Centre for
Data Analytics

Insight

Adventures in Digital…..

Augmenting the Physiotherapist

Prof Brian Caulfield

Director, Insight @ University College Dublin

@caulfieldbrian


Insight
Centre for Data Analytics

- Combines 5 Centres of Excellence
- 8 Institutions
- 40+ Principal & Funded Investigators
- 400+ Researchers (PD, PhD)
- 50+ Collaboration Partners
- 30% of primary funding base from industry

Data Science

Biomedical Engineering

Chemistry

Data Science

Physiotherapy

Material Science

Medicine

Sports Science

Nursing

Systems

Biology

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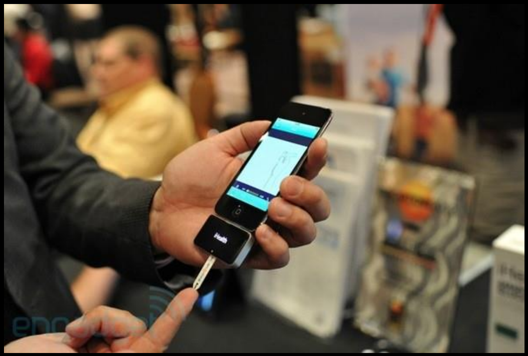
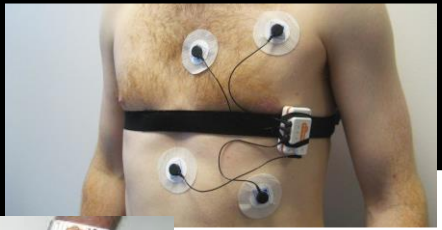
Rehabilitation &
Exercise Science
Sensing & Processing
Knowledge Extraction
Visualisation,
Recommendation & Actuation



