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AI-assisted Personal Training Gear

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Contents

Title: AI-assisted personal training gear

Descriptor

Proper posture and muscle engagement during exercise are crucial for maximizing training efficiency, minimizing unnecessary stress on ligaments and joints, and lowering injury risks. However, existing wearable technologies fall short in meeting the demands of high-intensity exercises.

This study introduces a personal training gear that leverages synchronized and continuous electromyography (EMG) signals, inertial measurement unit (IMU) data, and imaging inputs to monitor body movement and muscle activity during exercise. These objective measurements offer a comprehensive, real-time overview of training performance, assisting personal trainers and athletes in optimizing training programs to enhance efficiency and minimize injury risks.

The research focuses on optimizing sensor placement and interfaces to ensure accurate data collection, as well as designing patterns and selecting fabrics that enable freedom of movement and wearing comfort. Machine learning and neural network algorithms were developed to (1) detect eight specific exercises and their common pose deviations using video imaging, and (2) assess Muscle Fatigue and predict the estimated number of remaining repetitions with EMG signals. The system also recommends the optimal training load to maximize efficiency. By monitoring muscle utilization patterns and body motion, the gear identifies incorrect exercise poses and provides real-time warnings to the user.

This AI-assisted personal training gear addresses critical technological gaps in current wearable systems, particularly in monitoring and enhancing strength training targeting specific muscle groups. Its advanced measurements and analytics offer a comprehensive evaluation of training performance in real-time, with applications spanning the healthcare and sports industries.

Patents are filed in China, Hong Kong and the United States. The research outputs have been presented at the *International Conference on Applied Human Factors and Ergonomics (2022 & 2023*), *TechConnect World Innovation Conference and Expo* in Washington, DC, exhibited in Paris, and featured in local media reports.

Personal Profile: Prof. Joanne Yip

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Professor Joanne Yip is Professor and Associate Dean (Industrial Partnership) at the PolyU School of Fashion and Textiles. Her research focuses on the development of textile-based medical devices and functional clothing, integrating functional textiles, smart materials, advanced production technologies, and healthcare innovation. A core area of her work is the creation of solutions for adolescent idiopathic scoliosis (AIS).

Professor Yip leads interdisciplinary research programmes that develop wearable interventions for early-stage AIS. These include the Posture Correction Girdle (PCG), which incorporates EVA padding, elastic straps, and plastic bones, and the Anisotropic Textile Brace (ATB), featuring an artificial hinged backbone, corrective straps, and semi-rigid silicone pads. She directs the methodological development, implementation, and dissemination of these projects, integrating anthropometric studies, finite element modeling (FEM) of spinal biomechanics, iterative design trials, and smart sensor technologies for real-time posture monitoring. To facilitate the translation of research outcomes into practice, she established the spin-out company Active Biotechnology (HK) Ltd., which advances wearable technologies for spinal health.

As Principal Investigator, Professor Yip has secured research funding exceeding HK$30 million, including the Research Impact Fund (RIF: P0044974, 2024–2028) and the Collaborative Research Fund (CRF: C5058-24G, 2025–2028) for projects investigating spinal flexibility, biomechanical behaviour, and predictive modelling in AIS. Her research outputs include 13 patents granted in the US, China, and Hong Kong, and over 300 peer-reviewed publications. Her findings have been widely disseminated through conference presentations, workshops, and exhibitions. Professor Yip’s work has been recognised with Gold Medals at the Silicon Valley International Invention Festival (2019, 2024) and the International Exhibition of Inventions Geneva (2023).

Research Co-Investigators

Role in the Programme:
Leads the project, overseeing the design and optimization of sensor placement, textile–sensor interfaces, and garment construction to ensure accurate data capture and user comfort, and supervised the development of machine learning models and the integration of EMG, IMU, and imaging data into a unified monitoring system.

Prof. Kit-Lun YICK	Dr. Sun-Pui Ng
	
Professor, SFT, PolyU Members of RISports, PolyU	**Assoc Div Hd (SEHS) & Assoc HoR, Division of Science, Engineering and Health Studies, PolyU**
Expertise: • Advanced fashion production technologies • 3D anthropometric body measurement **Role in the Programme:** • Conducts fit analysis using 3D body scanning technology • Develops comfort assessment protocols for wear trials	**Expertise:** • Composite materials stress analysis • Mechanical failure testing **Role in the Programme:** • Evaluates material durability under cyclic loading

Research Questions

Question 1:

- Smart clothing in the market do not monitor and analyse ***muscle activation level***, ***utilization pattern*** and ***fatigue status,*** which are critical for more demanding physical exercises like resistance training. The potential of wireless **surface electromyography** (sEMG) technologies should be investigated in smart clothing.
- The location of the sEMG sensors is critical in the precision and accuracy of the collected data. However, there is a lack of reference on such information for users of various body sizes and shapes,

Design and develop a set of whole-body **training garments** that are **skin-tight fit**, **moisture wicking**, **breathable**, and can detect muscle utilization patterns by using wireless surface electromyography (sEMG) sensors.

Question 2:

- Correct postures and use of muscles in weight training exercises can maximize training efficiency and minimize additional stress on the ligaments and joints and hence reduce the risk of injuries. However, very limited smart clothing in the market can detect pose anomalies and give specific correction suggestions.

Design and develop a complementary **coaching system** to assist users to perform weight training exercises **correctly** by using AI algorithms that **monitor exercising poses**, **predict muscle fatigue**, and **give instant coaching instructions.**

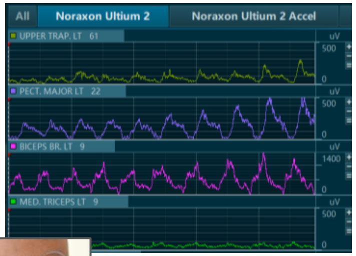
Research Outputs

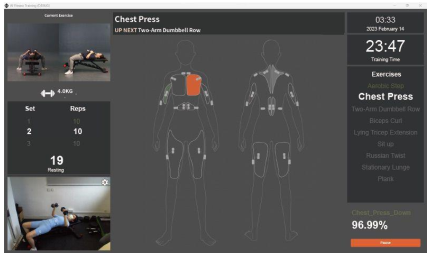
AI-assisted Personal Training Gear (First published on 24th July 2022)

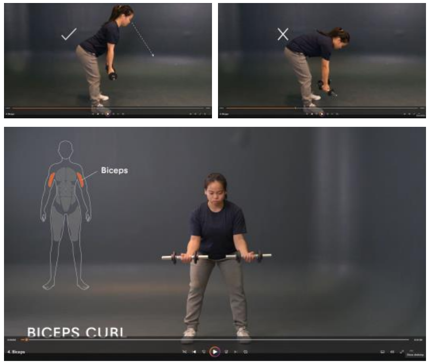
An **<u>AI-assisted</u> wearable sensor-based personal training gear** and a complementary coaching software are developed to

- <u>simultaneously monitor</u> posture, muscle activity and muscle fatigue in real-time during exercise;
- <u>evaluate exercise performance</u> with newly developed AI algorithms based on collected sensor data, and
- <u>provide real-time feedback</u> for enhanced physical performance and reduced risk of injuries.

The invention can be used to plan and revise training programmes, hence enhancing training efficiency, and reducing the risk of injuries.







