, that produces the level of central nervous system activity, improved balance and coordination, skeletal loading and bone density enhancement, muscular stimulation and growth, connective tissue stress and strength, psychological demand and toughness, and overall systemic conditioning than the correctly performed full squat."

- Mark Rippetoe

A Solid Foundation

Squats are a foundational movement pattern. While proper execution has many benefits, improper execution can lead to strain, disability, and loss of work.

What's the cost?

CLAIMS MADE:

151,752 Claims
2016-2020

DAYS LOST:

8,319,279 Days
2016-2020

DOLLAR COST:

$1,869,042,089
2016-2020

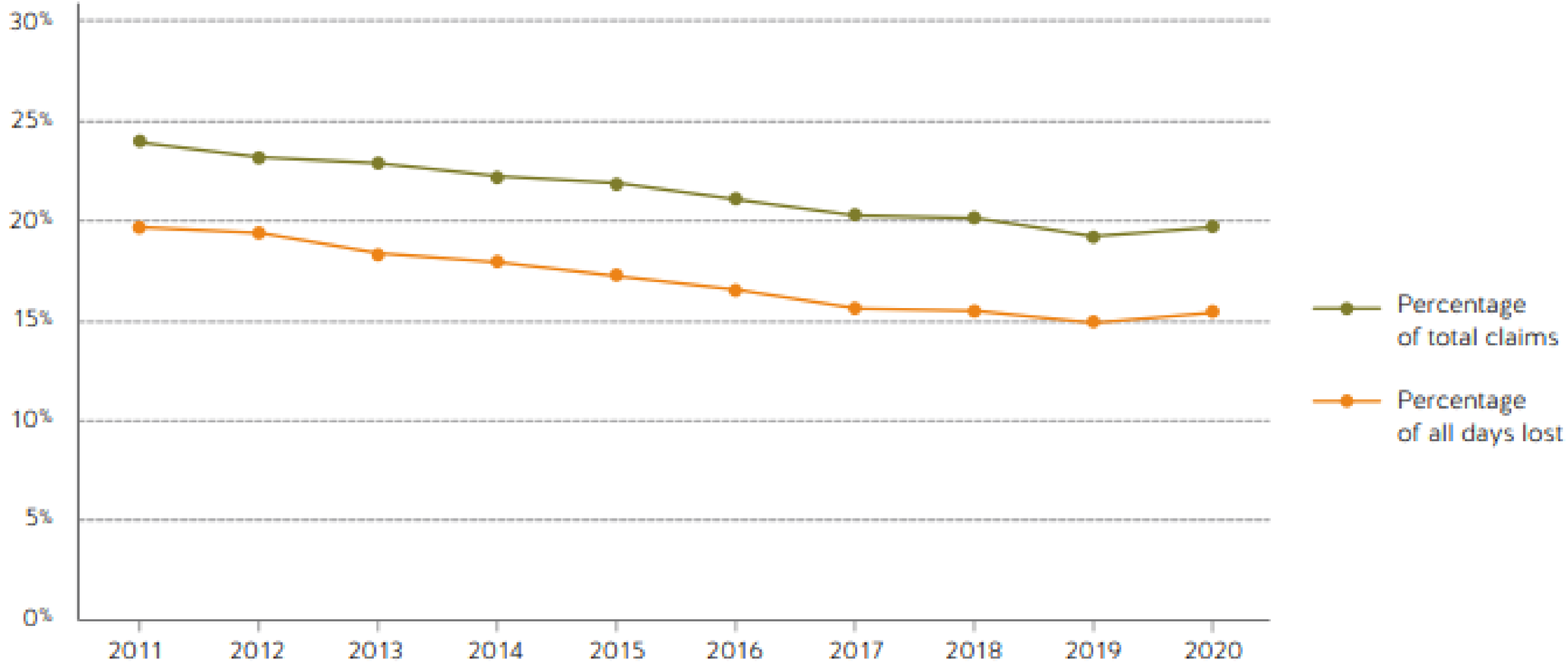
%TOTAL:

55.8% of Claims
2016-2020

Data from WorkSafeBC Statistics 2020 Report
'Strain, Back','Strain, Other','Hernia'

Back Strain

Back Strain claims as % of total claims and days lost.