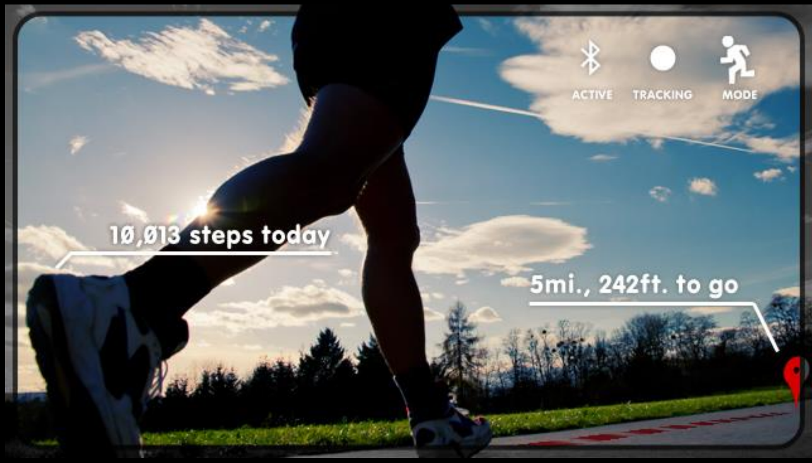

Made for
iPod iPhone iPad



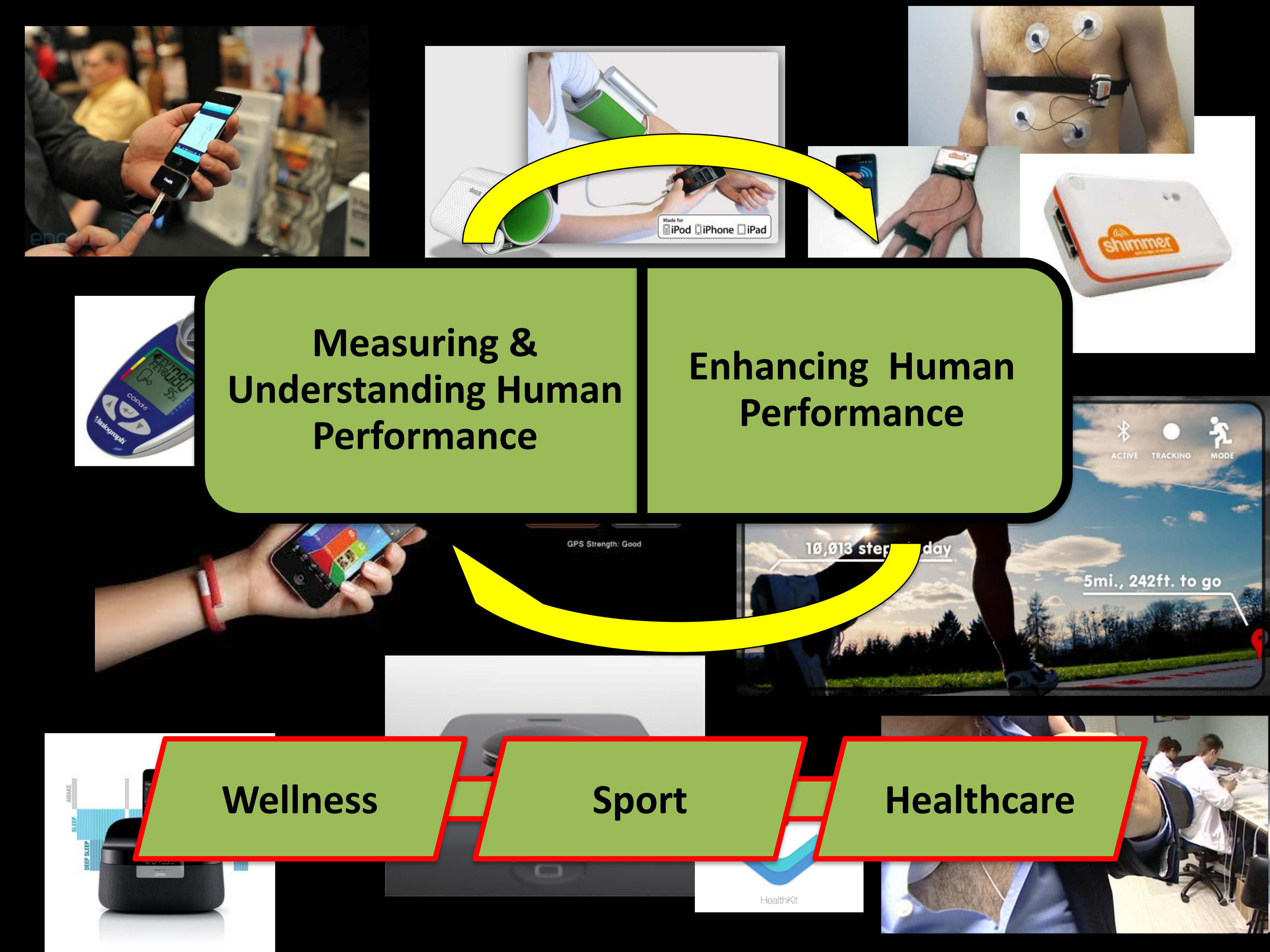

shimmer


copd6
Vitalograph

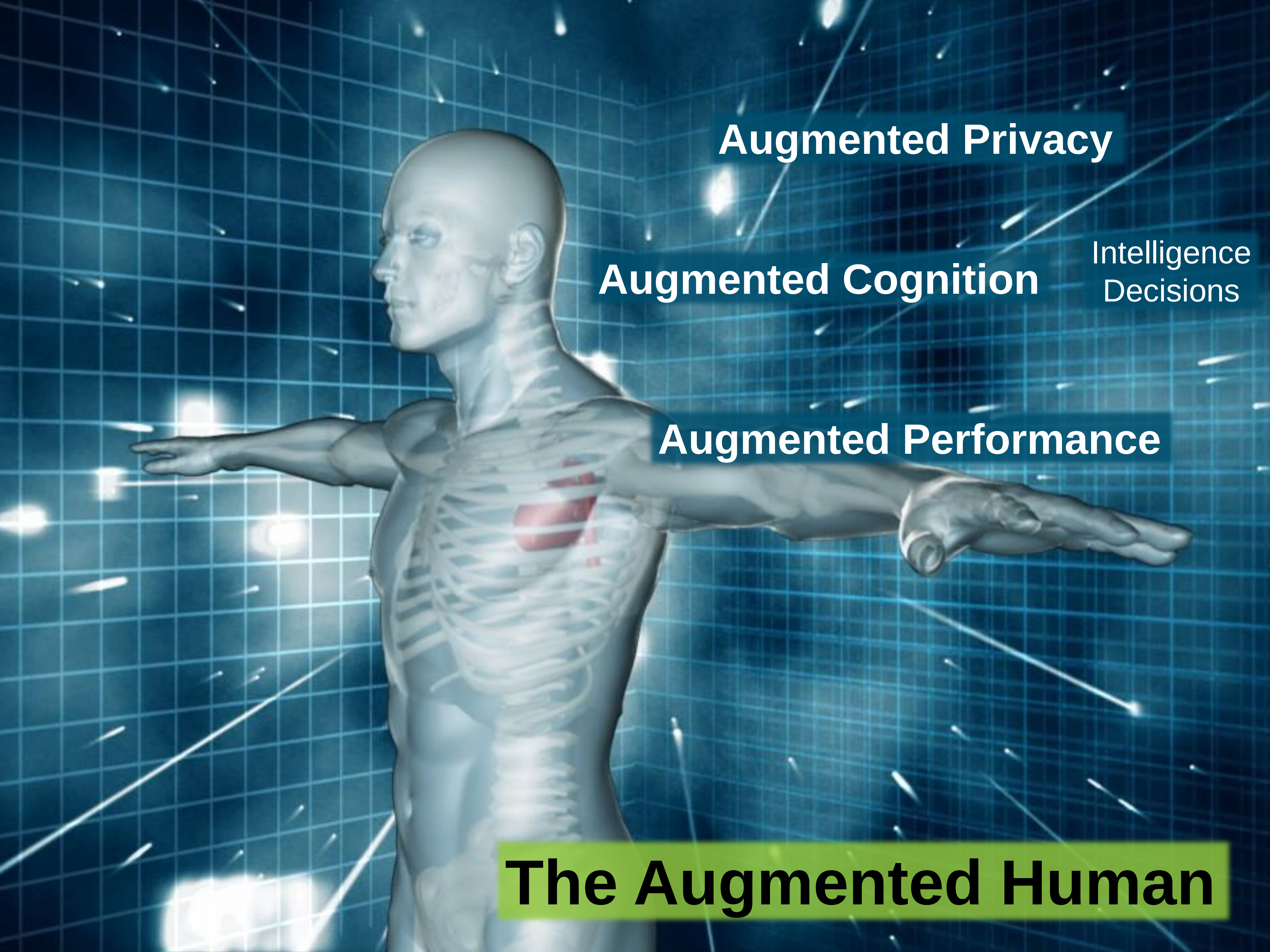

RunKeeper
7.12 Mph
32:34
8:25 min/mile
10.2 miles
Stop
Pause
GPS Strength: Good

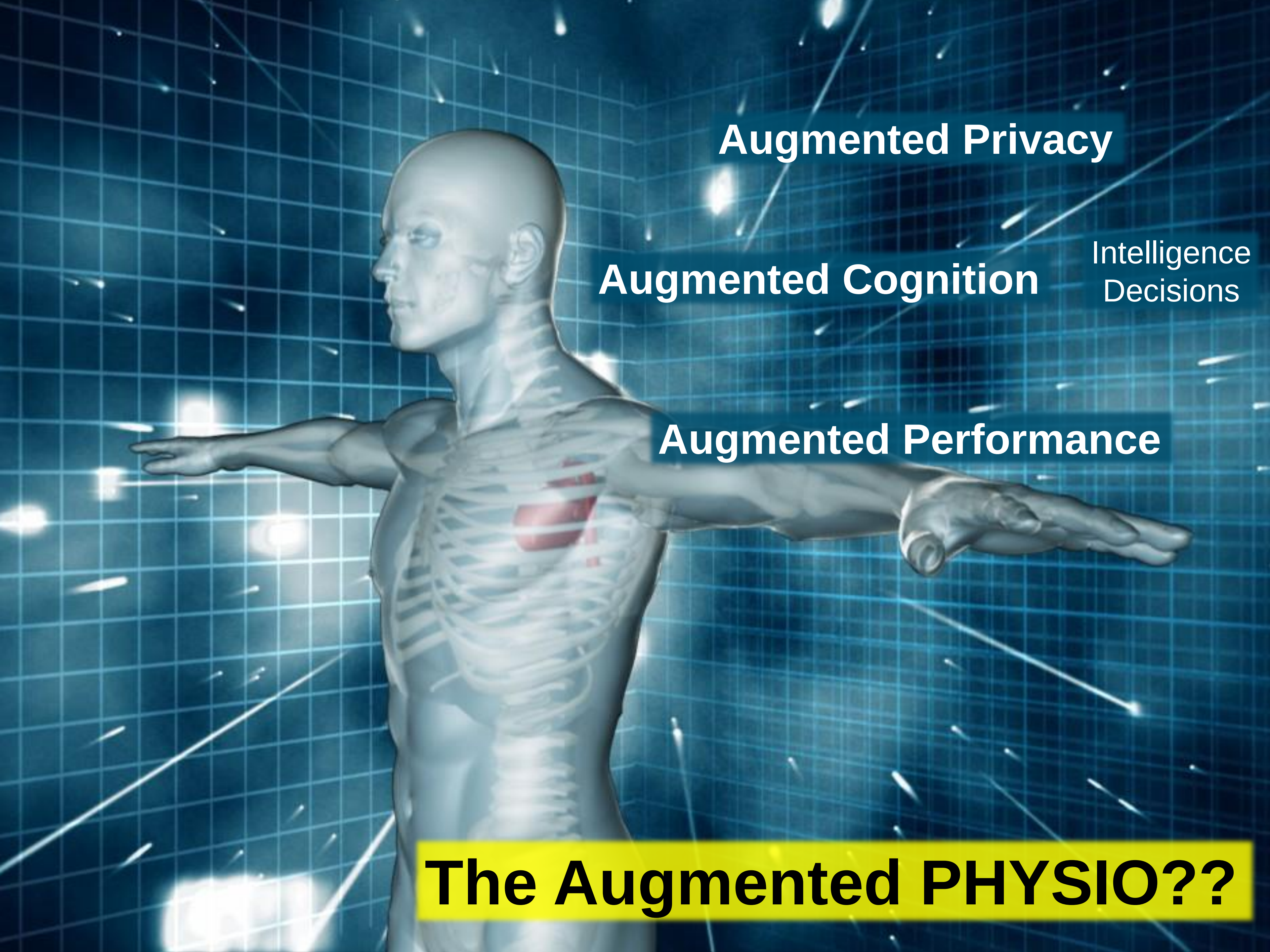

ACTIVE
TRACKING
MODE
10,013 steps today
5mi., 242ft. to go

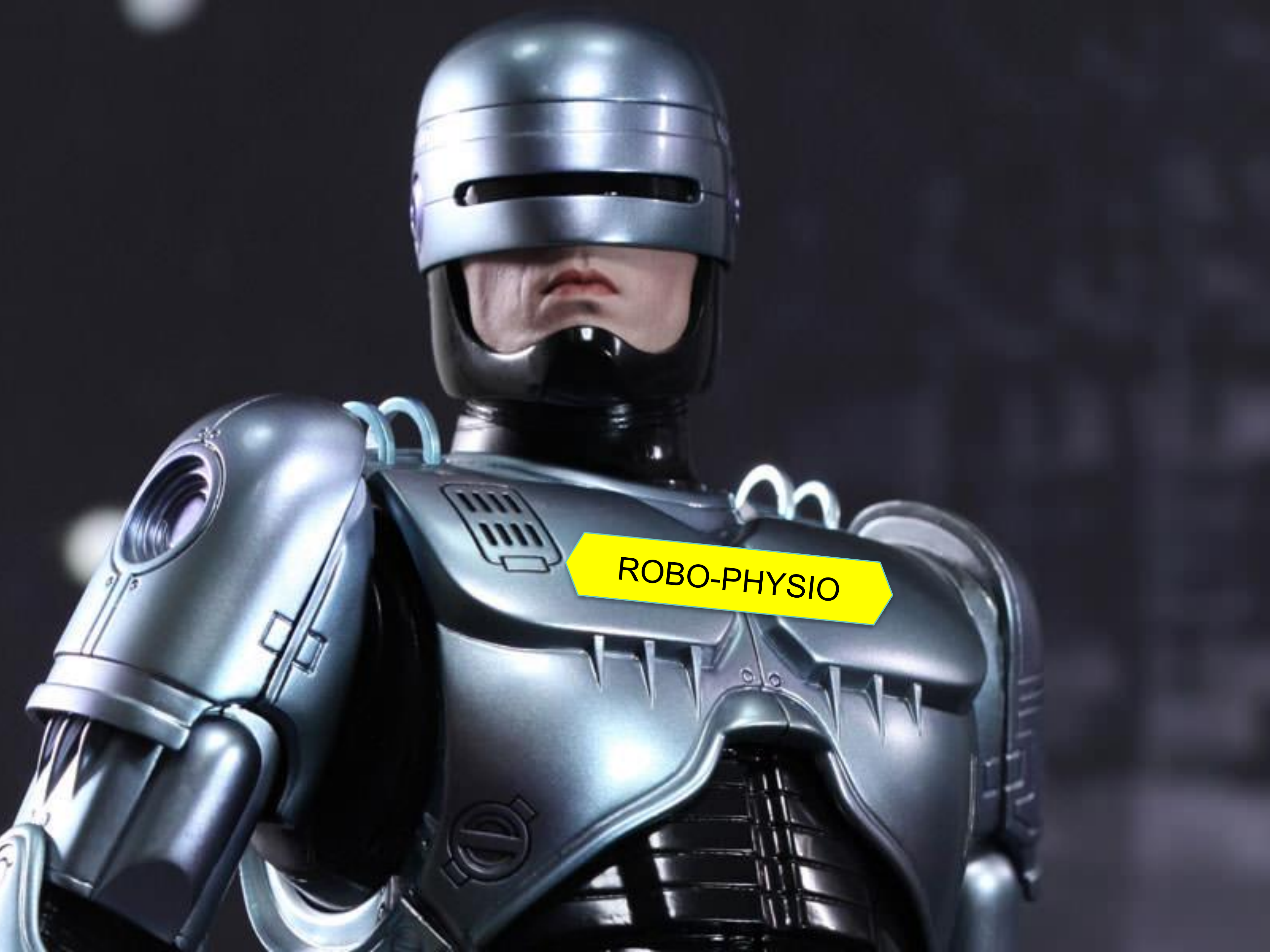

AWAKE
SLEEP
DEEP SLEEP
07:35


Measuring & Understanding Human Performance
Enhancing Human Performance
Wellness
Sport
Healthcare
Made for iPod iPhone iPad
shimmer
ACTIVE
TRACKING
MODE
GPS Strength: Good
5mi., 242ft. to go
HealthKit


Augmenting Human Effectiveness in a Digital World
…..where we create an enormous digital footprint and are overwhelmed with data....
…..but get limited intelligence from it....
…..and have little control over its journey....


Augmented Privacy
Augmented Cognition
Intelligence
Decisions
Augmented Performance
The Augmented Human


Augmented Privacy
Augmented Cognition