Research Outputs

Patents / Publications / Exhibitions / Interviews

Category	Details
Patents	• "人工智能輔助個人訓練系統、個人訓練裝置和控制裝置" **China Patent** Application No. 202210781291.7. Publication No.: CN117379069A, filed on 4 July 2022 • "Artificial Intelligence Assisted Personal Training System, Personal Training Device and Control Device", US Non-Provisional Patent (20240001196 A1) published on 4 Jan 2024, filed on 23 March 2023 (Application No.: 18/188,560). • "AI-assisted Personal Training System, Personal Training Gear and Control Device", **Hong Kong Standard Patent**, published on 8 March 2024. (Publication No.: 40097168 A), filed on 22 January 2024 (Application No. 42024085760.7)
Conference Articles	• Cheah, Y.T., Wan, K.W.F., **Yip, J.** (2022). Prediction of Muscle Fatigue During Dynamic Exercises based on Surface Electromyography Signals Using Gaussian Classifier. In: Ravindra S. Goonetilleke and Shuping Xiong (eds) *Physical Ergonomics and Human Factors. AHFE (2022) International Conference.* AHFE Open Access, vol 63. AHFE International, USA. http://doi.org/10.54941/ahfe1002597 • Wan F., **Yip J.**, Mak A., Kwan K., Cheung M.C., Cheng B., Yick K.L. and Ng Z. (2023). Anomaly detection of bicep curl using pose estimation. In: Pedro Arezes and Anne Garcia (eds) Safety Management and Human Factors. AHFE (2023) International Conference. AHFE Open Access, vol 105. AHFE International, USA. http://doi.org/10.54941/ahfe1003069
Conference Presentation	• Presented by **Prof. Joanne Yip**. Title: AI-assisted Personal Training Gear to Monitor and Enhance Exercise Performance.*15th International Convention on Rehabilitation Engineering and Assistive Technology (i-CREATe 2022)*. 26 Aug 2022
Conferences & Exhibitions	• *TechConnect World Innovation Conference and Expo 2023,*19-21 June 2023, Washington, DC, USA. • *"Flying High"*- Exhibition by the Hong Kong Polytechnic University, 25 Jun – 1 Jul 2024, Paris, France
Media Reports	• 《香港故事:創科夢工場 》- 科研都要靚 : 葉曉雲. Radio Television Hong Kong (RTHK). Published on 13th February 2023.

Research Field & Key References

Background

Exercising for Health

- **Resistance training** is a form of physical activity that is designed to **build muscle strength** [1], **muscle mass**, and **anaerobic endurance** through muscular contraction against resistance. It is proved to have immense health benefits for all ages such as to better protect the joints from injury [2], improved flexibility, mobility, and balance [3, 4, 5], etc.
- This form of training has become an emerging fitness trend in recent years [6]. In Hong Kong, the **number of gyms increased** from 548 to 743 (35.6% increase) between 2009 to 2017 [7].

Exercising safety

- Incidents of **injury** due to *Exercise and Equipment* ranked 2nd among all types of injury for age between 25 – 44 in the U.S. in 2018 (Centers for Disease Control and Prevention, 2018). An estimated 3,988,903 incidents of injury were found in the U.S. from 2007 to 2016 that were related to strength training exercises such as burpees, push-ups, and lunges, and the use of exercise equipment such as barbells, kettle bells, and boxes [8]
- **Correct posture** and **use of muscles** in exercise activities not only maximize training efficiency but also minimize additional stress on the ligaments and joints and hence reduce the risk of injuries.

Research Field & Key References

Latest technologies in Smart Clothing and AI in Sports Training

Current Smart Clothing Technologies

- The most common type of smart clothing available on the market is compression shirts with built-in biometric sensors to track *heart rate* and its variability [9], ***breathing rate***, monitor ***body temperature***, and track ***movements*** and ***position*** [10,11] .
- A few inventions can analyse motion and give instant feedback/ advice to users to enhance exercise performance [12, 13].
- However, for more demanding physical exercises like resistance training, the ***muscle activation level***, ***utilization pattern*** and ***fatigue status*** are more important. Wireless **surface electromyography** (sEMG) technologies should be introduced in smart clothing.

AI in bio-feedback sports gear

- Previous studies have demonstrated how to use machine-learning methods to ***provide feedback*** captured by a depth sensor for a set of training motions [14], to predict how a runner would rate perceived exertion based on motion data obtained with a fused inertial [15], and to differentiate runner groups by skill level based on inertial measurement units (IMU) data [16].
- Adopting artificial intelligence technologies can lead to a better interpretation of sensor-collected data and efficient extraction of useful guiding information to achieve training goals.

Hexoskin Smart Garments continuous cardiac, pulmonary, activity & sleep data [10].

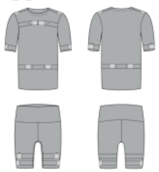
Sensoria's smart tops monitor heart rate while their smart socks detect cadence, foot landing and impact forces [13].

Research Methods, Prototypes & Materials

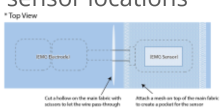
Implementation Plan

Milestone 1: *Design*, *Develop* and *Optimise* Personal Training Gear Equipped with Wearable Sensors

Task 1.1 - ***Design*** and ***develop*** personal training gear equipped with wearable sensors.



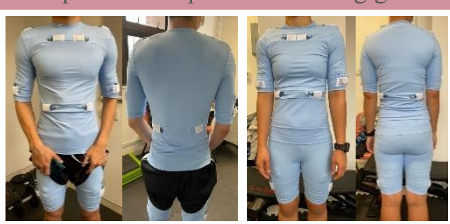
Minimise and optimise sensor locations



Task 1.2 - ***Select fabric*** materials that are subjected to ***physical and mechanical testing***

- Stretch and recovery
- Strength of seams
- Air permeability
- Moisture management
- Surface smoothness
- Thermal conductivity

Task 1.3 - Conduct ***preliminary wear trial*** to evaluate and optimize the personal training gear



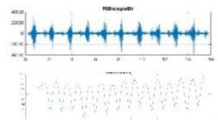
Evaluation forms

Milestone 2: *Develop AI algorithms* to Assess Exercise Performance Based on Sensor Data Collected from Personal Training Gear

Task 2.1 - ***Collect*** and ***pre-process*** training data

6 Weeks

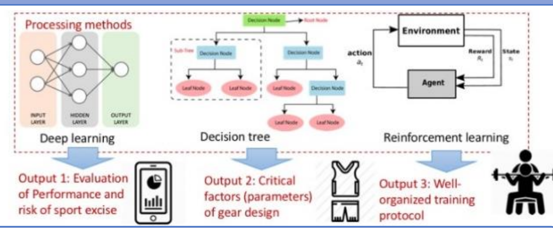
3 x 1 hour per week



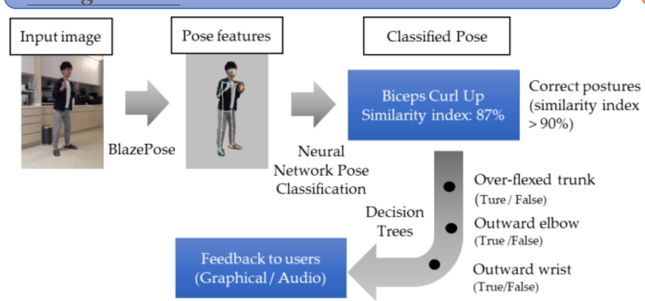
Evaluation forms

50 subjects (18-31 yrs), BMI between 20 – 25

Task 2.2 - Develop ***machine learning-based approach***

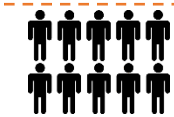


Task 2.3 - ***Integrate*** designated training gear with ***AI algorithms***



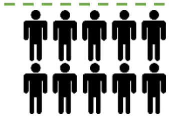
Milestone 3: *Evaluate the Overall Effectiveness* of the AI Personal Training Gear in Monitoring and Enhancing Exercise Performance

Task 3.1 - ***Recruit subjects*** and conduct pre-exercise assessment



Conventional Training

Vs



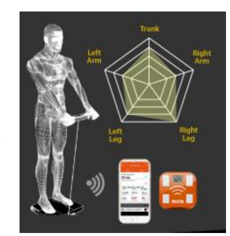
AI-assisted Training

Task 3.2 - Conduct ***fitness training*** sessions

1-hour training sessions x 6

Task 3.3 - ***Analyze results***

Sports performance can be assessed: skill, strength, endurance, and recovery.



Research Methods, Prototypes & Materials

Milestone 1 - Personal Training Bodywear

Design

Conceive the designs based on specific design criteria

Material Sourcing

Select suitable fabrics and materials

Pattern Making and Production

Construct 2D-patterns for the prototypes

Wear Trial

Arrange wear trials and collect user feedback

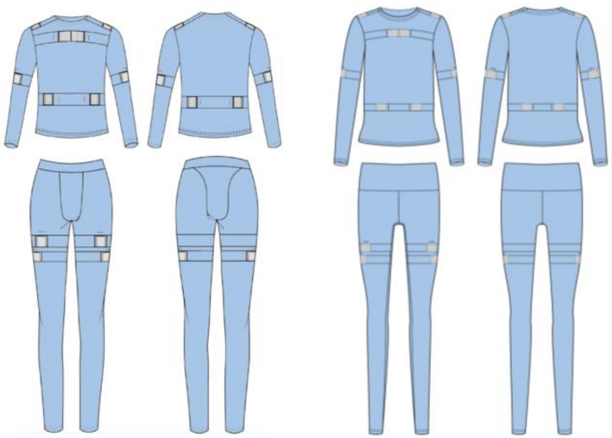
Modification

Modify the design based on user feedback and problems noted.