Dataset and Approach

2000+ VIDEOS

Good squats and 6 common errors with varied angles and settings

SPLIT VIDEOS INTO FRAMES

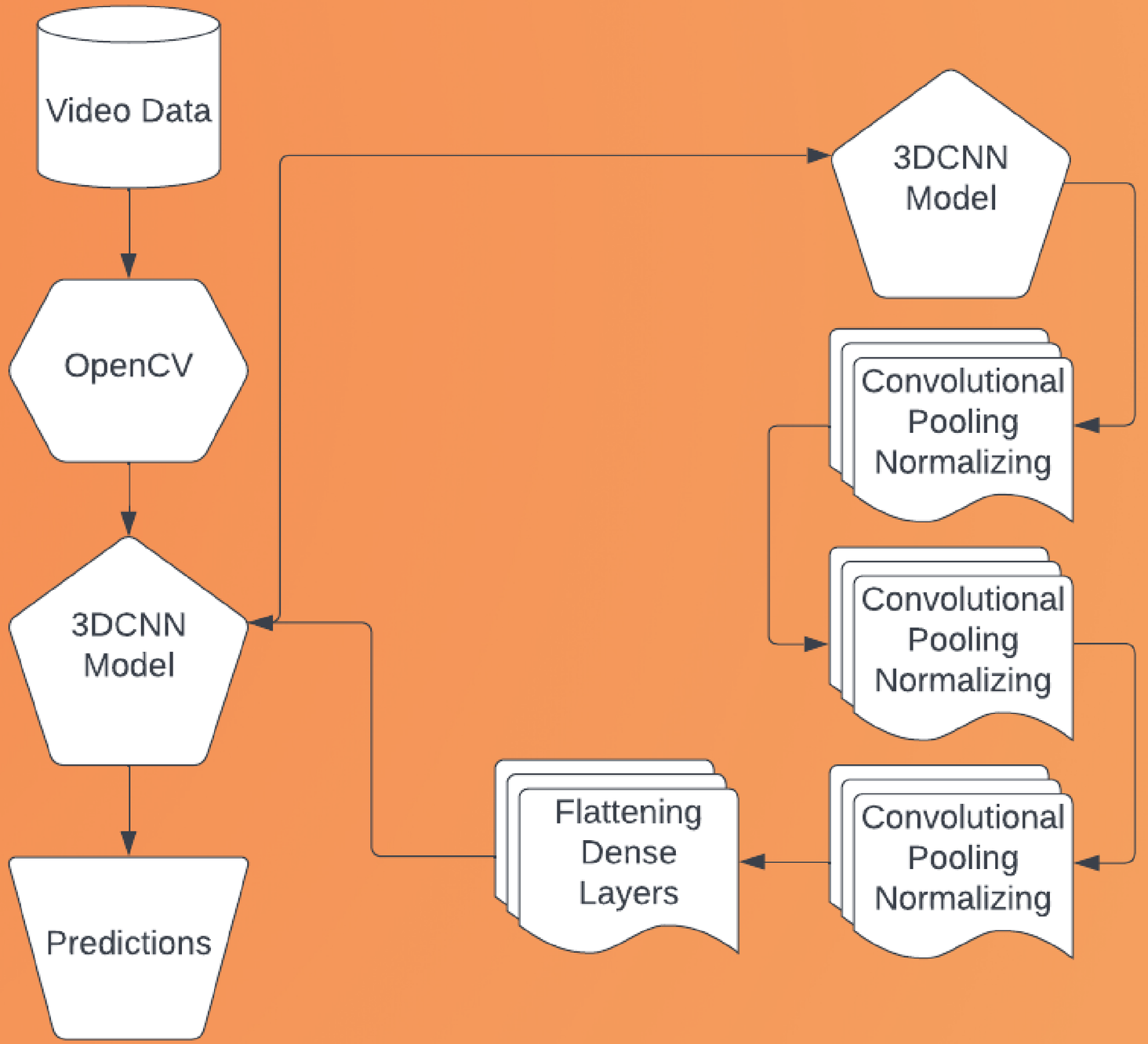
Create images for use with model

TRAIN MODEL ON IMAGES

Feed image data to 3DCNN architecture.