Intelligence
Decisions
Augmented Performance
The Augmented PHYSIO??


ROBO-PHYSIO

CBOT

TRATAMIENTOS ROBOTIZADOS

Automated PT?

Robotic PT?

Automated PT?

Robotic PT?


KUKA
KUKA

augment

verb
/ɔːgˈmɛnt/

1. make (something) greater by adding to it; increase.
   synonyms: increase, make larger, make bigger, make greater, add to, supplement, top up, build up, enlarge, expand, extend, raise, multiply, elevate, swell, inflate; More

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Effective Exercise Implementation

creating a data-driven society

Existing technologies to assist with implementation of Rehabilitation Exercise……..

provision of interactive feedback to motivate patient

guidance through exercise performance

measurement of compliance

accurate measurement of technique with clinically relevant feedback

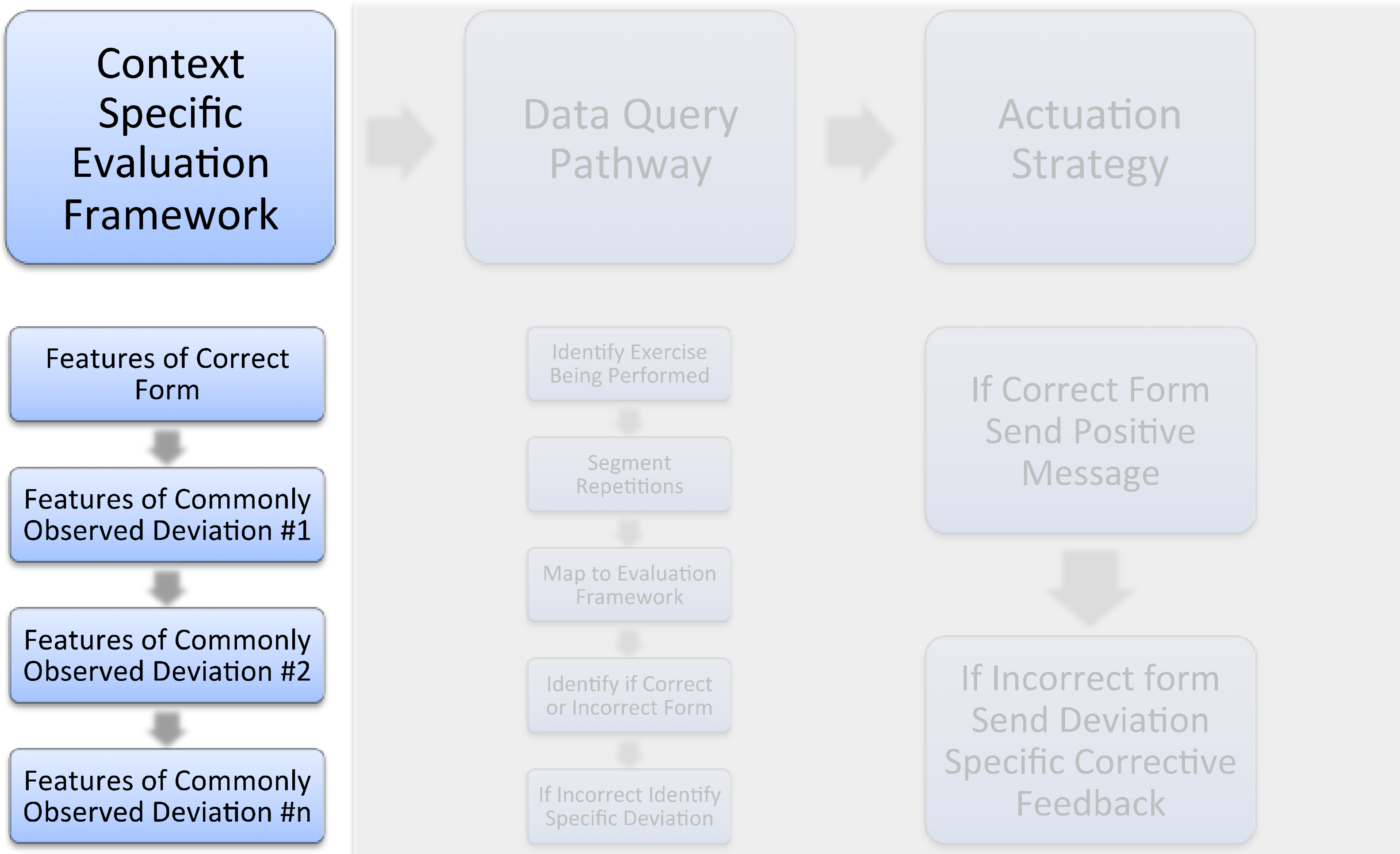
Context Specific Evaluation Framework → Data Query Pathway → Actuation Strategy

steps towards data driven classification of performance…..