Research Methods, Prototypes & Materials

Milestone 1 - Personal Training Bodywear

Design



Designs of the first prototypes

Skin-tight fit

- Allows freedom of movement
- Cutting and fit
- Size grading
- Use of fabric

Wear comfort

- Moisture control
- Stretchability
- Thermal conductivity
- Tactile comfort

Design of pockets and openings

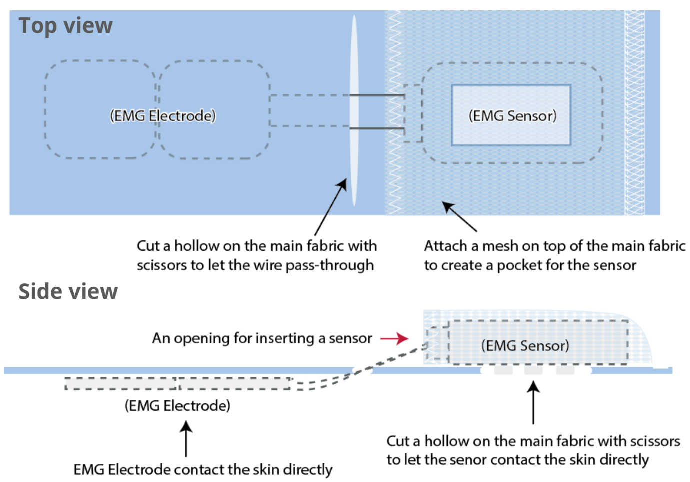
- Allows easy sensor attachment
- Secures and stabilizes sensor positions

Optimized positions of 16 sensor pockets

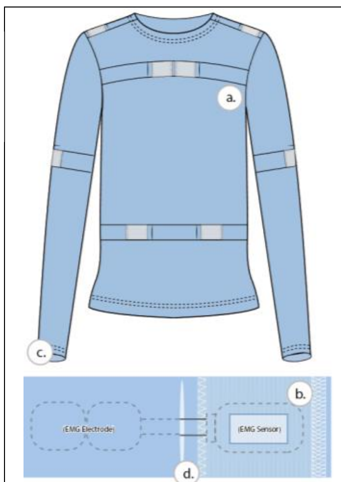
- EMG electrodes on muscle bellies
- EMG/IMU sensor parallel with body segments, off target muscle
- Generic solutions for users of various sizes and shapes

Pattern making

Sensor pocket design



Stitches & Construction



	Stitch	Seam	Function
a.	4- thread Overlock	Plain seam	To join all the fabric panels
b.	3-needle 5-thread cover stitch	Flatlock seam	To attach the mesh fabric
c.	3-thread cover stitch	Single-fold hem	To finish the neckline, sleeve and leggings' hem
d.	One point zig zag	Single-fold hem	To finish the pockets' hem

Research Methods, Prototypes & Materials

Milestone 1 - Personal Training Bodywear

Sourcing

Series of fabric tests were carried out to select the best materials that satisfy the design criteria.

Main fabric

L1	Lycra	76% Polyamide, 24% Elastane
L2	Lycra	76% Polyamide, 24% Elastane
L3	Lycra	76% Polyamide, 24% Elastane

Pocket Material

M1	Powernet	74% Polyamide, 26% Elastane
M2	Powernet	82% Polyamide, 18% Elastane
M3	Powernet	80% Polyamide, 20% Elastane

Tested Properties		Test Standards	Equipment
Dimensional Properties	**Weight (g/m²)**	ASTM D3776/D3776MREV A	Mettler PE 360 DeltaRange® Digital Scale Balance
	Thickness (mm)	ASTM D1777	Thickness Gauge
Mechanical Properties	**Stretch and Recovery (%)**	ASTM D6614	Instron 4411 Tensile Strength Tester
Physiological Properties related to wear comfort	**Air Permeability (kPa.s/m)**	KES- F8	Air Permeability Tester
	Thermal Conductivity (W/Mk)	KES - F7	Thermo Labo II Tester
	Water vapour permeability (g)	ASTM E96	Water Vapour Permeability Tester

Tests	Main Fabric			Pocket Material		
	L1	L2	L3	M1	M2	M3
Thickness	0.60 ±0.018	0.64 ±0.008	**0.53 ±0.010**	0.40 ±0	**0.34 ±0**	0.34 ±0
Weight	213.4 ±1.8	229.6 ±0	**196.8 ±0.4**	173.2 ±2.4	**78.6 ±1.4**	93.2 ±1.6
Stretch and Recovery						
Warp – stretch	**97.27 ±1.33**	92.34 ±1.55	85.75 ±3.37	**116.12 ±1.41**	156.62 ±1.41	118.54 ±2.95
Warp – recovery	95.28 ±7.52	87.84 ±0.59	**95.40 ±7.4**	98.66 ±2.4	98.08 ±0.56	**98.88 ±2.19**
Weft – stretch	91.17 ±1.58	95.08 ±6.23	**149.12 ±0.95**	**87.91 ±1.73**	58.01 ±0.88	73.96 ±0.14
Weft – recovery	89.28 ±1.33	82.715 ±17.83	**97.6 ±3.82**	**100.57 ±0.05**	96.93 ±5.84	95.74 ±5.84
Air permeability	0.6232 ±0.158	0.274 ±0.029	**0.1404 ±0.032**	**0.003 ±0.042**	0.027 ±0.001	0.007 ±0.007
Thermal conductivity	**0.172 ±0.003**	0.149 ±0.026	**0.172 ±0.002**	**0.146 ±0.004**	0.103 ±0.001	0.100 ±0.001
Water vapor permeability	-1.76 ±0.155	-1.56 ±0.085	**-1.90 ±0.015**	**-1.86 ±0.005**	-2.34 ±0.200	-2.36 ±0.165

Research Methods, Prototypes & Materials

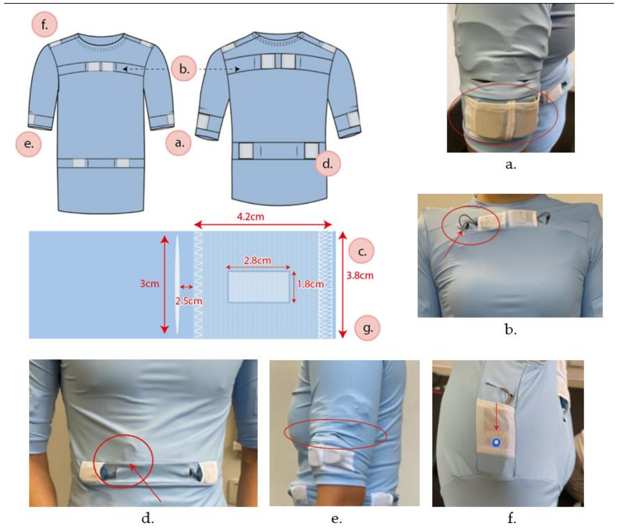
Milestone 1 - Personal Training Bodywear

Wear Trial

- **First prototypes**

- 22 Subjects (9 males, 13 females)
- 1-hr weight training
- Questionnaire (score 0 -10)
  - Fit
  - Comfort
  - Aesthetics
  - Other comments

Modification



a. Incorrect biceps and triceps sensor locations when users are thin

b. Incorrect opening location for the smart lead of pectoralis sensor

c. Sensor pocket can be tightened further

d. Abdomen sensor location can be higher

e. Sleeve length of women's top of sizes M and L is too long

f. Incorrect trapezius sensor location for men's top

Research Methods, Prototypes & Materials

Milestone 1 - Personal Training Bodywear

The Final Designs

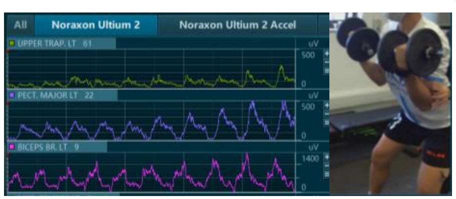
Gender	Size	Top				Shorts	
		Shoulder width (cm)	Chest Circum. (cm)	Arm Circum. (cm)	Waist circum. (cm)	Hip Circum. (cm)	Thigh Circum. (cm)
Male	S	42-46	85-90	28-31	70-78	80-88	48-52
	M	44-48	90-95	32-35	74-82	86-94	52-56
	L	46-50	95-100	36-39	78-86	92-100	56-60
Female	S	36-42	75-80	22-24	60-68	82-90	45-50
	M	38-44	80-85	24-26	66-74	88-96	50-55
	L	40-46	85-90	26-28	72-80	94-102	55-60