TEST MODEL WITH VIDEO

Evaluate trained model on unseen video


Video Data
OpenCV
3DCNN Model
Predictions
3DCNN Model
Convolutional Pooling Normalizing
Convolutional Pooling Normalizing
Convolutional Pooling Normalizing
Flattening Dense Layers

Performance Evaluation

BASELINE

14.65%

BEST ACCURACY

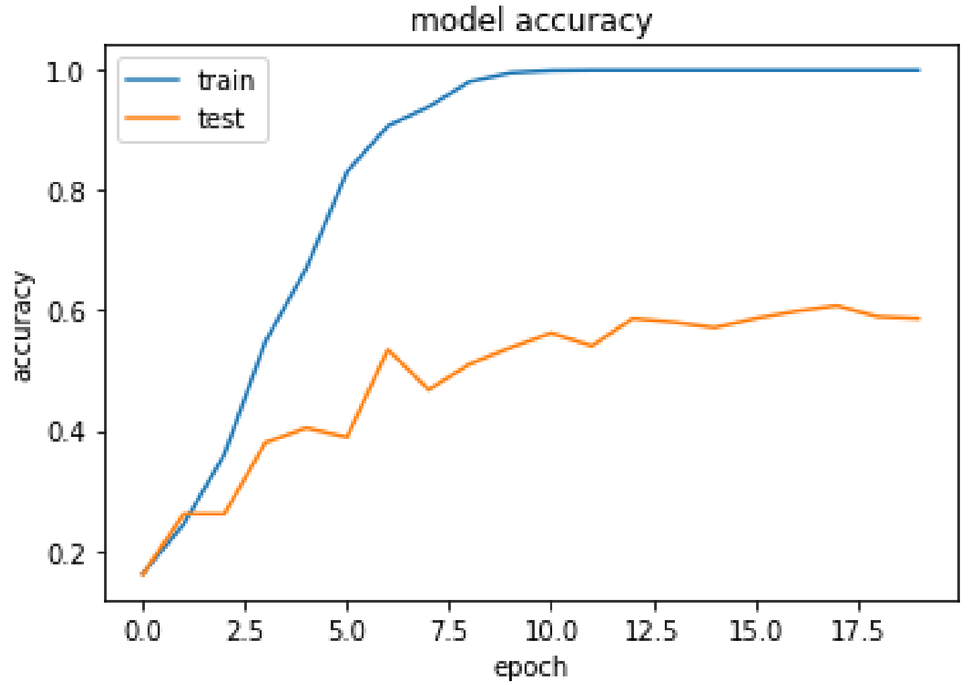
60.79%

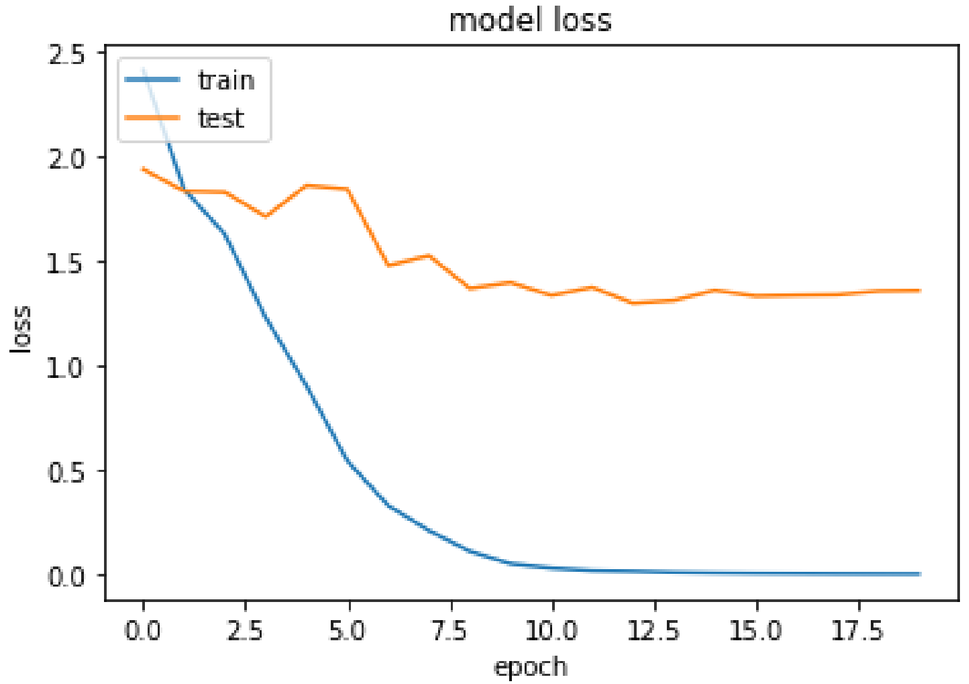
BEST PRECISION BY CLASS

81.07%

Accuracy and Loss

Training and Validation metrics across Epochs





Class Confusion

WARPED BACK

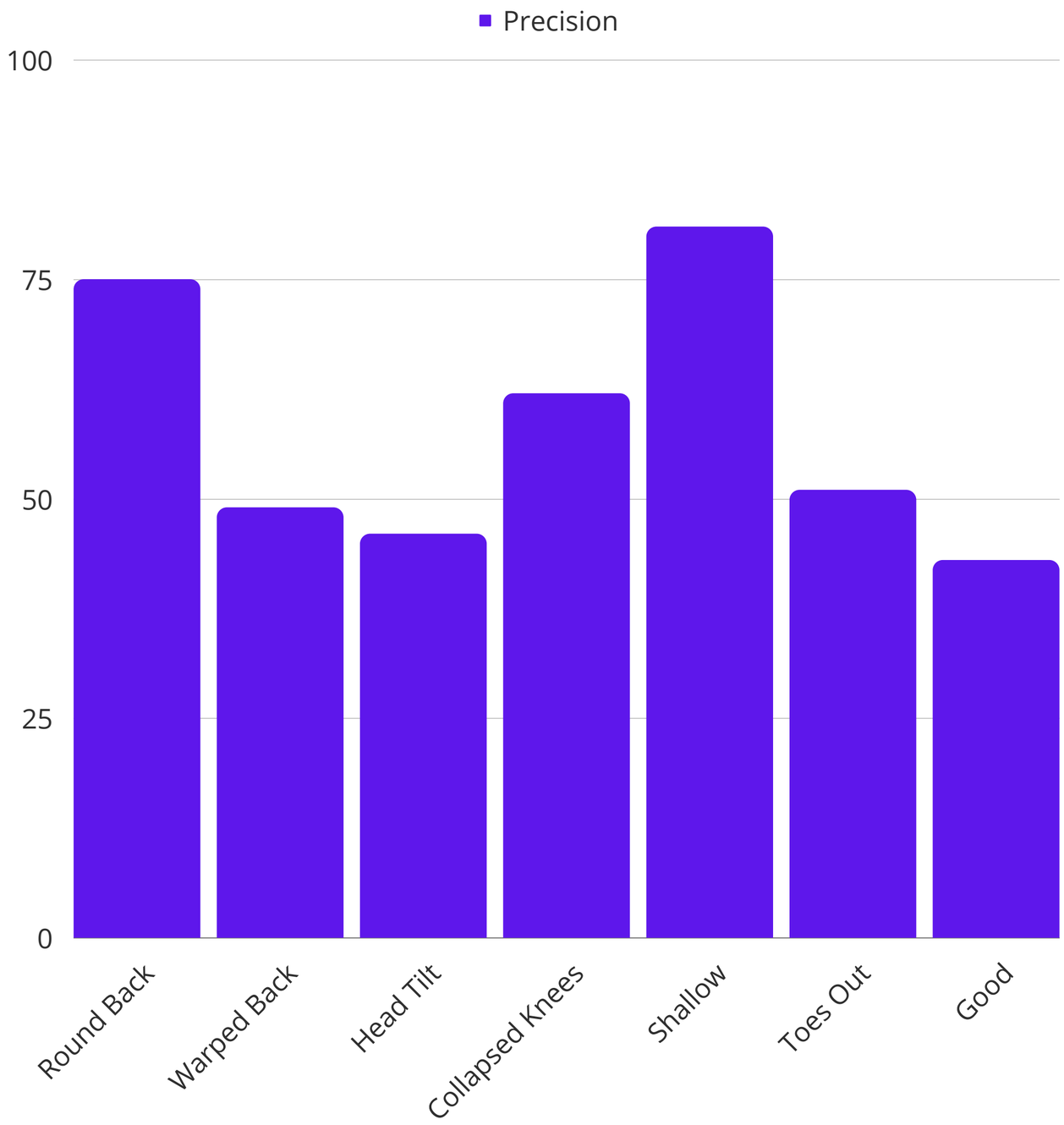
Without Pose data, hard to differentiate Z-axis