Features of Correct Form
Features of Commonly Observed Deviation #1
Features of Commonly Observed Deviation #2
Features of Commonly Observed Deviation #n

Identify Exercise Being Performed
Segment Repetitions
Map to Evaluation Framework
Identify if Correct or Incorrect Form
If Incorrect Identify Specific Deviation

If Correct Form Send Positive Message
If Incorrect form Send Deviation Specific Corrective Feedback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Context Specific Evaluation Framework

Features of Correct Form

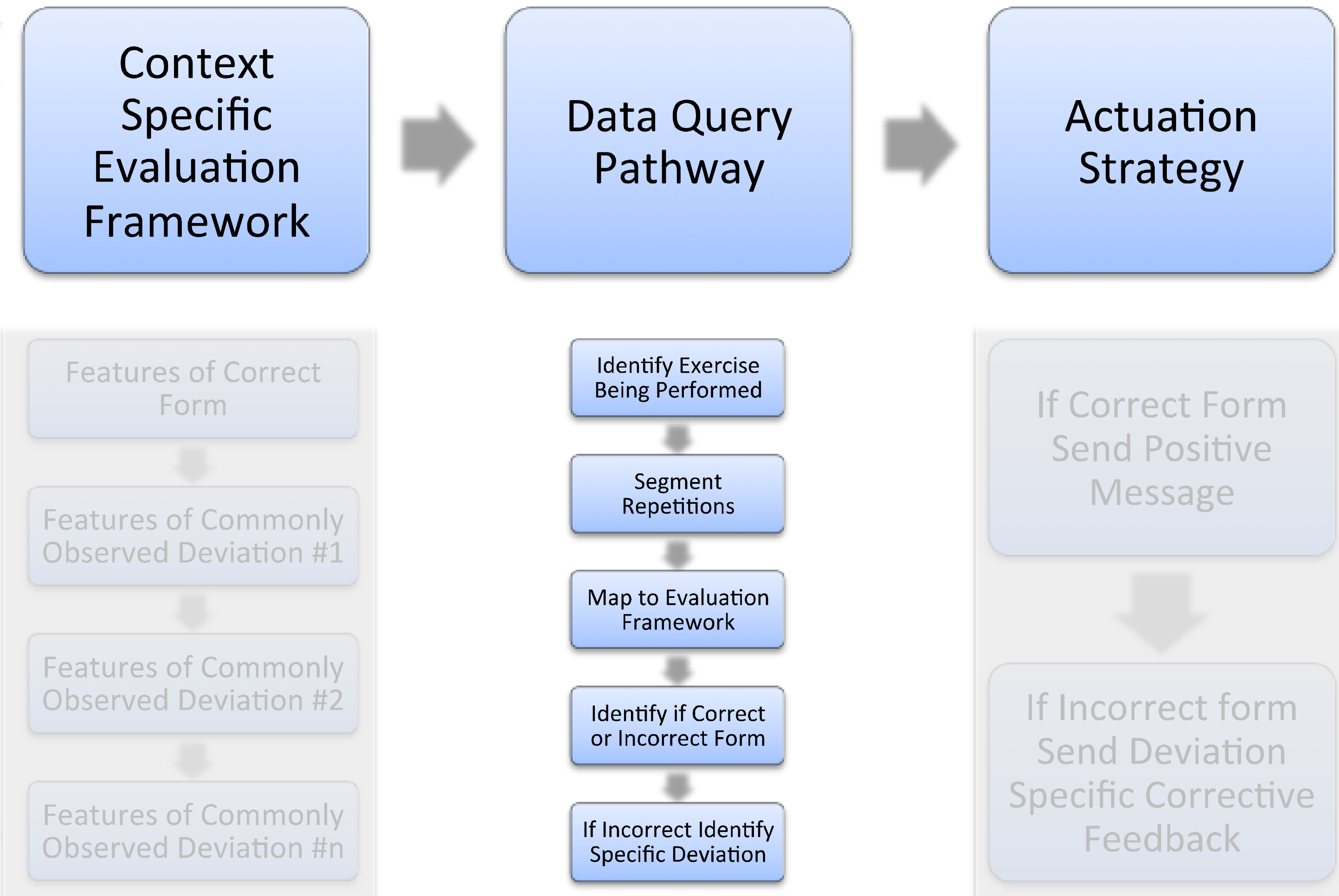
Features of Commonly Observed Deviation #1

Features of Commonly Observed Deviation #2

Features of Commonly Observed Deviation #n

KVL	Left knee coming towards mid-line during downwards phase
KVR	Left knee moving away from mid-line during downward phase
KTF	Left knee ahead of toes during downward phase
HSR	Excessive lean to left hand side during entire lunge exercise
HSL	Excessive lean to right hand side during entire lunge exercise
BO	Excessive flexion of hip and torso during entire lunge exercise
BFO	Right foot externally rotated
SS	Loss of balance during upward phase resulting stuttered steps
PB	Pushing backwards during upwards phase
STS	Starting stance too short
STL	Starting stance too long

Specific Deviation


Context Specific Evaluation Framework
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Context Specific Evaluation Framework → **Data Query Pathway** → **Actuation Strategy**

Context Specific Evaluation Framework:

- Features of Correct Form
- Features of Commonly Observed Deviation #1
- Features of Commonly Observed Deviation #2
- Features of Commonly Observed Deviation #n

Data Query Pathway:

- Identify Exercise Being Performed
- Segment Repetitions
- Map to Evaluation Framework
- Identify if Correct or Incorrect Form
- If Incorrect Identify Specific Deviation

Actuation Strategy:

- If Correct Form Send Positive Message
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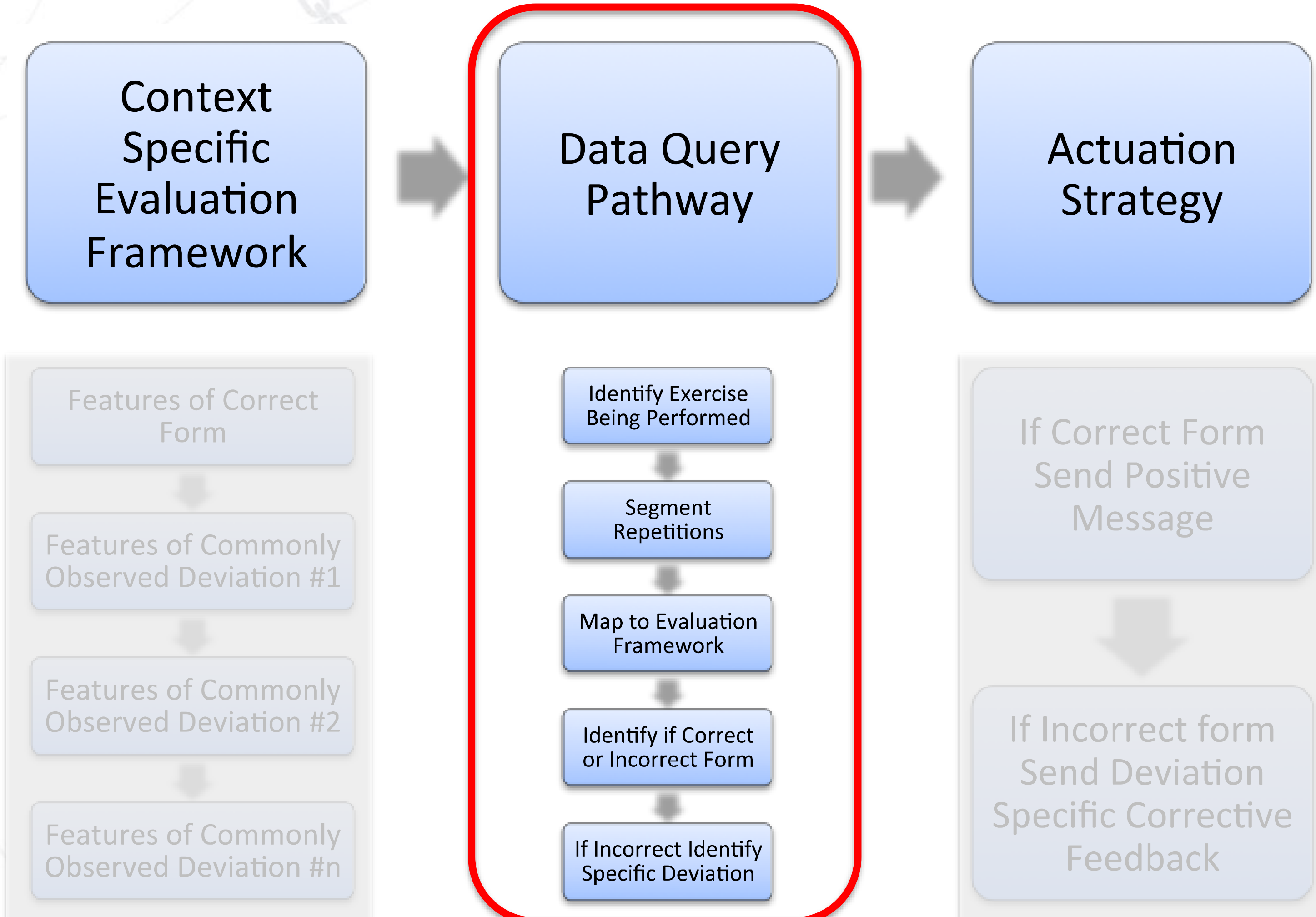
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IMUs