Research Methods, Prototypes & Materials

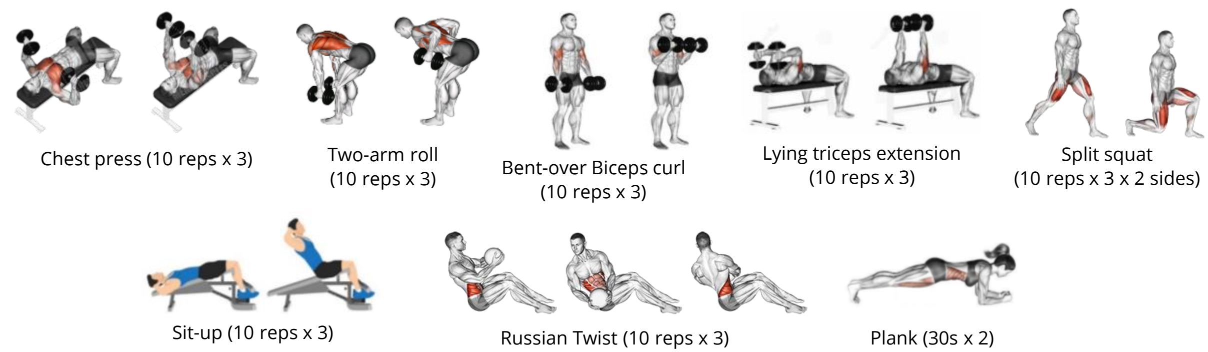
Milestone 2 - Wear Trials and Sensor Data Collection

50 subjects, inclusion criteria:
(a) between 18 to 30 years old
(b) physically fit for exercise
(c) not receiving physical training elsewhere

18 training sessions: 6 weeks x 3 sessions
Monitored by a qualified personal trainer

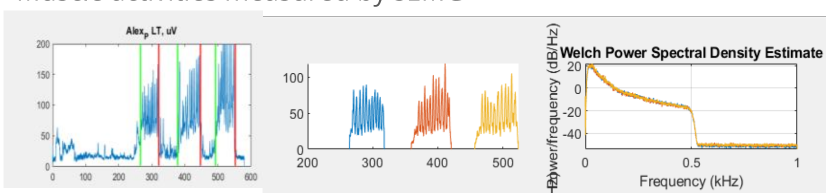


Sensor data: sEMG and camera
Other subject data: muscle mass, rating of perceived exertion (RPE)



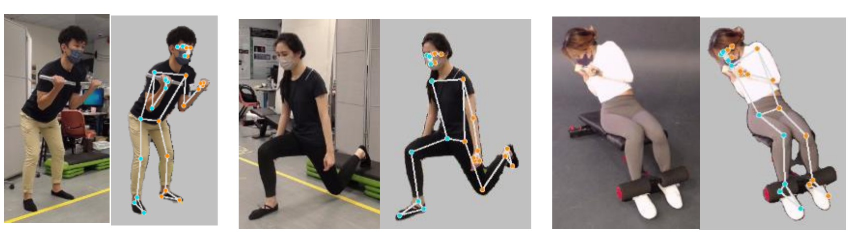
The 8 resistance exercises included in the coaching system that train the major muscle groups (e. g. pectoralis, biceps, triceps, trapezius, abdominis, quadriceps, hamstrings) across the whole body.

Muscle activities measured by sEMG



Pre-process data to establish the training and testing datasets

A Gaussian classifier to predict muscle fatigue in real-time



Establish a pose library containing images capturing the terminal poses of the eight exercises.