GOOD

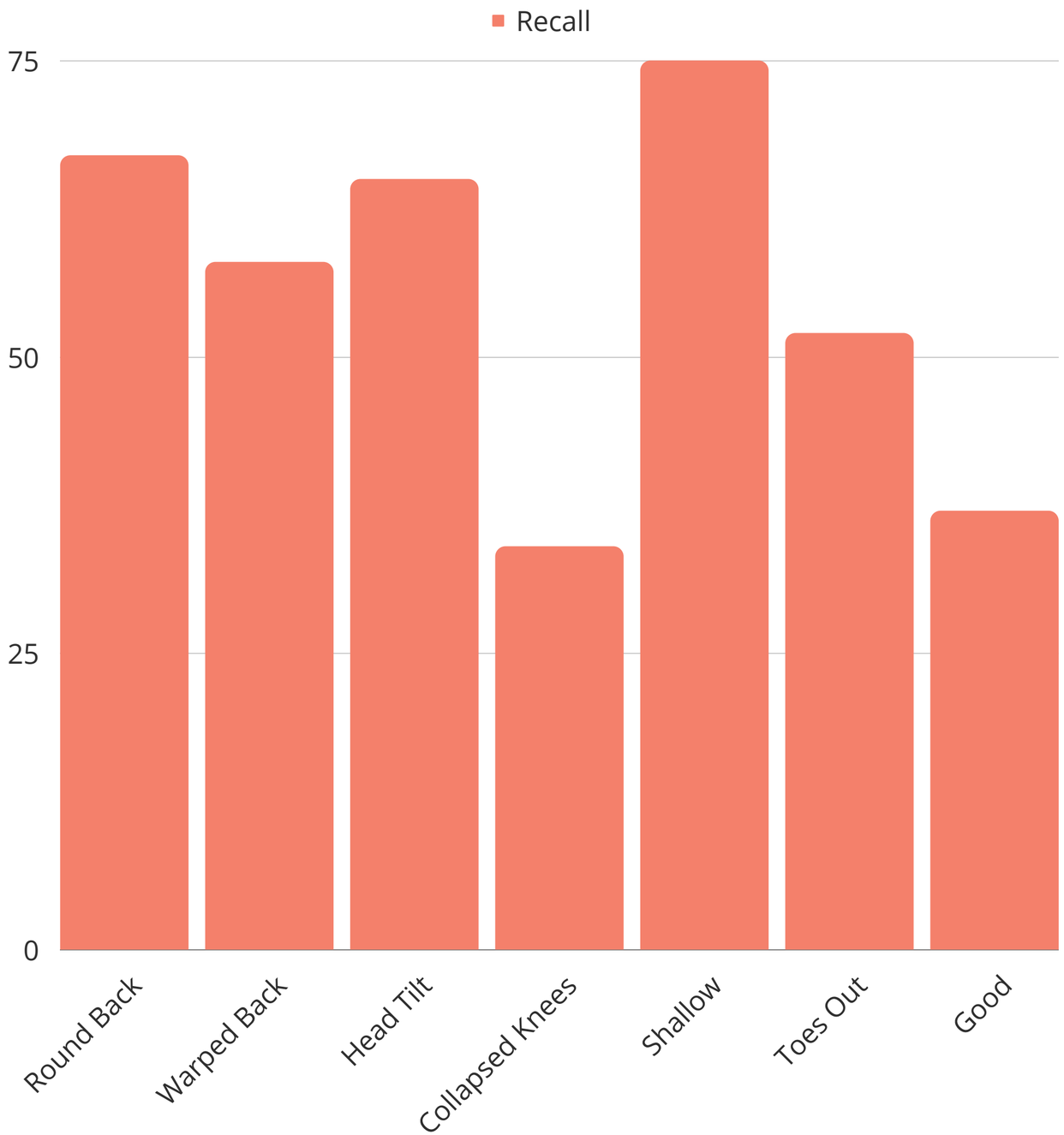
Very similar to Warped Back from same angle