- Advantages
  - Objective measurement
  - Quick to apply
  - Inexpensive
  - Allow natural movement
  - Lead to possibility of using mobile phone as sensor

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Data Collection

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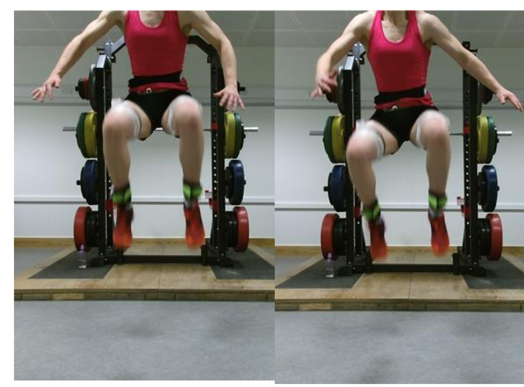
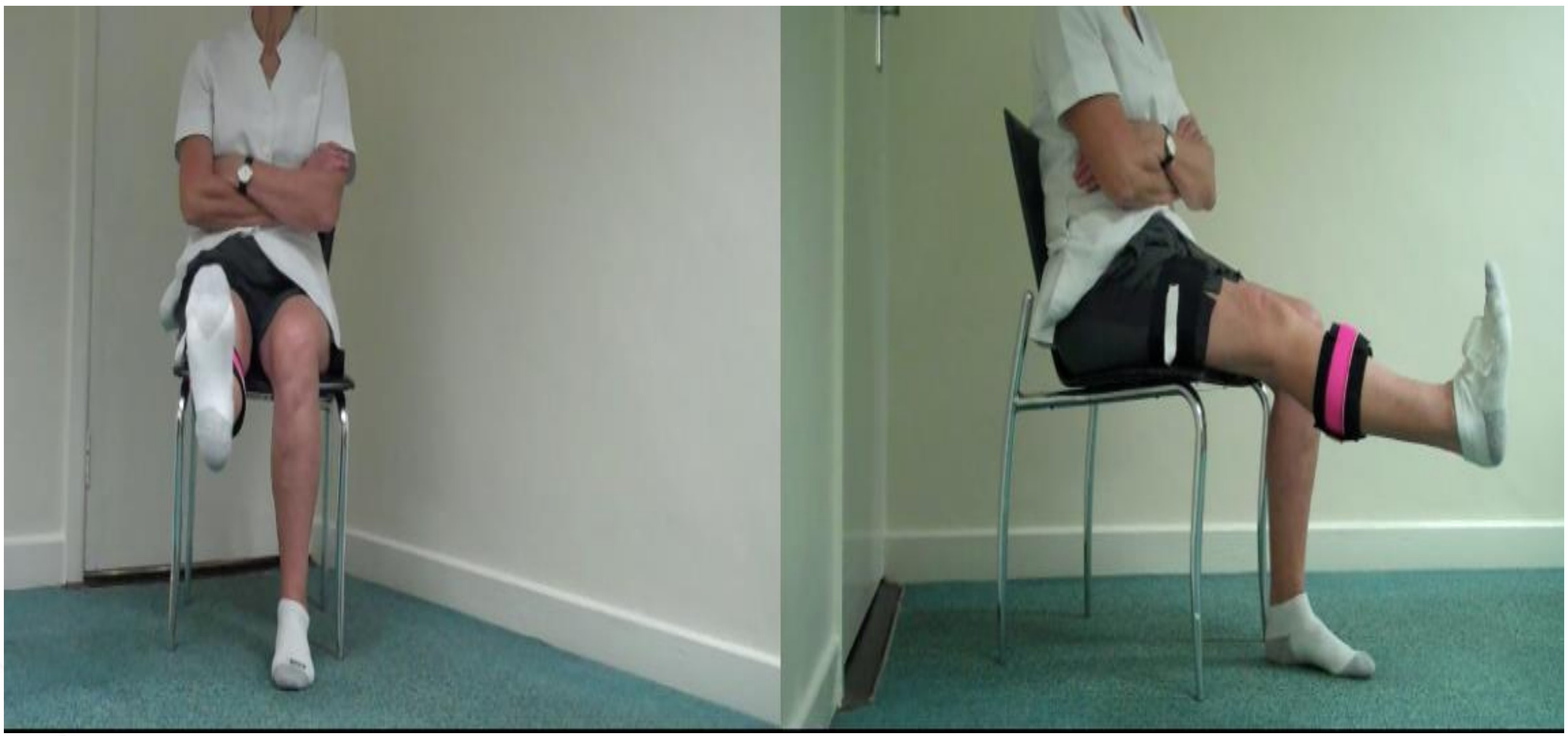
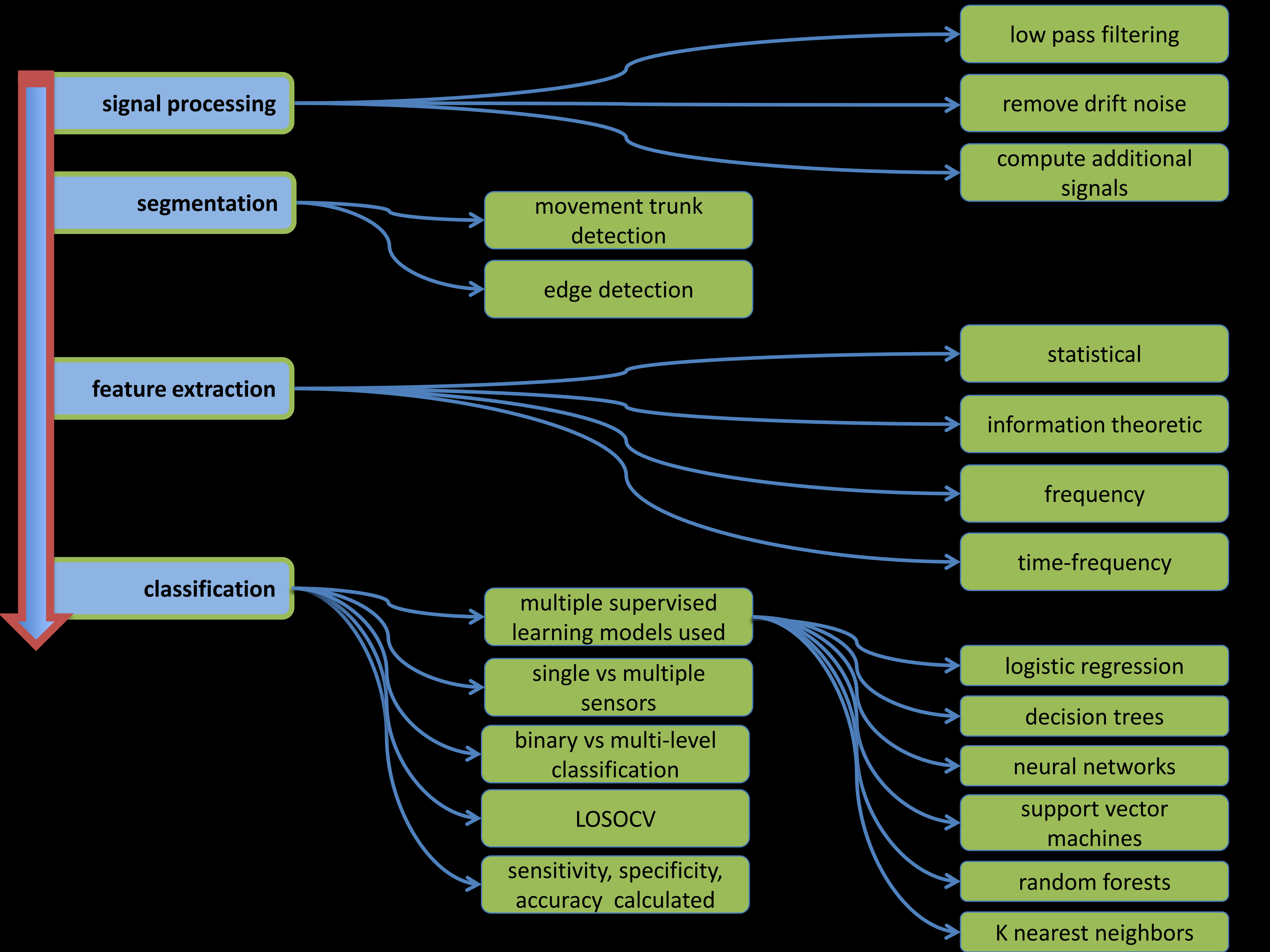