Neural Network algorithms for pose classification and anomaly detection

Research Methods, Prototypes & Materials

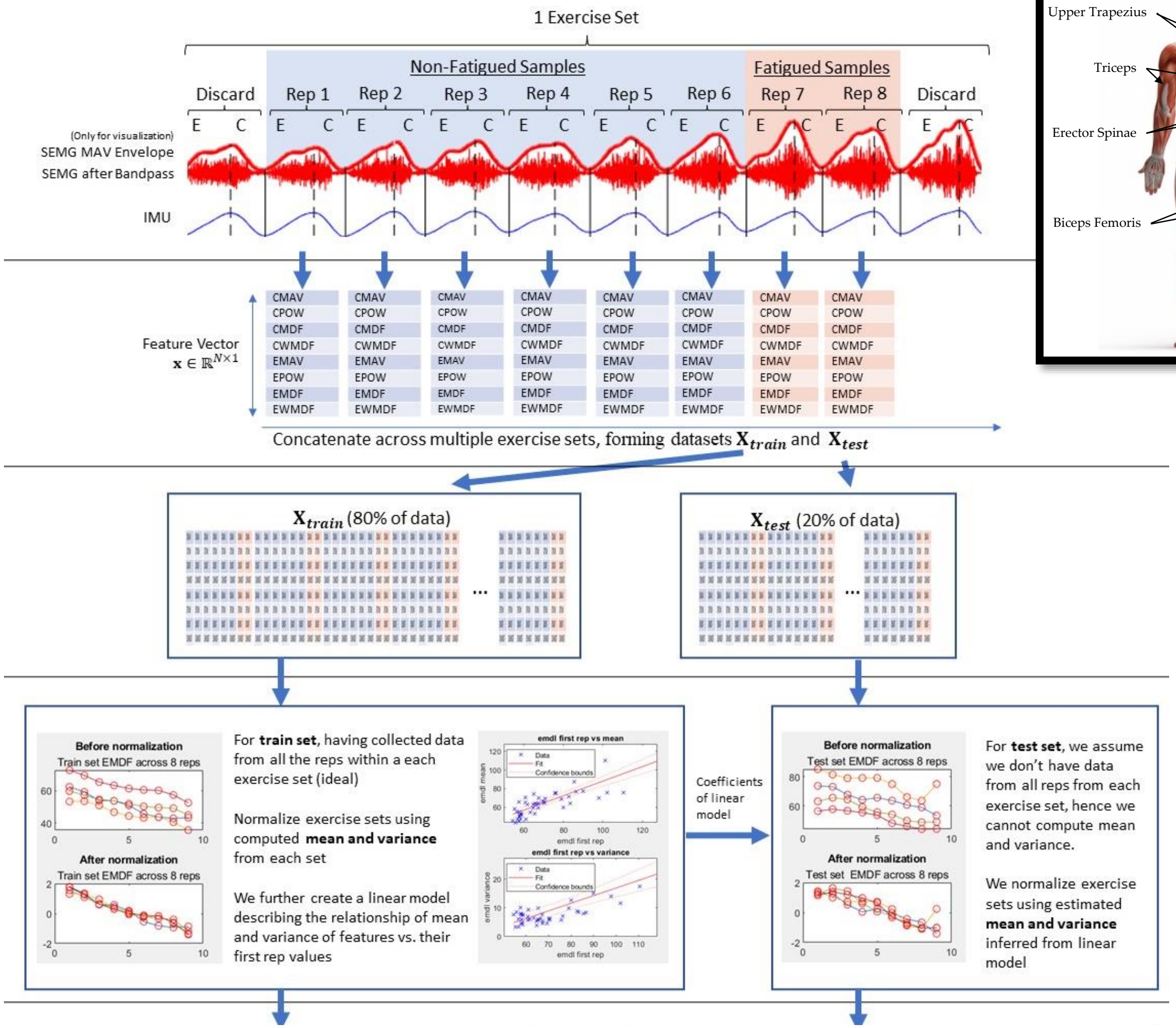
Milestone 2 - Muscle Fatigue Analysis

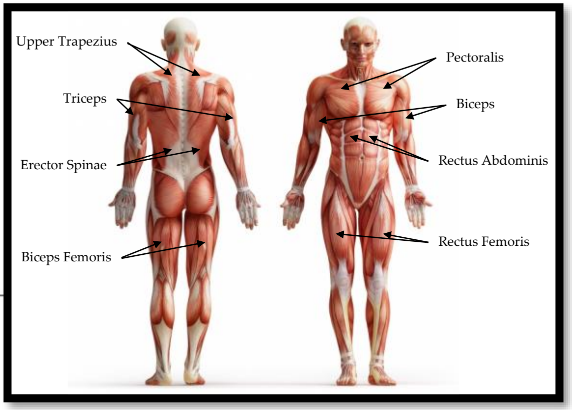
Data Segmentation

Feature Extraction

Train/ test split

Normalization

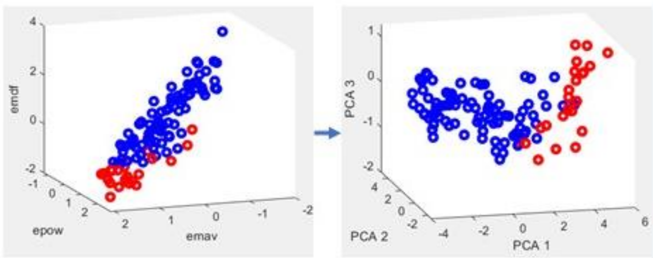




Research Methods, Prototypes & Materials

Milestone 2 - Muscle Fatigue Analysis

Original Feature Space | Projected Feature Space

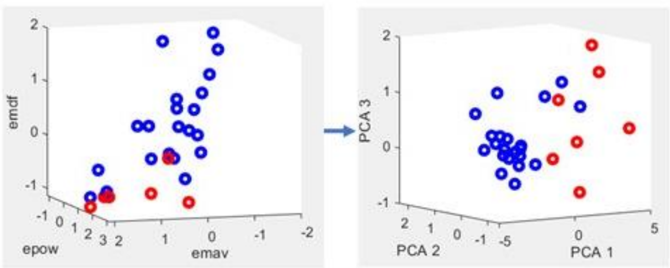


For **train set**, we perform SVM on $\mathbf{X}_{train}$, obtaining matrices U, S, V. Using matrix V, we project data from the original feature space to projected feature space based on the Principal Component Axes

We can selectively use the first n dimensions of the projected data to reduce feature dimensions while losing minimal information.

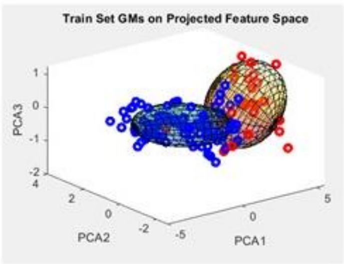
V Matrix

Original Feature Space | Projected Feature Space



For **test set**, we perform the same projection process using matrix V obtained from the train set.

We can selectively use the first n dimensions of the projected data to reduce feature dimensions while losing minimal information.

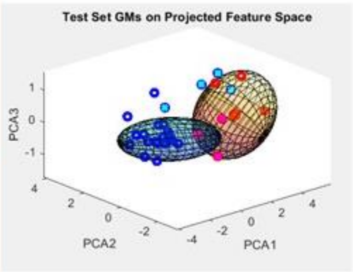


We fit Gaussian models onto $\mathbf{X}_{train}$

Red and blue circles represent fatigued and non-fatigued training samples respectively that were used to fit the gaussian model.

Red and blue ellipsoids represent mean and covariance of gaussian models.

Gaussian Models



Using Gaussian classifier for the binary case, we can now use the gaussian models fitted on the training set to predict whether a muscle belongs to a fatigued sample or a non-fatigued sample.

Red and blue circles represent fatigued and non-fatigued testing samples; cyan and magenta refers to misclassifications by the classifier

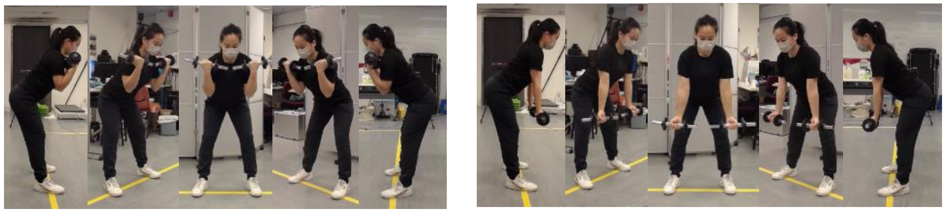
Conclusion: Our work demonstrated a novel method to detect muscle fatigue status in real time by normalizing sEMG signals to estimated means and variance inferred from linear models, and using Gaussian Models as the classifiers to differentiate fatigued and non-fatigued data samples.

Research Methods, Prototypes & Materials

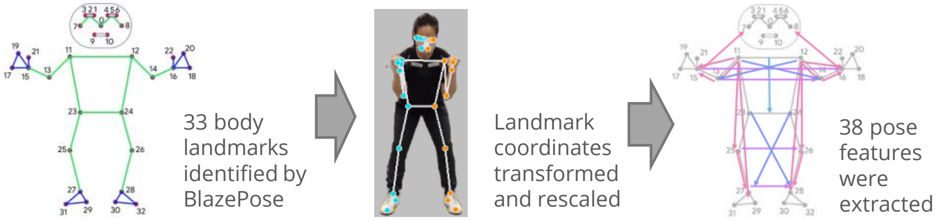
Milestone 2 - Pose Classification

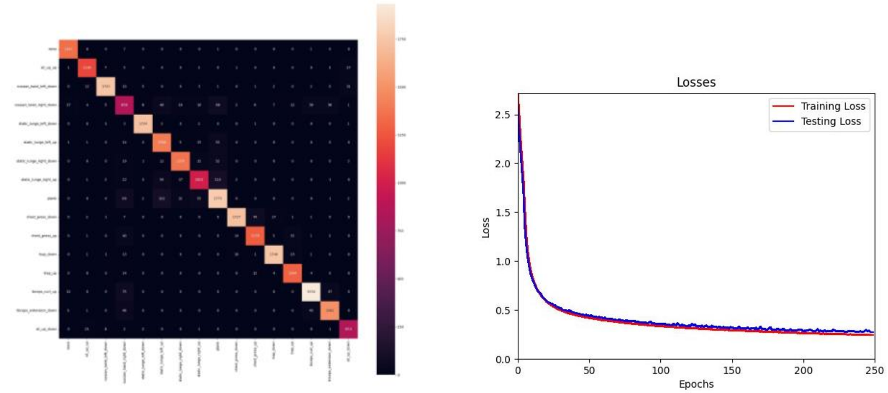
Establishing **a pose library** to supply the training and testing dataset for the AI algorithms.

- **38 subjects** were invited to perform the ***eight weight training exercises*** under the supervision of a qualified personal trainer.
- 10 repetitions were performed for ***each exercise*.**
- A **5-camera array** (Logitech C930e) was set up to collect video sequences (1920 x 1080 pixels; 30 Hz) from different view angles simultaneously.
- Images capturing the **terminal poses** of the exercises were selected and processed to build the pose library. Including the “none” class, all images were sorted into **18 classes of pose**.
- **33 body landmarks** were identified by BlazePose, which were then **transformed** to a local coordinate system defined by the spinal axis (vector from hip centre to shoulder centre) and re-**scaled** such that values of all coordinates lie between 0 to 1.
- **38 Pose features** incl. 35 distances and 3 vectors were extracted.



Terminal poses of bicep curl (up and down) were captured by a 5-camera array simultaneously.





Confusion matrix (left) and training loss (right) of the training dataset showing the classification performance of the prediction model

Prediction result: The overall model precision and sensitivity of the model reaches 93%, specificity and negative predictive value is approaching 99.5%. The overall accuracy is 99.2%.

Research Methods, Prototypes & Materials

Milestone 2 - Pose Anomaly Detection

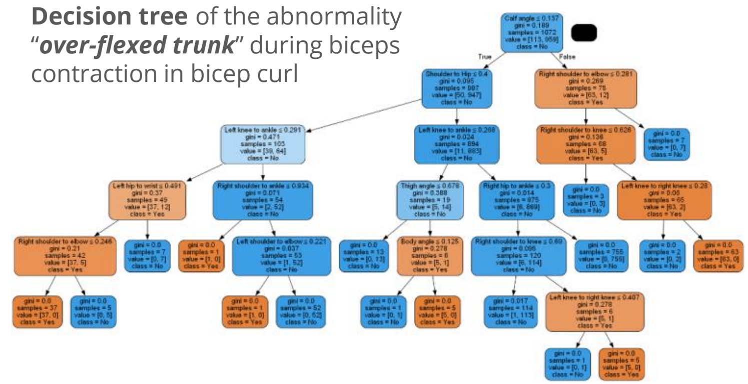
1. **Define pose anomalies** for each of the 8 exercises.