SHALLOW

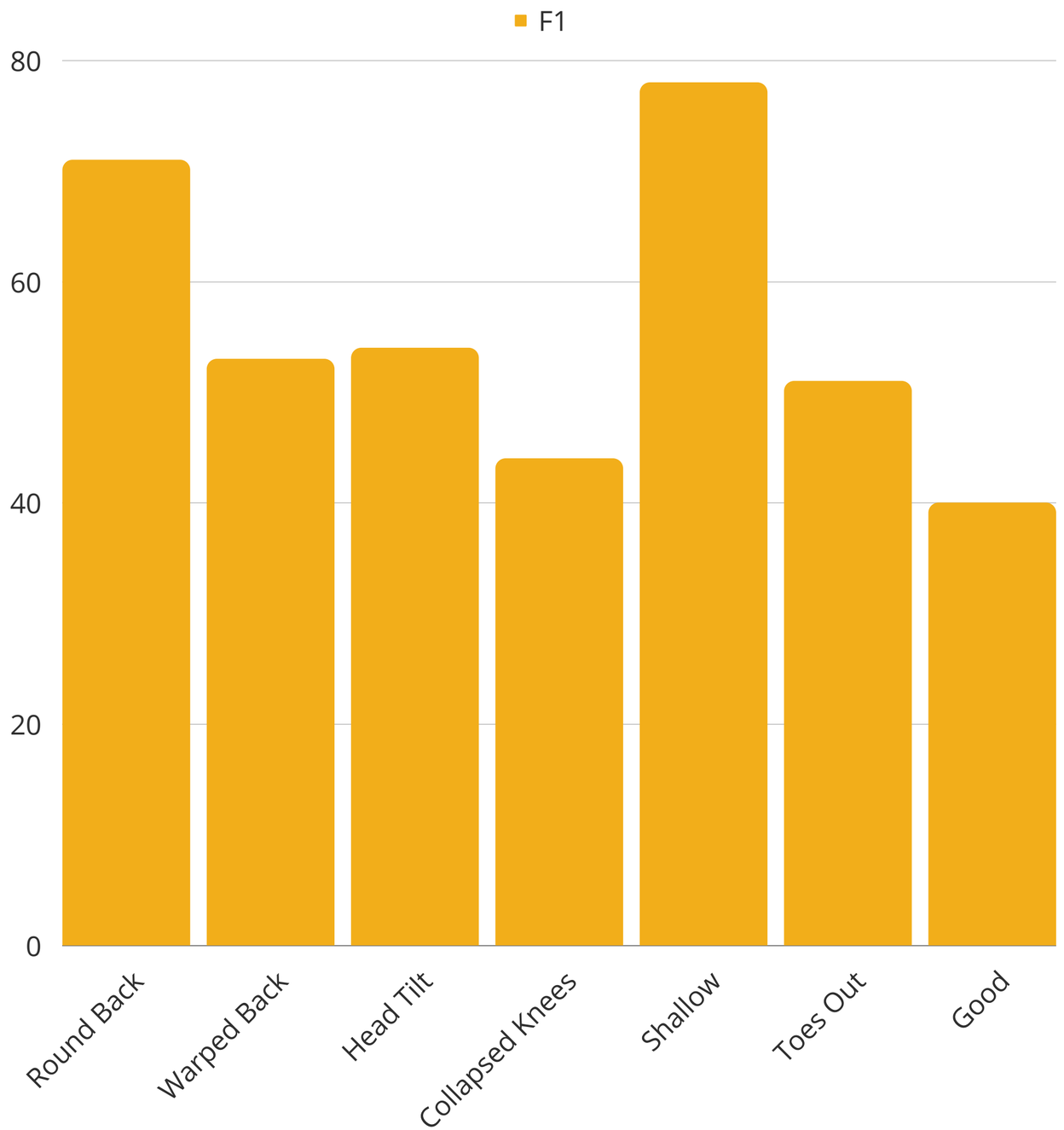
A much more distinct class



Precision by Class



Recall by Class



F1 Score by Class

Future Improvements

Techniques to implement for increased performance

PRE-TRAIN MODEL ON IMAGE DATA

UTILIZE POSE ESTIMATION DATA

FURTHER ADJUSTMENTS TO ARCHITECTURE

Thank you for listening!

Please reach out for any additional questions or comments

Appendix

APPENDIX A

Links to video and WorkSafe data

APPENDIX B

Model summary for 3DCNN architecture

APPENDIX C

Overall Class balance

APPENDIX D

Classification Report

Appendix A

VIDEO DATASET

http://hi.cs.waseda.ac.jp/~ogata/Dataset.html

WORKSAFE BC STATISTICS

https://www.worksafebc.com/en/resources/about-us/annual-report-statistics/2020-stats/2020-stats?lang=en

Appendix B

```
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv3d_40 (Conv3D)          (None, 58, 62, 62, 64)    5248

 max_pooling3d_30 (MaxPoolin  (None, 29, 31, 31, 64)   0
 g3D)

 batch_normalization_30 (Bat  (None, 29, 31, 31, 64)   256
 chNormalization)

 conv3d_41 (Conv3D)          (None, 27, 29, 29, 128)   221312

 max_pooling3d_31 (MaxPoolin  (None, 13, 14, 14, 128)  0
 g3D)

 batch_normalization_31 (Bat  (None, 13, 14, 14, 128)  512