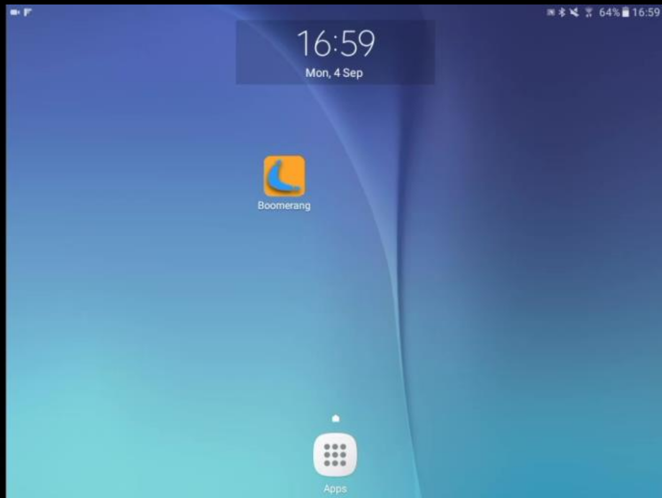


signal processing
segmentation
feature extraction
classification
low pass filtering
remove drift noise
compute additional signals
movement trunk detection
edge detection
statistical
information theoretic
frequency
time-frequency
multiple supervised learning models used
single vs multiple sensors
binary vs multi-level classification
LOSOCV
sensitivity, specificity, accuracy calculated
logistic regression
decision trees
neural networks
support vector machines
random forests
K nearest neighbors

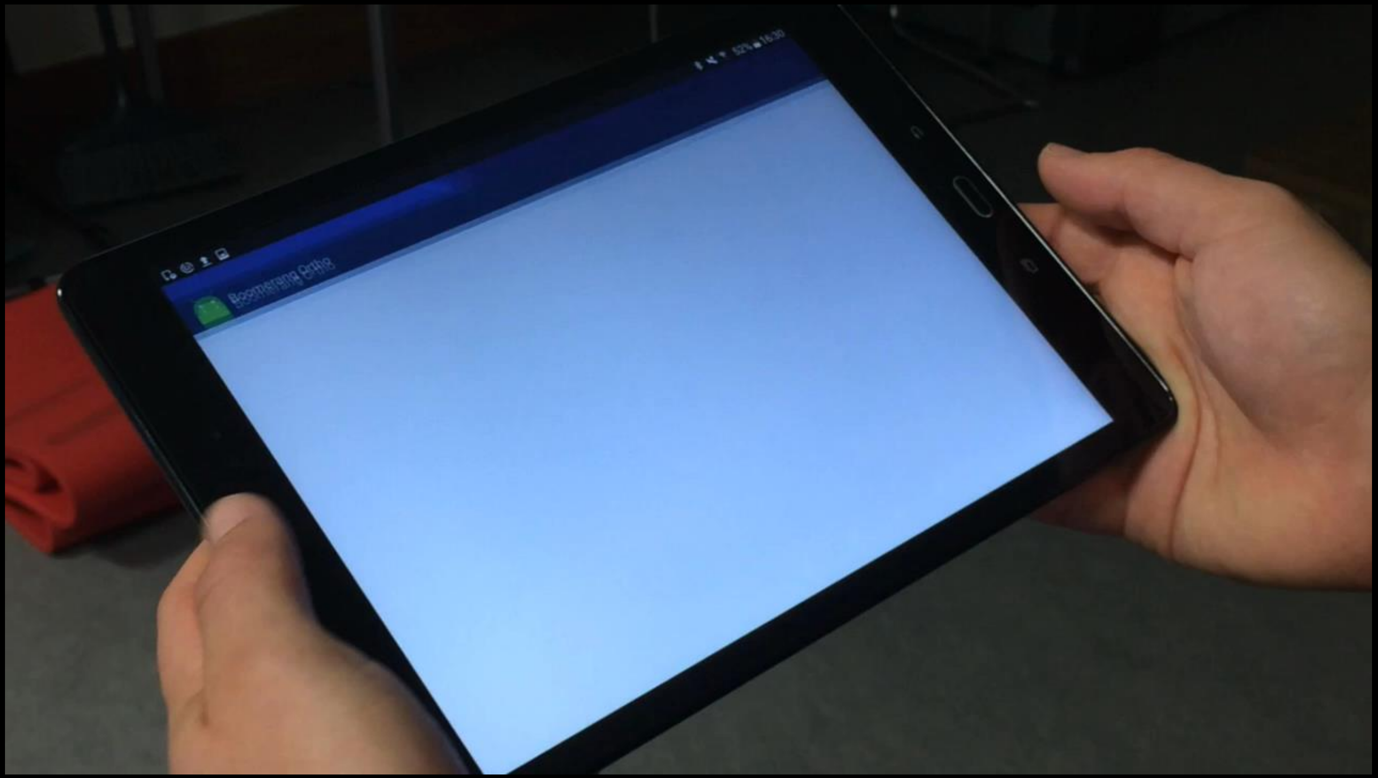
Model Evaluation

		% ACCURACY (Single Sensor)	% ACCURACY (Multiple Sensors)
Single Limb Exercises (Ortho Rehab)	*Detection & Segmentation*	95-99	95-99
	Binary Classification	80-85	85-95
	Multi-label Classification	80-85	85-95
Complex Multijoint Exercises (S&C Exercises)	*Detection & Segmentation*	95-99	95-99
	Binary Classification	80-85	85-95
	Multi-label Classification	40-50	70-75

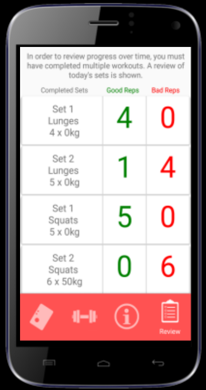
currently evaluating personalised classifier model…..

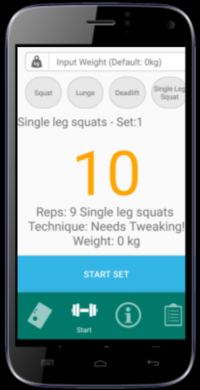


Boomerang Ortho



FormuLift


In order to review progress over time, you must have completed multiple workouts. A review of today's sets is shown.
Completed Sets
Good Reps
Bad Reps
Set 1 Lunges 4 x 0kg
4
0
Set 2 Lunges 5 x 0kg
1
4
Set 1 Squats 5 x 0kg
5
0
Set 2 Squats 6 x 50kg
0
6
Review


Input Weight (Default: 0kg)
Squat
Lunge
Deadlift
Single Leg Squat
Single leg squats - Set:1
10
Reps: 9 Single leg squats
Technique: Needs Tweaking!
Weight: 0 kg
START SET
Start

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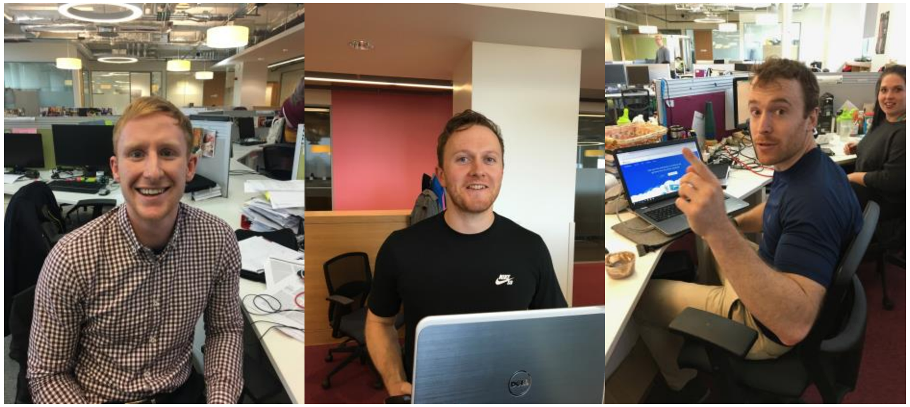
Mobile Balance Evaluation Toolkit