- **Chest Press**
  - Over extended elbows
  - Internal rotated shoulders
  - External rotated shoulders
- **Back row (Trapezius)**
  - slumped back
  - Raised shoulders
  - Over-flexed elbows
- **Biceps Curl**
  - Over-flexed trunk
  - Slumped back
  - Abducted shoulders
- **Triceps extension**
  - Elbows out
  - Elbows over shoulder
- **Sit-up**
  - Arched back
  - Extended neck
  - Over-flexed shoulders
- **Russian twist**
  - Arched back
  - Elbow out
  - Raised shoulders
- **Static lunge**
  - Forward trunk
  - Knee out
  - Knee in
- **Plank**
  - Flexed hips
  - Relaxed abs
  - Feet together

2. Based on the 38 pose features, detect pose anomalies for each exercise by using **binary decision trees**, a powerful classification and regression tool in machine learning. One decision tree is developed for each anomaly.

Common pose anomalies of bicep curls

Decision tree of the abnormality "***over-flexed trunk***" during biceps contraction in bicep curl



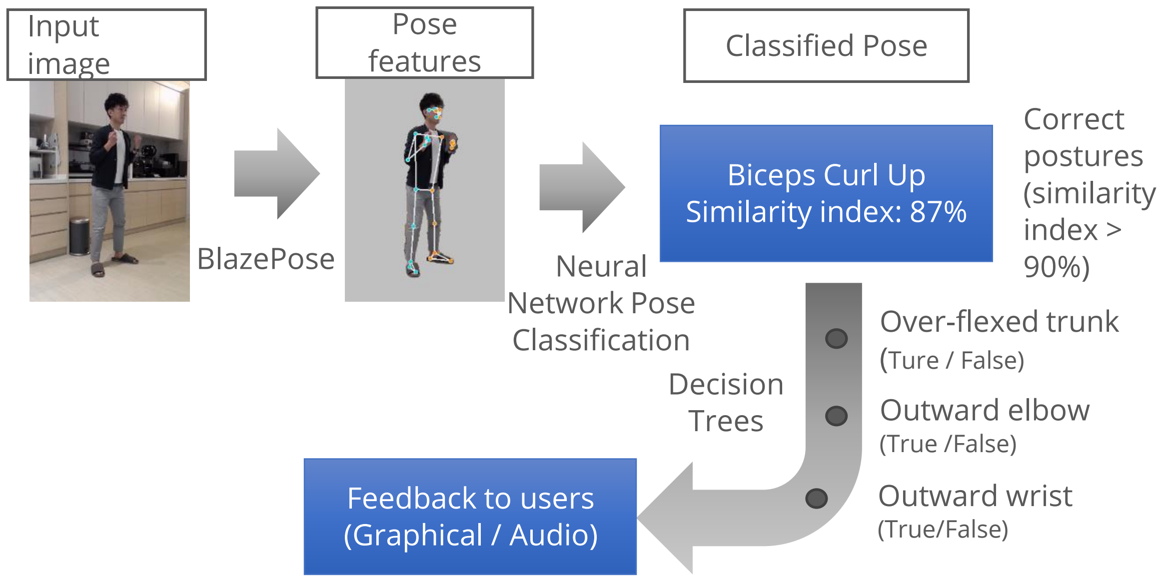
Conclusion: Our work demonstrates the feasibility of using normalized distance features extracted from BlazePose to detect ***multiple pose anomalies*** from correct norms by binary decision tree algorithms. The prediction results are very useful in giving specific postural advises to learners of fitness exercises.

Research Methods, Prototypes & Materials

Milestone 2 - The Coaching System (Operation functions)

Tutorial Videos

Pose Intelligence



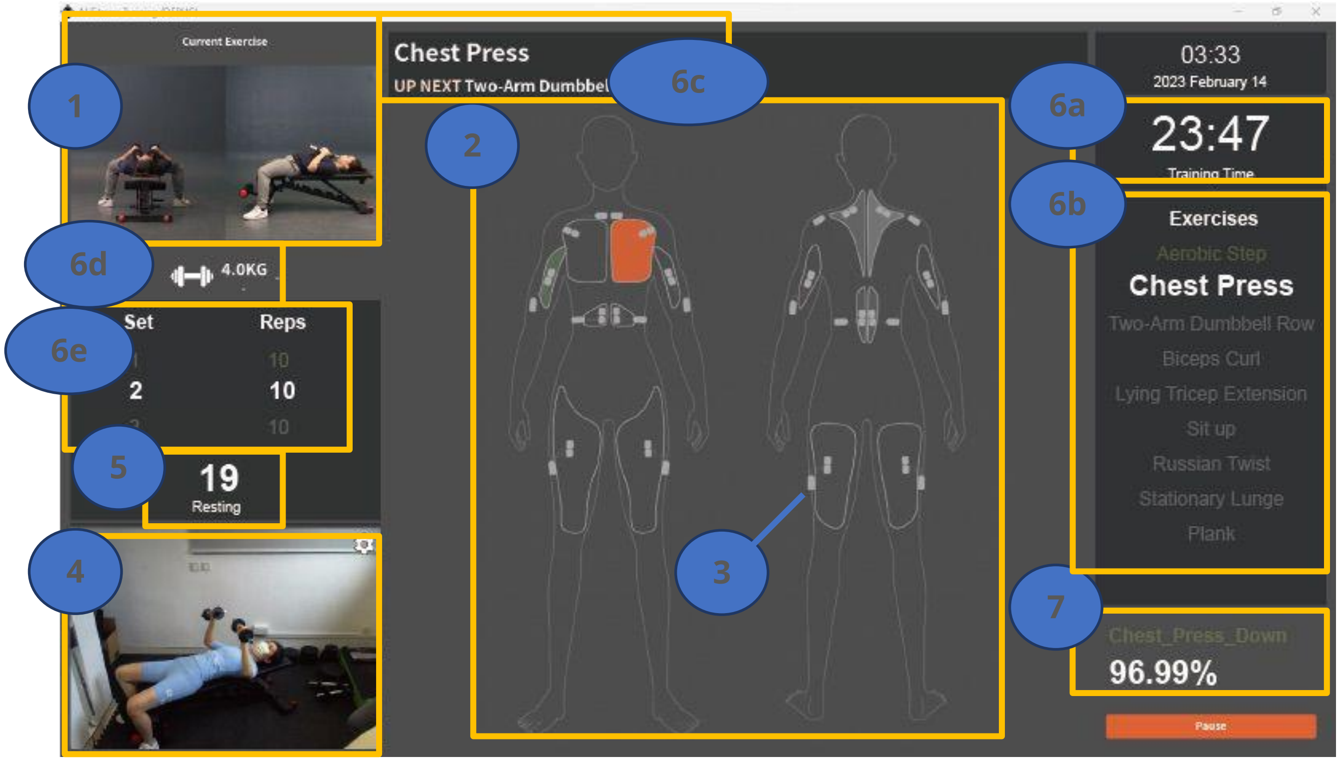
To allow easy control the sensors and provide exercise coaching intelligence to users, an operating software was developed. Software features include:

(1) **EMG sensor control:** sensor allocation, wi-fi connection status check, receiving EMG signals
(2) **Camera control:** camera selection, video streaming
(3) **Tutorial videos:** demonstrate the proper forms
(4) **Pose intelligence:** pose classification and anomaly detection
(5) **Audio coaching instructions:** audios announcing the no. of repetitions of current set, up-coming exercise, counting down the last 10 seconds of rest period, as well as suggestions (e.g. arms vertical, arch back, bend forward) to improve poses

Research Methods, Prototypes & Materials

Milestone 2 - The Coaching System (Graphical User Interface)

A user-friendly Graphical User Interface (GUI) is designed to enhance the user experience with the coaching system.