 chNormalization)

 conv3d_42 (Conv3D)          (None, 11, 12, 12, 256)   884992

 conv3d_43 (Conv3D)          (None, 11, 12, 12, 512)   131584

 max_pooling3d_32 (MaxPoolin  (None, 11, 12, 12, 512)  0
 g3D)

 batch_normalization_32 (Bat  (None, 11, 12, 12, 512)  2048
 chNormalization)

 dense_34 (Dense)            (None, 11, 12, 12, 256)   131328

 flatten_16 (Flatten)        (None, 405504)            0

 dense_35 (Dense)            (None, 512)               207618560

 dense_36 (Dense)            (None, 7)                 3591

=================================================================
Total params: 208,999,431
Trainable params: 208,998,023
Non-trainable params: 1,408
```

Appendix C

	Videos	%
good	311	15.07
bad_back_round	288	13.95
bad_back_warp	320	15.50
bad_inner_thigh	235	11.39
bad_toe	305	14.78
bad_shallow	325	15.75
bad_head	280	13.57

Appendix D

	precision	recall	f1-score	support
bad_back_round	0.75	0.67	0.71	49
bad_back_warp	0.49	0.58	0.53	69
bad_head	0.46	0.65	0.54	57
bad_inner_thigh	0.62	0.34	0.44	44
bad_shallow	0.81	0.75	0.78	72
bad_toe	0.51	0.52	0.51	58
good	0.43	0.37	0.40	62
accuracy			0.56	411
macro avg	0.58	0.55	0.56	411
weighted avg	0.58	0.56	0.56	411