creating a data-driven society

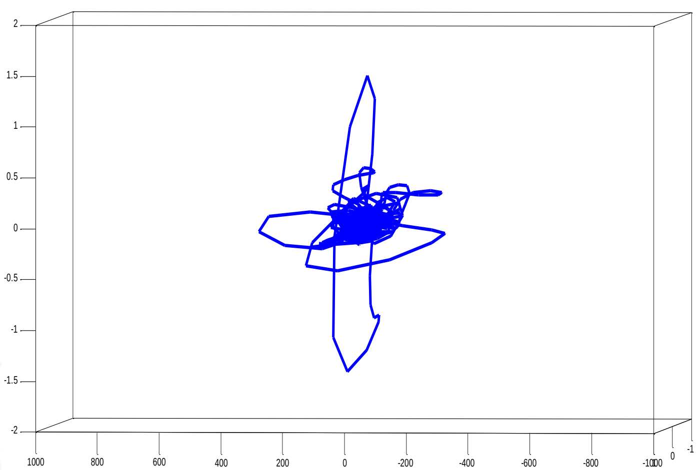
Y Balance Test

Y Balance Test

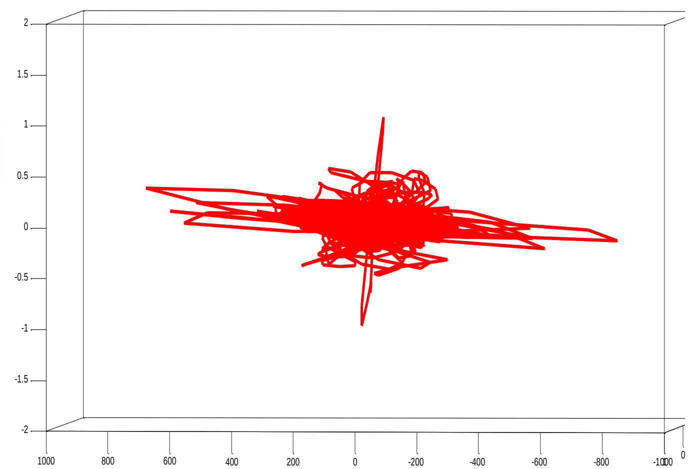
Can we move it from analog to digital?

If so, what more can we learn from it?

Normal Balance



Abnormal Balance



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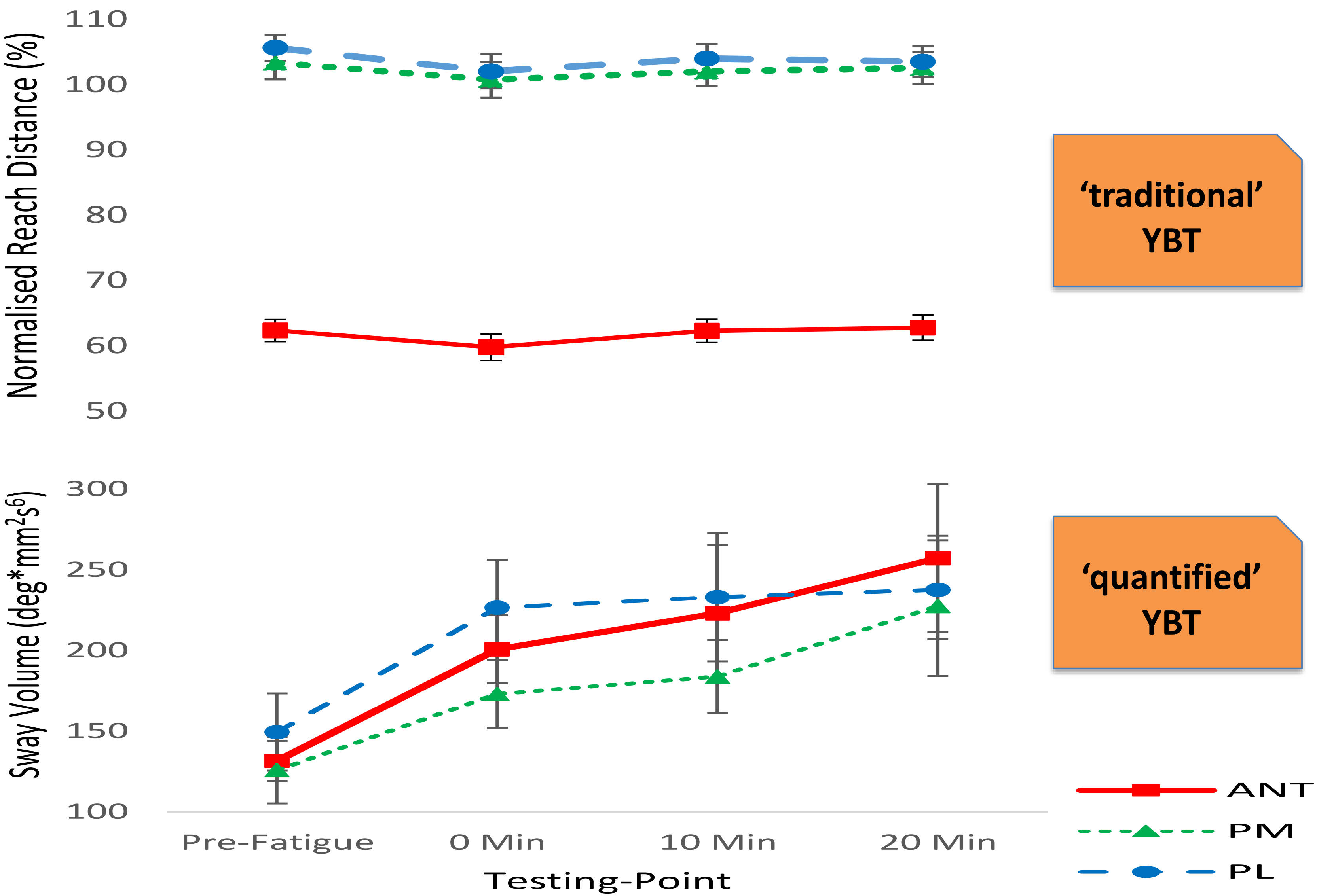