1. **Tutorial videos** – looping videos showing the front and side views of the current exercise. The user can also click the frame to view the introductory tutorial videos (2-3 mins long) with more detailed instructions.
2. **Muscle activity map** – shows the relative muscle activities of the target (red) and supporting (green) muscles of the current exercise with colour maps. Brighter colours indicate higher activation.
3. **Sensor status** – Connected sensors are shown in grey. Disconnected sensors are shown in blinking red.
4. **Camera display** – shows the current streaming video.
5. **Repetition counter / Timer** – shows the remaining time for aerobic steps and plank, and number of reputations completed for other exercises.
6. **Training progress** – shows (a) accumulated training time, (b) exercises include in the training programme, (c) current and up-coming exercise, (d) current training load, (e) current set of exercise.
7. **Pause / resume button**

Research Outcomes, Findings & Further Research

- After several wear trials and construction of numerous prototypes, the **placement of the sEMG sensors is optimized** for users with a body size that ranges from small to large. The sensor pocket and opening design also ensures **secured sensor attachment.**
- A novel method Is proposed to **detect muscle fatigue status** in **real time** by normalizing sEMG signals to estimated means and variance inferred from linear models, and by using *Gaussian models* as classifiers to differentiate between fatigued and non-fatigued data samples.
- A high-quality **pose library** that consists of frames of the terminal poses of eight common resistance training exercises is established. The images are taken by using high resolution webcams at different view angles, with volunteers of different heights, ages, genders, and body shapes under the supervision of a qualified personal trainer.
- The *neural network algorithms* developed can **classify various exercising poses** with good precision (92.9%), sensitivity (93%) and accuracy (99.2%), which are critical in the user experience of the coaching system.
- A versatile solution is formulated to **detect pose anomalies** with *binary decision trees*. This approach allows **multiple anomalies** to be detected in a single pose. The predicted results are very useful in giving specific postural advice to learners of fitness exercises.
- The research outputs enhance user experience in **human/machine interactions** and are likely to be useful for a diverse range of applications in the **medical, healthcare** and **sports** sectors.

Research Dissemination

Conference Articles

International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE) 2022 & 2023

Physical Ergonomics and Human Factors, Vol. 63, 2022, 62–70
https://doi.org/10.54941/ahfe1002597

Prediction of Muscle Fatigue During Dynamic Exercises based on Surface Electromyography Signals Using Gaussian Classifier

Yeok Tatt Cheah, Ka Wing Frances Wan, and Joanne Yip

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ABSTRACT

Muscle fatigue is shown to be associated with incidence of musculoskeletal injuries found with sports training and competition. The real-time detection of fatigue onset allows preventative measures to be taken in time to minimize injuries. In this paper, we aim to provide a framework that classifies muscle fatigue based on surface electromyography (sEMG) features extracted during dynamic exercises. This includes the use of data segmentation, real-time-compatible data normalization, a principal component analysis (PCA) based feature reduction and Gaussian classifier methods. An experiment has been carried out to acquire the sEMG signals of the upper two pairs of rectus abdominis muscles of four healthy adult volunteers during weighted decline and bench-assisted sit-ups. The collected sEMG signals are then segmented into concentric and eccentric segments by using the inertial measurement unit (IMU) data. Eight commonly used sEMG features are extracted from each segment. We fit two Gaussian models (GMs) on the distribution of fatigued and non-fatigued data samples and show that the GM can utilize this information to predict the number of repetitions possible before task failure. We fit another set of GM on a reduced feature space by projecting the data onto principal component axes obtained through singular value decomposition (SVD). By projecting the features onto the first two principal axes, we achieve similar accuracy and f1-scores compared to the GM by using 6 handpicked features. This reduction in the feature space greatly reduces the training samples necessary for such class-imbalanced datasets. This classifier can also be directly used in the real-time detection of muscle fatigue during dynamic movements, which can be adopted in applications in sports, workplaces, and rehabilitation sciences. These frequency-time characteristics also provide insight into the function of low-level feature extractors when developing deep learning models to identify muscle fatigue.

Keywords:

INTRODUCTION

Analyzing signals during dynamic contractions is an important avenue for research as many injury-prone movements are dynamic in nature. Although most research has focused on signals collected during isometric contractions,

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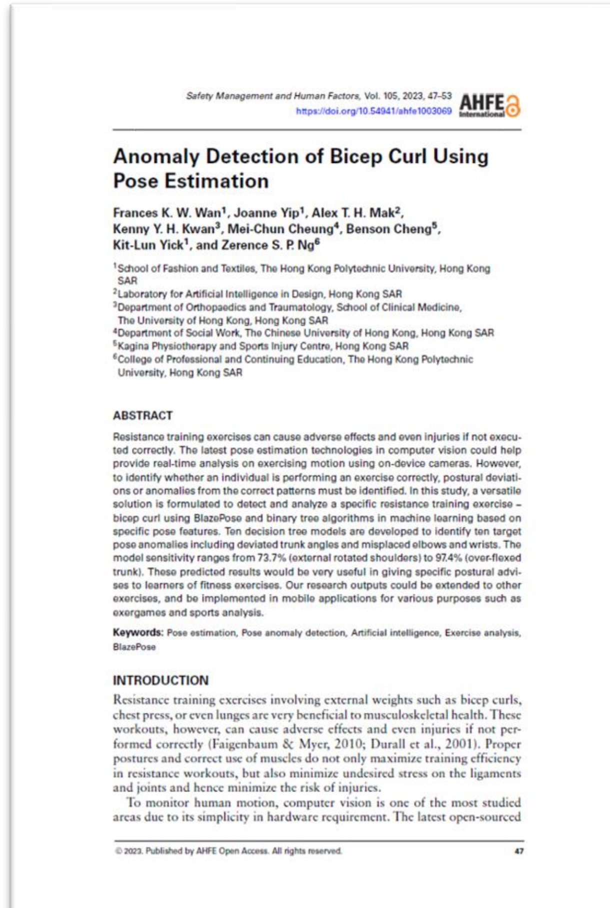

Safety Management and Human Factors, Vol. 105, 2023, 47–53
https://doi.org/10.54941/ahfe1003069

Anomaly Detection of Bicep Curl Using Pose Estimation

Frances K. W. Wan[1], Joanne Yip[1], Alex T. H. Mak[2], Kenny Y. H. Kwan[3], Mei-Chun Cheung[4], Benson Cheng[5], Kit-Lun Yick[1], and Zerence S. P. Ng[6]

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ABSTRACT

Resistance training exercises can cause adverse effects and even injuries if not executed correctly. The latest pose estimation technologies in computer vision could help provide real-time analysis on exercising motion using on-device cameras. However, to identify whether an individual is performing an exercise correctly, postural deviations or anomalies from the correct patterns must be identified. In this study, a versatile solution is formulated to detect and analyze a specific resistance training exercise – bicep curl using BlazePose and binary tree algorithms in machine learning based on specific pose features. Ten decision tree models are developed to identify ten target pose anomalies including deviated trunk angles and misplaced elbows and wrists. The model sensitivity ranges from 73.7% (external rotated shoulders) to 97.4% (over-flexed trunk). These predicted results would be very useful in giving specific postural advises to learners of fitness exercises. Our research outputs could be extended to other exercises, and be implemented in mobile applications for various purposes such as exergames and sports analysis.

Keywords: Pose estimation, Pose anomaly detection, Artificial intelligence, Exercise analysis, BlazePose

INTRODUCTION

Resistance training exercises involving external weights such as bicep curls, chest press, or even lunges are very beneficial to musculoskeletal health. These workouts, however, can cause adverse effects and even injuries if not performed correctly (Faigenbaum & Myer, 2010; Durall et al., 2001). Proper postures and correct use of muscles do not only maximize training efficiency in resistance workouts, but also minimize undesired stress on the ligaments and joints and hence minimize the risk of injuries.

To monitor human motion, computer vision is one of the most studied areas due to its simplicity in hardware requirement. The latest open-sourced

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http://doi.org/10.54941/ahfe1003069

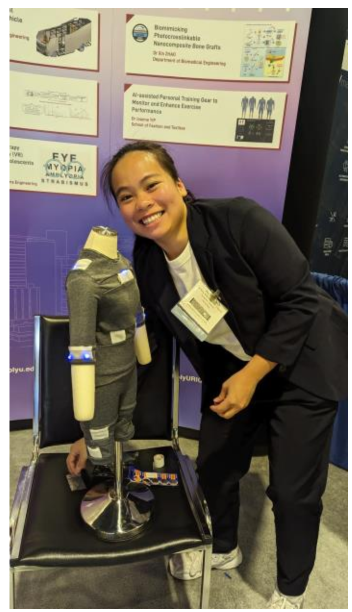
Research Dissemination

Exhibitions

TechConnect
WORLD INNOVATION
CONFERENCE & EXPO

JUNE 19-21, 2023
WASHINGTON, DC

$20B	250	1000	2000	2500
Tech Funding	Exhibitors	Prospectors	Innovators	1-on-1 Meetings

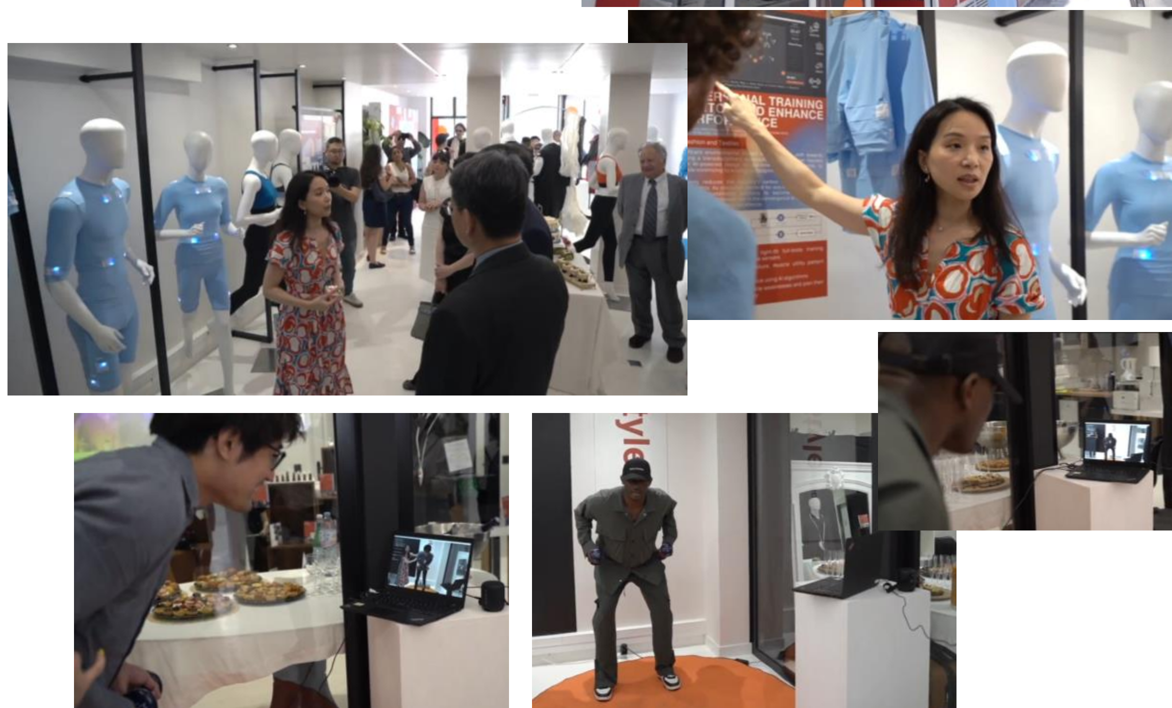


Research Dissemination

Exhibitions

《Flying High》Exhibition in Paris

- 25 Jun - 01 Jul 2024
- Paris (GMT +2) 10:00am – 7:00pm
- 7 Rue Notre Dame des Victories, 75002 Paris, France
- https://www.polyu.edu.hk/en/rio/event-calendar/2024/06/20240625---paris-exhibition/



Research Dissemination

Media Reports

《香港故事: 創科夢工場》

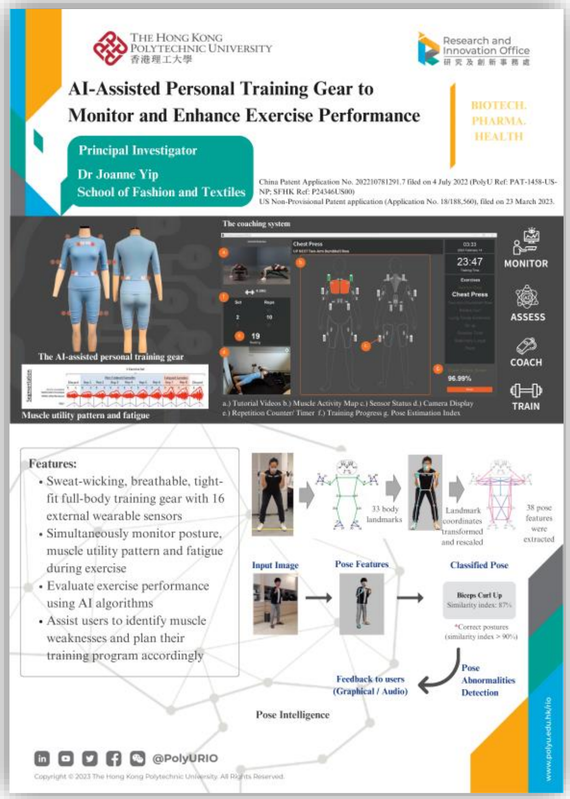
科研都要靚：葉曉雲 (Dr. Yip Yiu-wan)

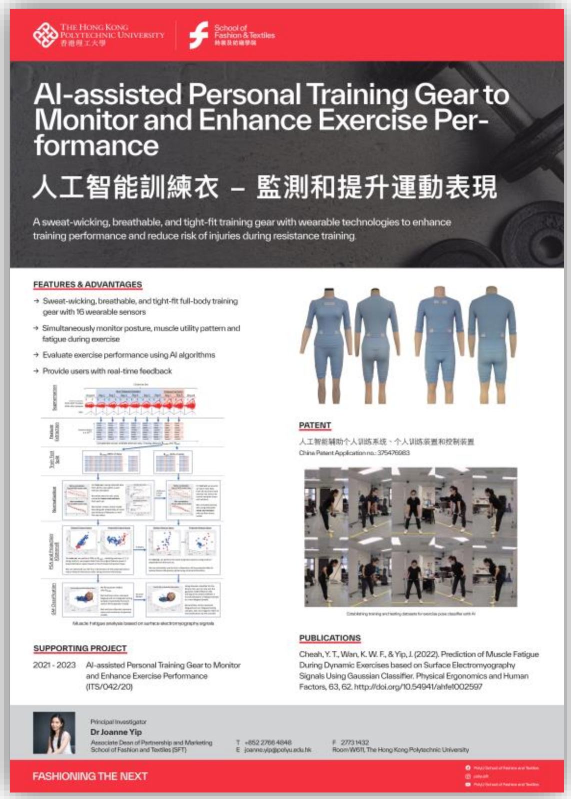
《香港故事: 創科夢工場》(“Hong Kong Stories: dream factory of technological innovations”) is a documentary TV series produced by RTHK that tells the stories of how various research talents chasing their dreams in Hong Kong

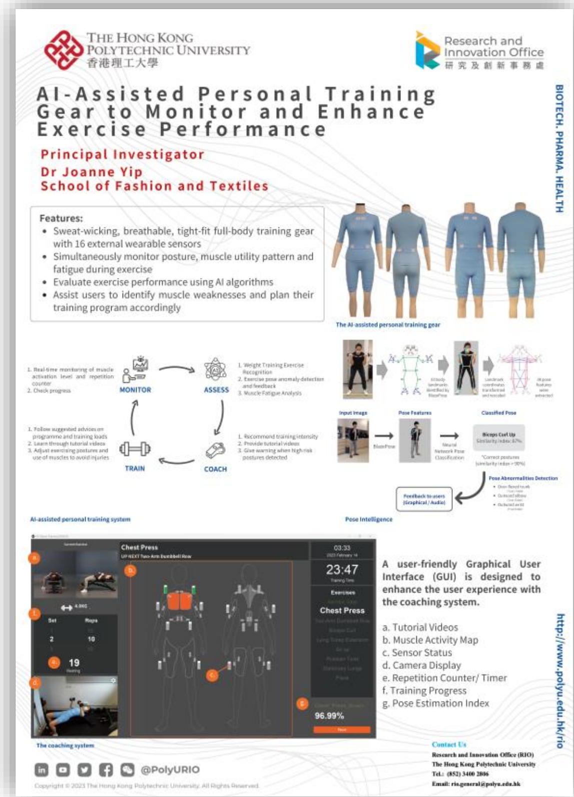
Research Dissemination

Other Publicity Activities

Posters created for various research showcases







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