YBT Testing Points

Pre-Season

Mid-Season

Concussion

HIA2

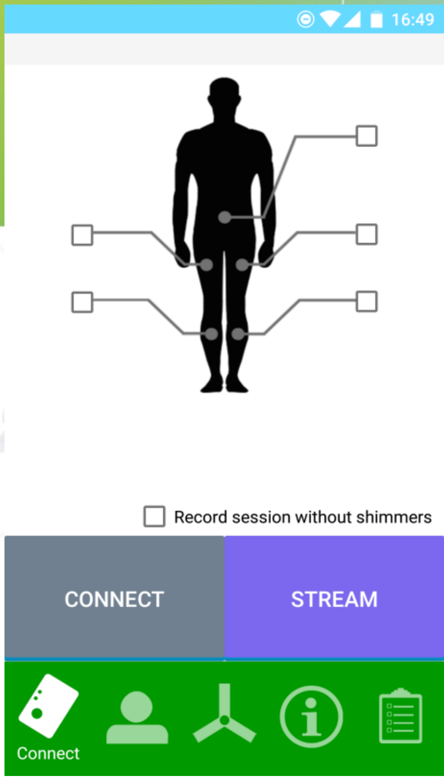
HIA3

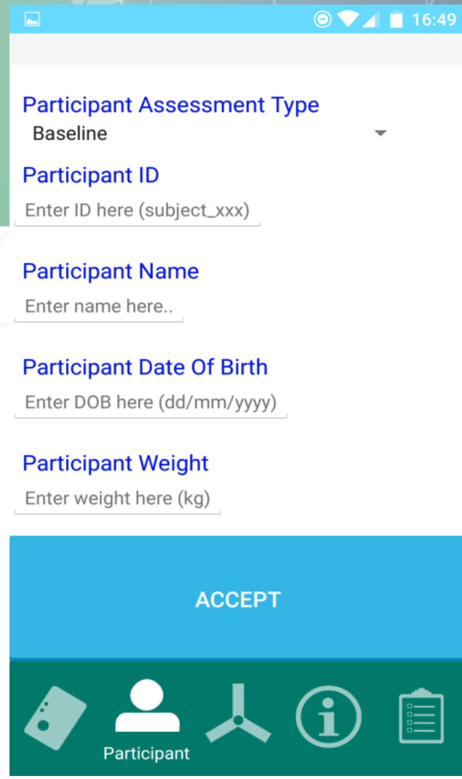
RTP

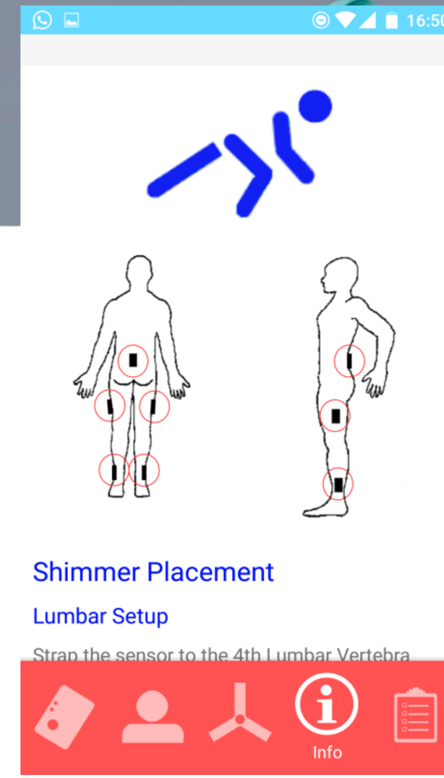
Baseline

'traditional' YBT n=268

'quantified' YBT N=109



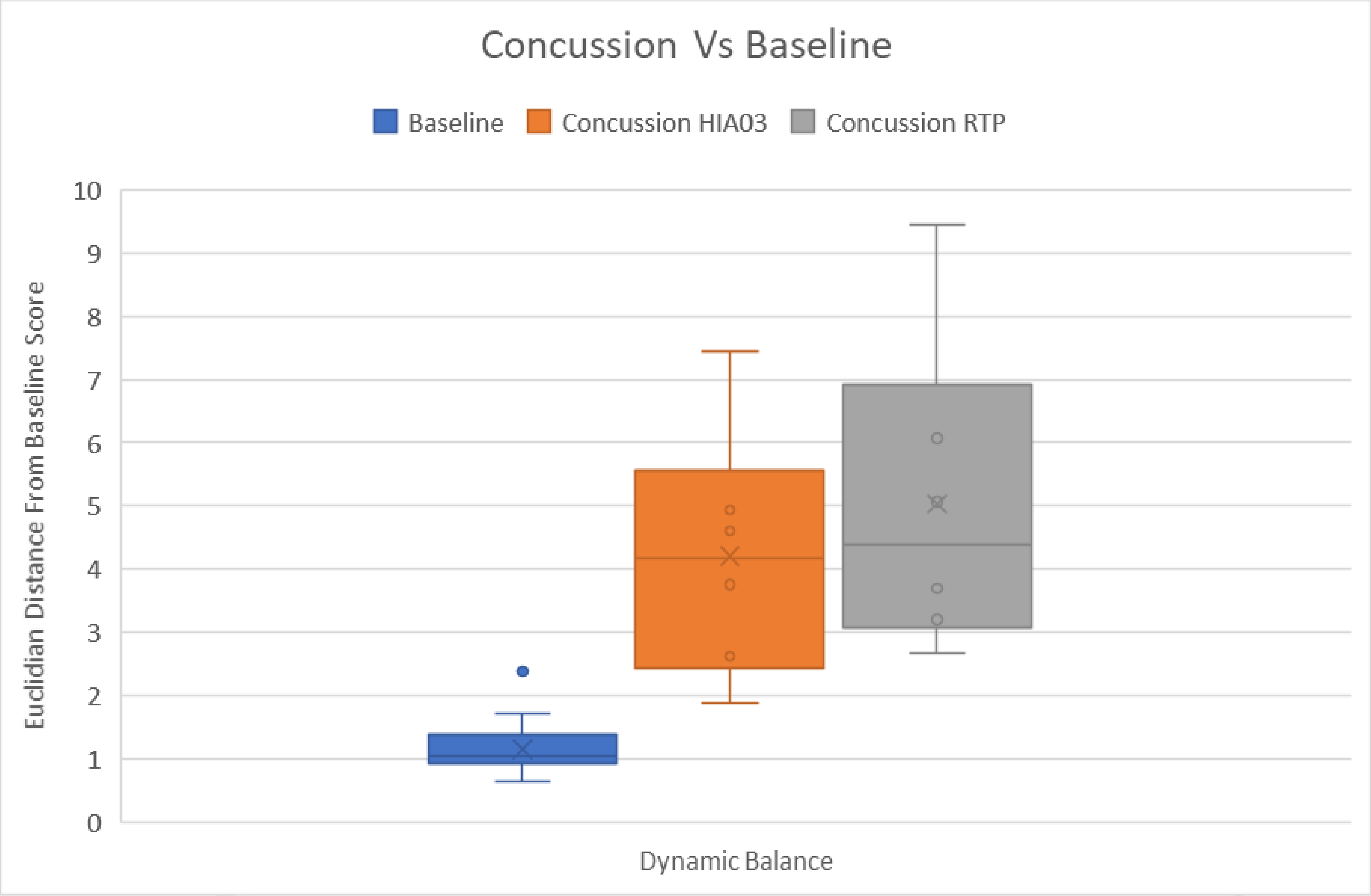




shimmer
DISCOVERY IN MOTION

creating a data-driven society

Can inertial sensor data capture dynamic balance control deficits following a concussive head injury?



Are dynamic balance control deficits at pre-season associated with an increased risk of sustaining a concussion?

simple answer…………….YES

Players with sub-threshold q-YBT performance at baseline 3 times more likely to sustain concussive injury throughout the season, controlling for previous history of concussion……

Thank You!

isek

international society of electrophysiology and kinesiology

UCD / Dublin / Ireland

30th June-2nd July 2018

www.isek.org

Call for Abstracts now open!

Bringing together researchers in human movement and the neuromuscular system

@caulfieldbrian

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Anterior

Regression Model	Predictors	P Value	Odds Ratio	LOWER	Upper
Model 1	Concussion History	0.03	2.94	1.10	7.85
	Constant	<0.01	0.14		
Model 2	ANT_R_GyromagApproxEntroy	0.015	3.84	1.29	11.40
	Constant	<0.01	0.104		
Model 3	Concussion History	0.045	2.81	1.024	7.736
	ANT_R_GyromagApproxEntropy	0.023	**3.63**	1.198	10.971
	Constant	<0.01	0.07		
Model 4	Concussion History	0.27	2.91	0.44	19.2
	ANT_R_ApproxEntropy	0.13	3.72	0.69	20.10
	ANT_R_GyromagApproxEntropy*Con Hx	0.97	0.96	0.10	8.9
	Constant	<0.01			

Postero-Lateral

Regression Model	Predictors	P Value	Odds Ratio	LOWER	Upper
Model 1	Concussion History	0.03	2.94	1.10	7.85
	Constant	<0.01	0.14		
Model 2	PL_R_lumbar_pitch_f95%_22.03	<0.01	5.962	2.08	17.07
	Constant	<0.01	0.097		
Model 3	**Concussion History**	**0.04**	**3.07**	**1.07**	**8.79**
	PL_R_lumbar_pitch_f95%_22.03	**<0.01**	$\boxed{6.04}$	**2.05**	**17.80**
	Constant	**<0.01**	**0.07**		
Model 4	**Concussion History**	**0.77**	**0.77**	**0.13**	**4.54**
	PL_R_lumbar_pitch_f95%_22.03	**0.38**	**1.95**	**0.44**	**8.66**
	PL_R_lumbar_pitch_f95%_22.03*ConHx	**0.05**	**9.68**	**0.99**	**94.82**
	Constant	**<0.01**	**0.12**		

Postero-Medial

Regression Model	Predictors	P Value	Odds Ratio	LOWER	Upper
Model 1	Concussion History	0.03	2.94	1.10	7.85
	Constant	<0.01	0.14		
Model 2	PM_L_lumbar_gyroY_approxDW_185	0.037	2.84	1.06	7.59
	Constant	<0.01	0.143		
Model 3	**Concussion History**	**0.043**	**2.82**	**1.03**	**7.70**
	PM_L_lumbar_gyroY_approxDW_185	**0.043**	$\boxed{\textbf{2.82}}$	**1.03**	**7.70**
	Constant	**<0.01**	**0.09**		
Model 4	**Concussion History**	**0.03**	**6.33**	**1.16**	**34.52**
	PM_L_lumbar_gyroY_approxDW_185	**0.21**	**0.26**	**0.03**	**2.17**
	PM_L_lumbar_gyroY_approxDW_185*conchx	**0.03**	**6.33**	**1.162**	**34.52**
	Constant	**<0.01**	**0.53**		